Capturing the sports design process to facilitate the uptake of inclusive design

NICKY WILSON

A thesis submitted to the University of Strathclyde

for the degree of Doctor of Philosophy

Department for Design, Manufacture and Engineering Management

University of Strathclyde

2016

Declaration of authenticity and author's rights

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

Signed: Date:

Acknowledgements

There were many people involved in this research over the last three years that I would like to thank. There were many more than I can mention here, but each contribution has helped progress my research to this stage.

I would like to express my gratitude to Dr Avril Thomson, my supervisor throughout my PhD. Firstly, for encouraging me to pursue a PhD and helping me to secure the necessary funding. Secondly, for her guidance and support over the last three years and her unwavering belief in my research. And thirdly, for helping me expand my skills beyond just my thesis, by encouraging me to take on additional commitments throughout my studies.

I would also like to thank Dr Philip Riches for his support as my second supervisor and offer an apology for the route my research has taken, away from the initial biomechanical approach. Despite being well outside his field of expertise Phil has continued to provide support and assistance to the research over the three years.

I would like to thank the undergraduate students of DMEM at the University of Strathclyde. There are far too many to mention by name, but their willingness to participate in pilot studies, workshops and provide feedback has been invaluable to my research. Special thanks go to those brave enough to adopt early versions of the sports design process model and inclusive design framework in their final year studies, before they were refined and validated.

This work would not have been possible without all those who gave up their time to participate in the various studies. Again, there are too many to name and many must remain anonymous.

Finally, I would like to thank my family for their support throughout this journey. To my mum, who has proof-read so many of my papers, proposals and thesis versions. To my dad for accepting this was all "too academic" for him but for his support regardless. And to Steven, for keeping me sane throughout this entire process.

Abstract

The aim of this research is, “to investigate how the sports design process can be used to improve inclusive design practice”. Sports design (or sports engineering) is the design of sports equipment and/or products that support the athlete (or user) in improving their overall sporting performance (Jenkins, et al., 2010) and (Muller, et al., 2007). In sport, the equipment and the athlete must work together to facilitate sporting performance. Despite limited work being undertaken into the sports design process, sports design is evidently highly user centred. However, there is no design process model that captures the characteristics of sports design as a whole (from project initiation to project sign-off).

This research captures the sports design process as a whole, using an iterative process of investigation, data collection, development, evaluation and validation, involving industry designers and sports design students. The outcome and contribution to knowledge is the first design process model to capture the sports design process as a whole. The characteristics of sports design captured in the model include user involvement throughout the design process, designer interaction with the user and iterations within design process stages.

To address the overall aim of the research, this thesis investigates whether the user centred nature of sports design is applicable in other design disciplines. Given the urgent global issue of the ageing population, this research explores the applicability of the sports design process model to inclusive design – another highly user centred design approach. This research takes a qualitative approach to understanding how the sports design process model could be applicable to inclusive design practice, involving both inclusive designers from industry and inclusive design experts from the Helen Hamlyn Centre for Design. An iterative approach of concept generation, development and evaluation was followed, with the outcome and further contribution to knowledge, an interactive framework that facilitates designer-client communication within the inclusive design process. This research will impact client engagement within the inclusive design process, increasing client awareness of inclusive design and encouraging the uptake of an inclusive design approach within industry. The inclusion of a diversity of users within the design process will result in a product that not only meets the needs of more diverse users, but will also be usable to those with greater capabilities.

Published work

Journal papers

Wilson, N.; Thomson, A.; Riches, P. "*Development and presentation of the first design process model for sports equipment design"* Journal of Research in Engineering Design, under third round of review process.

Wilson, N.; Thomson, A. *"What differentiates the sports design process from traditional product design?"* Journal of Design Science. Paper submitted.

Conference proceedings

Wilson, N., Thomson, A., Riches, P. (2015) *"Can the sports design process help the inclusive design community?"* International Conference on Engineering Design, Milan, July 27th-30th 2015.

Wilson, N., Thomson, A., Riches, P. *"Improving inclusive design: Designer recommendation for the development of a sports design model".* Paper accepted for DESIGN 2016, Dubrovnik, Croatia.

Presentation of journal paper: *"What differentiates the sports design process from traditional product design?"* PUBLISH-ED conference 2016. 4th-5th February, Grenoble, France.

Wilson, N.; Thomson, A.; Riches, P. *"Improving inclusive design practice – transferring knowledge from sports design practice".* Submitted for ICED 2017.

Contents

Figures

Chapter 1: Introduction

Chapter 2: Literature review

Chapter 5: Development of the sports design process model

Chapter 6: Application of the sports model in the inclusive design process

Chapter 7: Development of the inclusive design framework

Tables

Glossary

Sport: sport involves the participation of one or more athletes in an activity involving physical exertion that can be primarily physical, mind, motorised, co-ordination or animal-supported, or a combination of these, with an element of competition, where the equipment acts as an extension of the athlete's body to facilitate the sporting action. This thesis will focus specifically on sports that fall under the "physical" category.

Sports design: the design and development process undertaken by the designer, with the outcome being sports equipment.

Sports equipment: the artefact that is used by the athlete to undertake participation, training of safety in their sport.

Sports engineers: the designers who design sports equipment.

Inclusive design: a design approach which aims to take into account the diverse needs and capabilities of the whole population during the design process.

User centred design: a design approach where the user is a central part of the design process and engaged throughout that process.

Chapter 1: Introduction

The aim of this research is:

To investigate how the sports design process can be used to improve inclusive design practice.

Sports design (or sports engineering) is the design of sports equipment and/or products that support the athlete (or user) in improving their overall sporting performance (Jenkins, et al., 2010) and (Muller, et al., 2007). The output of the sports design process (the equipment) should enable the athlete or user to participate in their sport, with the interaction between the athlete and the equipment facilitating that sporting performance (Stefanyshyn & Wannop, 2015). It is therefore apparent that usability is a core aspect of sports design – if the equipment does not facilitate sporting performance, it cannot be regarded as a successful product, regardless of its engineering. If the outcome is user centred, it can be argued that the sports design process itself must be user centred too. Sports design (engineering) is a young and evolving design discipline (Jenkins, et al., 2010) and (Medwell, et al., 2011) with limited published work relating to the sports design process. This research will build on existing work in the field of sports design in addition to providing new insights into the sports design process.

User centred design is defined by Clarkson et al. (2003) as a "design approach that places the user at the heart of the design process and often involves and engages with users in ways that make them part of and integral to the process itself". This research suggests that sports design is a highly user centred design discipline due to the performance requirements of the athlete and how this translates into the design of the equipment. It is argued that to ensure the outcome is user centred, the user must be considered throughout the design process (McGinley & Macredie, 2011). The outcome of a user centred design process should be a product that is taken beyond being purely functional and improves the overall user experience of the product (McGinley & Macredie, 2011). Given the anticipated user centred nature of sports design, it is suggested that principles of sports design and its process may be transferrable between other user centred design disciplines. This research will focus specifically on the area of inclusive design.

The philosophy of inclusive design is to include users with diverse needs and capabilities within the design process and is defined by Foresight (2000) as: "a process whereby designers and manufacturers ensure that their products and services address the needs of the widest possible audience". Inclusive design differs from user centred design as it encourages the inclusion of a *diversity* of user groups within the design process. Like sports design, inclusive design is a highly user centred discipline, with the needs of the user central to the design process. This research will investigate whether user centred design principles that are currently followed within sports industry practice are applicable and transferrable to inclusive design practice, with the intention of improving inclusive design uptake in industry.

1.1. Motivation for the research

Participation in sport is increasing. Sport England reported that 15.8 million people participate in sport at least once a week – an increase of 1.75 million people from 2005 (Sport England, 2016) as shown in Figure 1.1. This trend is representative of many Western countries, where participation in sports has increased since the mid-1900s (Muller, 2011). The sports industry itself is estimated to be worth between $480-620 billion (AT Kearney, 2011) with this figure expected to grow – Forbes predict an increase in the size of the sports market from $60.4 billion in 2014 to $73.5 billion in 2019 (Forbes, 2015).

Given this rise in sports participation and the size of the global sports market, it is surprising that there is a lack of research to date that focuses specifically on the design process within sports design as a discipline. The Journal of Sports Engineering documents extensive work undertaken within engineering and technology in sport. However, there appears to be a lack of work examining the sports design process as a whole and what characterises sports design as a discipline. Given the increasing size and value of the sports industry, there is a need to understand fully the process behind designing sports equipment. There are extensive reports of the benefits of following a design process – these include financial benefits and more successful products, in addition to identification of areas of improvement. This research therefore suggests that a better understanding of the sports design process will allow improvements to be made within the sports design industry.

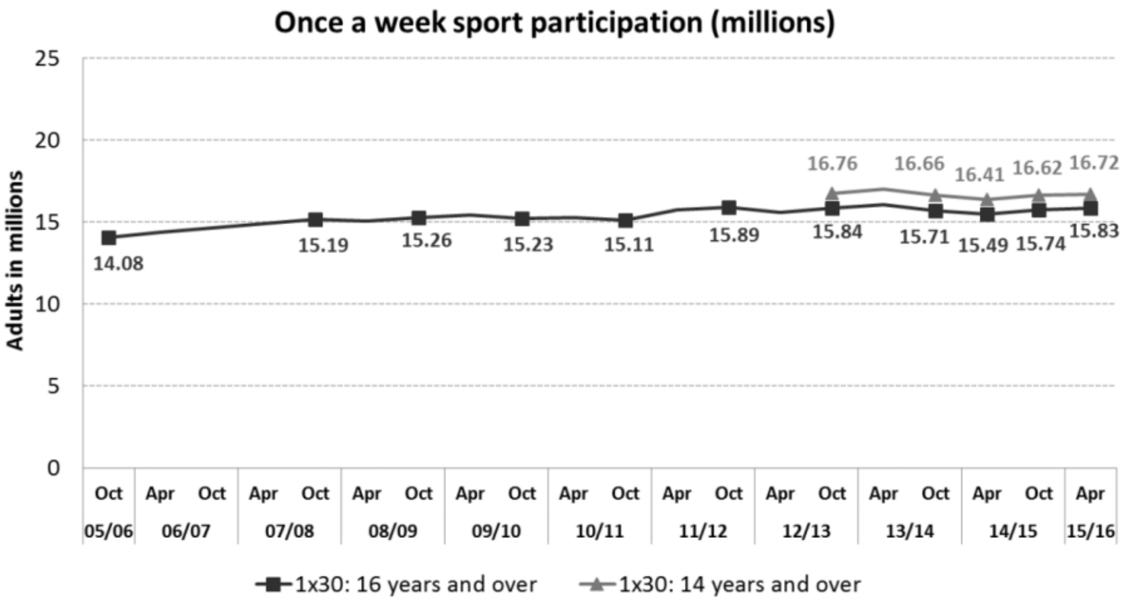


Figure 1.1 – Participation in sport from 2005-2016 (Sport England, 2016)

In addition to the motivation to improve sports design practice, there are also current drivers for the uptake of inclusive design. While inclusive design is not limited to the older adult, the ageing global population is one of the most pressing global issues that inclusive design can address. However, it is acknowledged that a change in physical capabilities can occur at any age and the inclusion of all users with reduced capabilities is vital when adopting an inclusive design approach. While the global ageing population is a motivator within this research for inclusive design, the benefits of inclusive design for younger, less-able user groups is acknowledged and remains vital to adopting an inclusive design approach.

The global population is ageing, with population ageing set to become one of the most significant social transformations of the twenty-first century (United Nations, 2015a). Life expectancy is increasing globally from 67 to 70 between 2000-2005 and 2010-2015 (United Nations, 2015b) with the global population aged over 60 increasing at a rate of 3.26% per year (United Nations, 2015b). Between 2015 and 2030 the number of people aged over 60 is expected to grow by 54% (United Nations, 2015a). This figure is higher for more developed countries – Figure 1.2 illustrates the predicted growth in the percentage population aged 60 years or over by region between 1980 and 2050 (United Nations, 2015c).

More details on the impact of population ageing are provided within this thesis. In summary, population ageing results in a change in physical capabilities of the population, with older adults often experiencing problems completing activities of daily life. People are working longer, but also find themselves excluded from many products and services. There is therefore a need to address this ageing population in the design of products and services. Design exclusion occurs when the capability demand of a product exceeds the capabilities of the user. It is therefore critical that the older user is fully integrated into the design process to ensure products meet their needs.

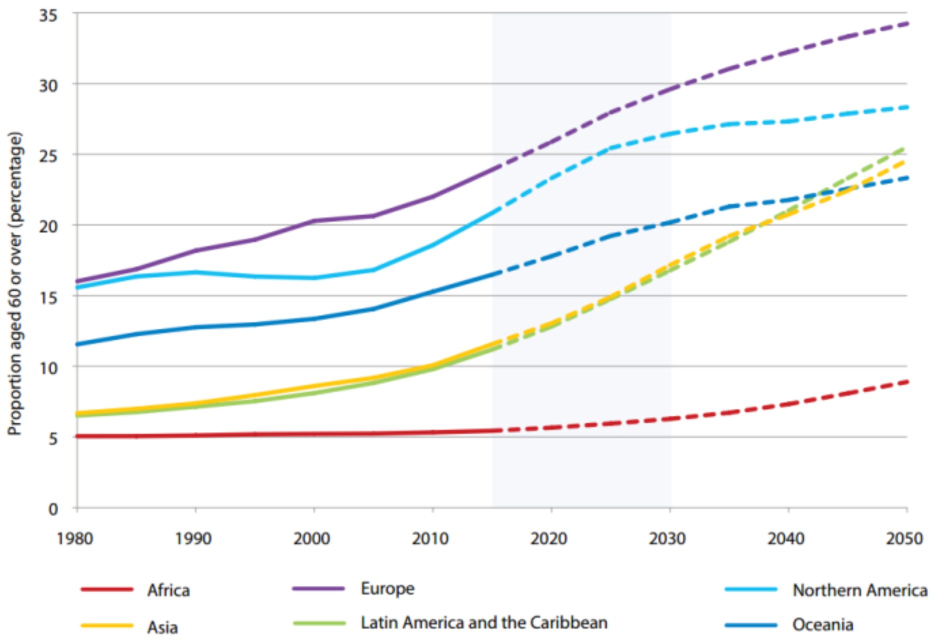


Figure 1.2 – Projected growth of population aged 60 or over from 1980-2050 (United Nations, 2015c)

1.2. Field of research

This research will cover four main areas of the literature: sports design, design processes, user centred design and inclusive design (illustrated in Figure 1.3). As will be discussed within the literature review, sports design is a young and evolving design discipline, with limited published work so far relating to the sports design process as a whole. However, much work has already been carried out into design processes in general, with multiple representations of the design process across a range of design disciplines. This research will focus specifically on the sports design process. Both user centred design and inclusive design have received large amounts of research interest. However, there is evidence that many products do not take into account a broad range of human capabilities. There is therefore scope to further improve the uptake and practice of inclusive design in industry. Given the user centred nature of both sports design and inclusive design, this research will assess parallels between both to establish if aspects of sports design practice are applicable to inclusive design.

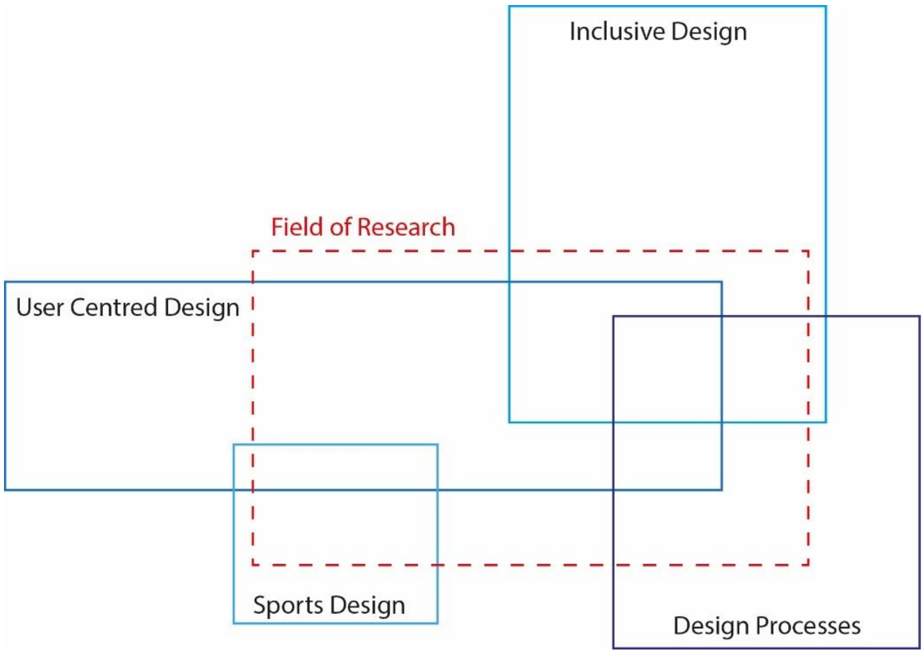


Figure 1.3 – Field of research

1.3. Research aims and objectives

To address the research aim (**to investigate how the sports design process can be used to improve inclusive design practice**) a practical approach was adopted, involving design companies within the research to ensure the research outcomes would be applicable to industry practice. Both sport and product design companies, in addition to product designers from industry with experience in user centred and/or inclusive design and inclusive design experts, were involved within this research to determine the applicability of the sports design process to inclusive design practice. To address the research aim, the following research objectives were identified:

1. To understand what differentiates the sports design and traditional product design processes in practice.
2. To determine what characterises the sports design process and to capture that process in a design process model.
3. To investigate the applicability of the sports design process to inclusive design practice.
4. To investigate how to improve the uptake of inclusive design in industry.
5. To validate the outcomes of the research.

All developments and refinements made to the research outcomes were made based on findings and recommendations from the designers themselves. Final year university student projects were also utilised in the validation of findings. The final outcome of this thesis should be a means of facilitating inclusive design practice within industry constraints and the resources available to designers, based on insights gained into the sports design process. The research will take into account current barriers to an inclusive design approach and will address the needs of the designers themselves.

This research will address three research questions, which will be presented within the context of the literature review (Chapter 2), where they originated from. The research approach (Chapter 3) provides detail on the structure and methodology of the overall thesis including each of the research questions and the studies undertaken to address them. The research questions that this thesis will address are:

1. What differentiates the sports design process from the product design process in practice?
2. What is the sports design process?
3. How is the sports design process applicable to inclusive design?

The rationale for each of the research questions is provided within the literature review.

1.4. Scope of the research

This research focuses on what characterises sports design practice, primarily the user centred nature of the discipline. Although much work has been conducted into the sports equipment itself, with the aim of enhancing safety and/or performance, there is a lack of published work into the process behind designing that equipment. In addition to sports design, this research will also address the issue of inclusive design. While there are many methods and tools that exist to aid the uptake of inclusive design, there are many designers and companies that do not adopt an inclusive design approach. This research will focus on the barriers to that approach and what can be done to address these barriers in design practice.

The outputs of this research are the first design process model to capture the sports design process as a whole and an interactive framework to facilitate designer-client communication within the inclusive design process. The sports design process model is descriptive of industry practice, while the framework intends to aid inclusive design uptake in industry, addressing some of the identified barriers to an inclusive design approach.

The research was conducted within the time and resource constraints of a PhD. Interviews were conducted and analysed by the researcher, which was a time consuming process – all interviews were recorded and transcribed, and analysed using a general inductive approach (Thomas, 2006) to identify core themes within the data. This research adopted a practical approach, involving design companies within each of the studies conducted to ensure the outcome is applicable within industry practice. Validation methods utilised with the research included a triangulation approach and respondent validation to ensure credibility in results. The outputs of the research were validated by the intended end users – the sports design process model was validated by practising sports designers, while the inclusive design framework was validated by both industry designers and design clients.

1.5. Structure of this thesis

Figure 1.4 illustrates the structure of this thesis. Chapter 2 presents the literature review, discussing existing research into sports design practice and design processes in general. The nature of user centred design will be discussed, as it is this approach that links both sports and inclusive design practice. Inclusive design is discussed, focusing on existing methods and tools to support its implementation and barriers to the approach. The literature review will also present the three research questions that this research will address, as outcomes of their respective sections.

Chapter 3 provides an overview of the research approach used within this research and discusses the structure of the research, research philosophy, theoretical positioning and research strategy and provides an overview of the research framework for each of the four studies conducted as part of this research. More details of the methodology for each of the four studies will be provided within the relevant chapters.

Chapter 4 addresses the first research question and presents the study conducted to identify the similarities and differences between the sport and product design processes in practice. The study utilises a triangulation approach involving interviews with sports and product designer companies, analysis of final year sports student university projects and validation of these findings against the literature.

Chapter 5 presents the iterative process of development, evaluation and validation of the first process model to capture the sports design process as a whole. The outcome of the chapter (the sports design process model) addresses the second research question.

Chapter 6 is the first step in addressing the third research question using interviews with industry designers and a workshop with inclusive design experts from the Helen Hamlyn Centre to discuss the potential of the sports design process model to aid inclusive design practice.

Chapter 7 presents the iterative process of concept generation, evaluation and development of an interactive inclusive design framework. The framework is based on requirements identified in Chapter 6 and undergoes multiple cycles of evaluation and development to ensure the outcome meets the needs of the designers.

Chapter 8 presents an interactive framework that facilitates designer communication with the client within the inclusive design process to fully address the third research question. The outcome is validated within the chapter through interviews with product designers and clients. The final interactive framework is presented here.

Chapter 9 provides a summary of the research as a whole, discussing the findings and conclusions, in addition to identifying limitations in the research and further work.

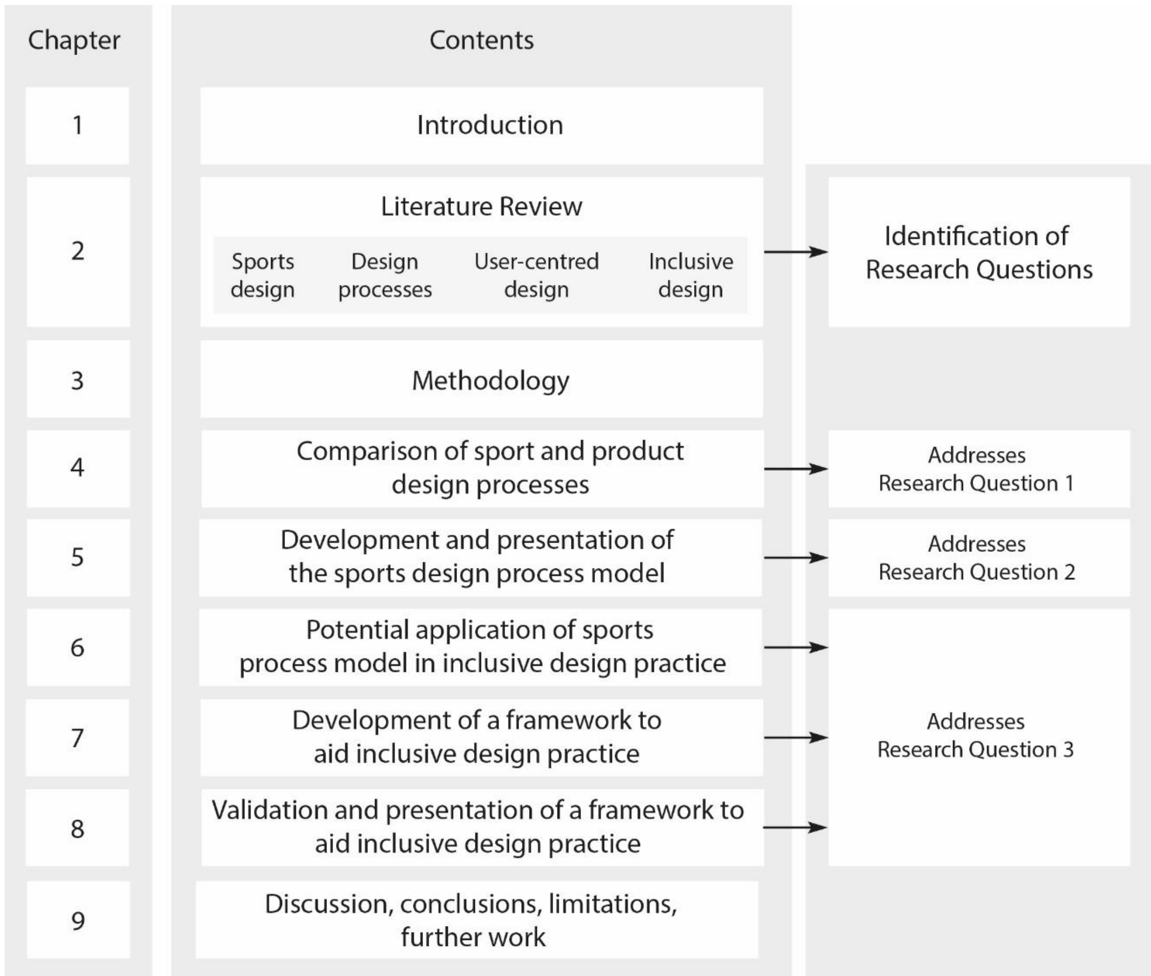


Figure 1.4 - Structure of thesis and research questions

Chapter 2 - Literature Review

This thesis will address the research aim presented in the introduction, "**to investigate how the sports design process can be used to improve inclusive design practice?**" through examination of the sports design process and the potential impact this process will have on inclusive design practice. There is therefore a need to understand work that has been completed within the relevant research areas and what has been done (if anything) to link these areas.

This section will present and discuss the literature relevant to the research conducted in this thesis. The literature covers four broad topics, which follow a sequential path to addressing the research aim. The structure of this chapter is illustrated in Figure 2.1. The introduction will provide a brief overview of the topics that will be discussed in the chapter and is followed by the methodology that was followed in undertaking the literature review. The literature itself has been organised according to the four high level research topics – sports design, design processes, user centred design and inclusive design, as illustrated in Figure 2.1. Each section contains a Venn diagram illustrating the breakdown of the literature discussed in that section. This is intended as a guide only to help the reader follow each section of the literature. A discussion section at the end of the chapter will provide a link between the four areas and consolidate the key findings from the literature review. The chapter findings will present the knowledge gap that this research will address.

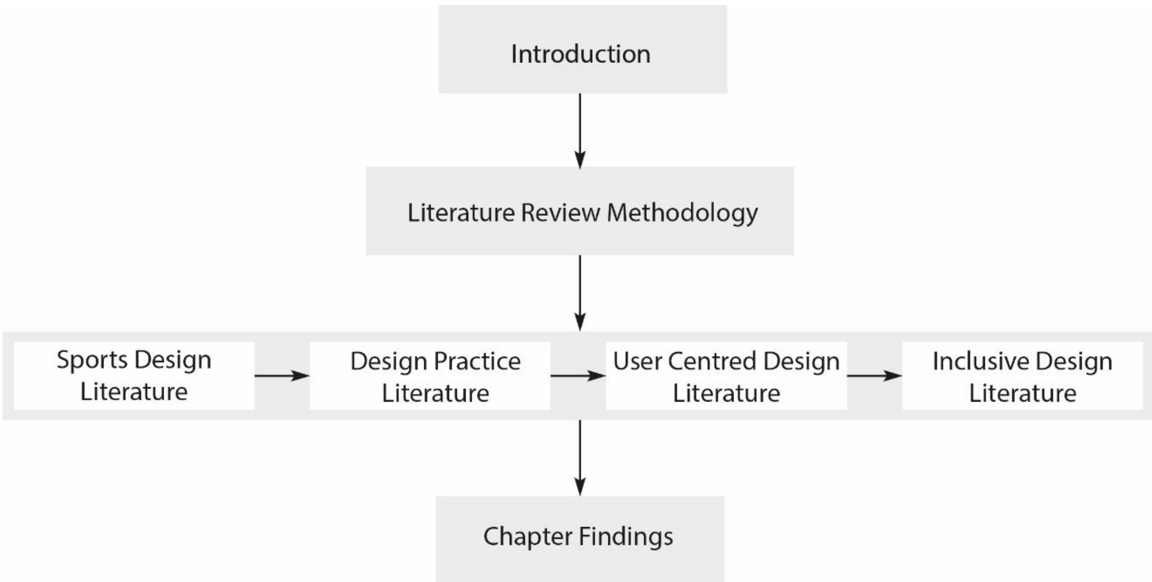


Figure 2.1 – Structure of Chapter 2

To understand the impact the sports design process can have on inclusive design practice, the sports design process itself must first be understood. Section 2.2 presents the literature relating to sports design practice. As will be discussed, this area of the literature is small, but presents an overview of what distinguishes sports design as a discipline and the work that has been completed regarding the design process specific to sports design. There is also a need to understand existing work that has been completed regarding design processes and the potential application of design processes across design disciplines. Section 2.3 presents the literature surrounding design processes in general and discusses the implementation of those design processes in industry.

As will be discussed in the literature review, sports design is a highly user centred design discipline. Existing research into user centred design practice will therefore be discussed in Section 2.4, which focuses on the importance of user centred design – specifically user information and user involvement within the design process. To address the research aim, there must also be an understanding of current inclusive design practice and the associated research. Section 2.5 provides an overview of current inclusive design practice, the tools and methods associated with the approach and the barriers to the uptake of inclusive design in practice. This will highlight areas within inclusive design research where there is work to be done to improve the uptake of inclusive design in practice.

At the end of each of the four main sections, a summary box is included to highlight the main findings from the literature discussed in that section. Three research questions were identified as a result of the literature review and are presented within the discussion of the relevant literature from where they originated.

2.1. Literature Review Methodology

The purpose of the traditional literature review is to explore issues, develop ideas and identify research gaps (Jesson, et al., 2011). The research conducted within this thesis explores the nature of the sports design process and the potential application of this design process within inclusive design practice, therefore a traditional approach to the literature review is applicable to the research presented here. The literature review conducted as part of this research is a scoping review (Jesson, et al., 2011) – aiming to “set the scene for a future research agenda. The review documents what is already known and then using critical analysis of the gaps in the knowledge, it helps to refine the questions to point a way to future research".

Key papers relating to each of the four main research areas discussed in the introduction to this section (sports design, design processes, user centred design, inclusive design) were identified using online search engines, located based on key words in the title and abstract as well as the number of citations – all papers came from peer reviewed sources. This identified several of the main contributors to the field. The references from these papers were then found and assessed for relevance to the research. Relevant papers were read and the reference lists from these papers were used to identify further literature. This process was repeated until a point of saturation – where no new relevant literature was found. The process followed in the literature review is illustrated in Figure 2.2. An additional search was carried out to search for existing inclusive design methods and tools. Not all of these were from peer reviewed sources but were considered relevant to this research and are therefore included in this literature review.

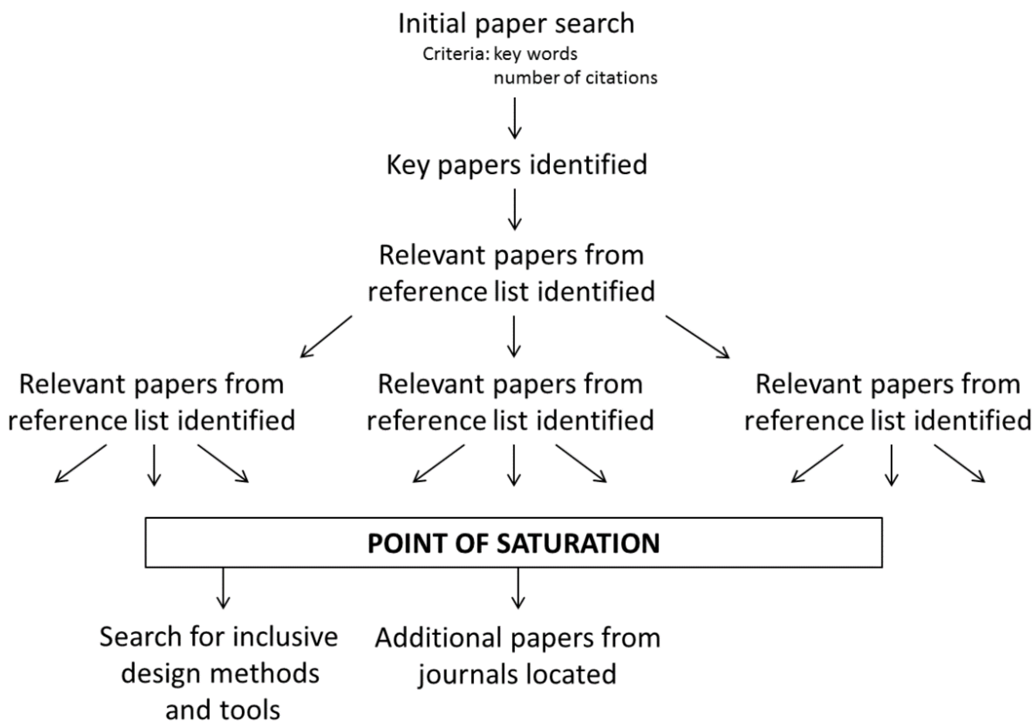


Figure 2.2 - Literature review methodology

To ensure new publications were included in the literature review, several key journals and conferences relevant to the field were identified – from the sources of relevant literature found during the initial search. Journals included in this search were Journal of Engineering Design, Design Studies, The Design Journal and Research in Engineering Design while conferences that were searched included the International Conference on Engineering Design and DESIGN. The volumes for each of these journals and conferences were searched for relevant papers – focussing on the last 10 years, with some new papers found from this search. This helped to ensure that new, relevant material was included in the literature review. The majority of the literature included in this review comes from peer reviewed journals and conference papers. However, key work in the area of design process models cannot be overlooked and must be included in the literature review. Several of these design process models are published in books and company/organisation reports (for example: the Design Council published the Double Diamond process model in their own report).

An initial systematic literature review was started using key words to identify relevant literature within the research areas identified in Figure 2.1. However, due to the size of the sub topics being covered, some sub-sections of the literature identified in Figure 2.1, resulted in tens/hundreds of thousands of related papers being found. As identified by Randolph (2009) an "exhaustive" coverage of the literature to consider all relevant research on a topic can be impractical given the time available. It would also be difficult to identify exclusion criteria for a systematic literature review – this research aims to be state of the art, but excluding literature before, for example 2000, would exclude a number of key foundation papers that are relevant to this research (for example – Pugh's Model of Total Design).

2.2. Sports Design Literature

This section of the literature review discusses what differentiates sports design from other design disciplines and provides an overview of studies that have been conducted into the design of sports equipment – in practice, research and education. The core areas of the sports design literature have been broken down, as illustrated in Figure 2.3 – the main research area of sports design is discussed in relation to its sub-sections of sports equipment, characteristics of sports design that differentiate it from other design disciplines, skills specific to sports designers and a review of existing processes and models specific to sports design.

The complexity and specialisation of high quality sports equipment is increasing, with the quality of the equipment becoming more and more important in all domains of sport (Krueger, et al., 2006). There is an abundance of research that has been undertaken into improving performance factors across all sporting domains, as reported in publications such as the Journal of Sports Engineering. This research is focused on both the equipment itself and the performance of the athlete. Sports design is a young and evolving discipline of engineering (Medwell, et al., 2011) and (Jenkins, et al., 2010). As stated by Jenkins, et al. (2010), it is only recently that the sports industry has seen the uptake of modern engineering techniques and methods into the research and development and manufacturing processes that are well established in other engineering disciplines, such as the aerospace and automotive industries. However, despite the recent growth in sports design as a field, there is a distinct lack of literature on the subject (Medwell, et al., 2012). This is in agreement with Muller (2011) who reported a lack of literature relating specifically to the design and manufacture of sports equipment.

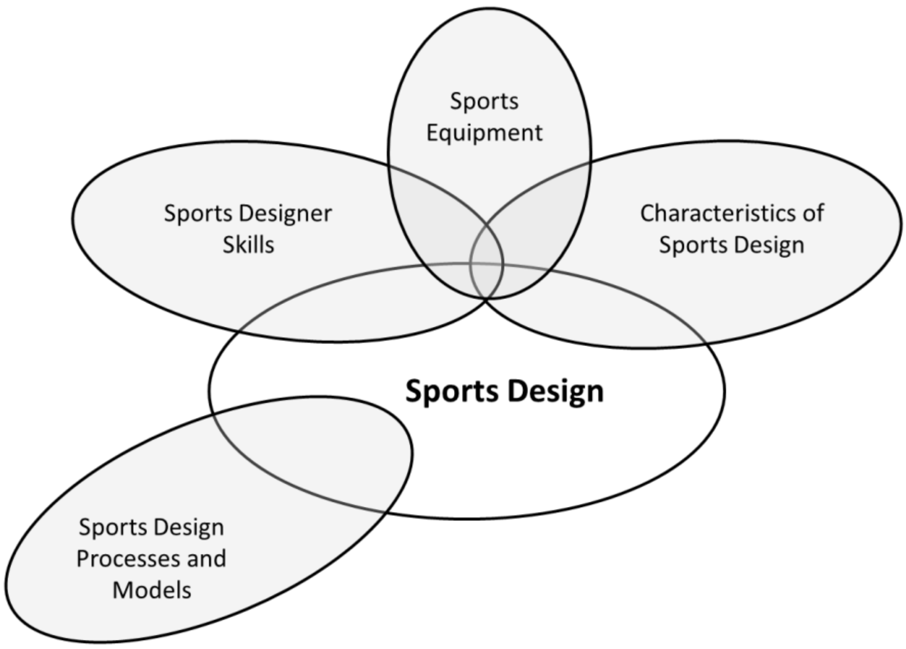


Figure 2.3 - Breakdown of key areas within the sports design literature

2.2.1. What is sports design?

> *"The major problem in defining sport is that the sport reality, that means what is perceived as sport by the society, is evolving"* (Muller, 2011, p.9).

The terms 'sport technologies', 'sports equipment', 'sports design', and 'sports engineering' are discussed throughout the literature with varying definitions provided. Krueger, et al. (2006) uses the terms 'sports equipment' and 'sports technology' synonymously to "include all goods for the use in sports". In order for an artefact to qualify as 'sports equipment' there is the requirement that at least one athlete be involved (Krueger, et al., 2006). Muller, et al. (2007) provides an alternate definition, where the term 'sports technologies' takes into account the artefact used to practice sport (the equipment), the materials used to build that equipment and the technologies used to produce the equipment. In later work, Muller (2011) discusses that the term 'sports equipment' may have become outdated due to the diverse applications and the increasing importance of technology in sport.

Wodehouse, et al. (2011) recognise sports engineering as an emerging cross-disciplinary industrial and academic field, with Muller, et al. (2007) stating that the term 'sports engineering' is "the area of research and design that ultimately generates knowledge to build and support sports technology". Jenkins, et al. (2010) defines sports engineering as: "involving trained professionals interacting with sports equipment manufacturers to develop new and better products". Within that paper, sports engineering is described as the link between classical engineering, sports science and medicine and the sports equipment, as illustrated in Figure 2.4. The outcome is a sports technology that is user friendly and will support the athlete in improving their performance (Jenkins, et al., 2010).

Sports engineers are defined as the people who "work with the sports equipment manufacturers to design and develop technology to solve the user's problems or to enhance the user's performance" (Jenkins, et al., 2010).

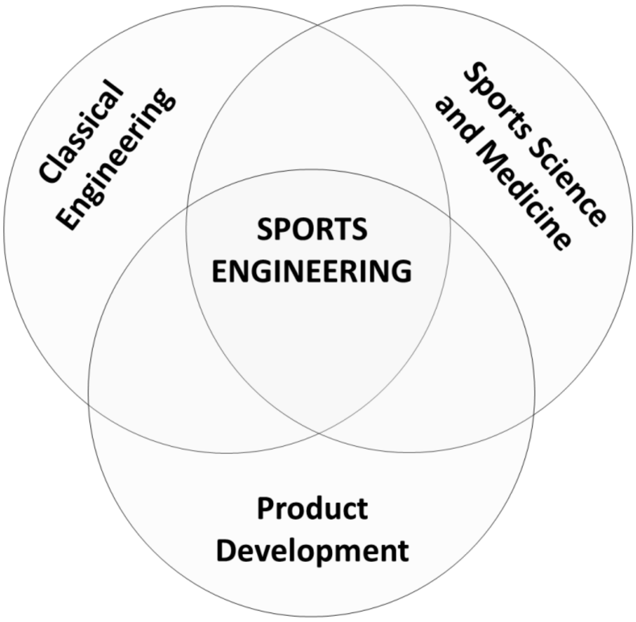


Figure 2.4 - Sports engineering within the context of classical engineering, sports science and medicine and sports equipment. Adapted from Jenkins, et al., (2010)

It is vital that the terminology used in sports design research is standardised to allow comparison between works and to provide a benchmark allowing those from other disciplines to understand the applicability of sports design research. This research proposes the following definitions, which will be used throughout the remainder of this thesis:

- Sports equipment refers to the artefact that is used by the athlete to undertake participation, training or safety in their sport.
- Sports design is the design and development process undertaken by the designer, with the outcome being sports equipment.
- Sports engineers (designers) are the designers who design the sports equipment.

It should be noted that within this thesis, the term sports equipment refers specifically to equipment that the athlete will interact with physically (for example, running shoes or a tennis racquet). Within this thesis, the term does not apply apparatus used in traditional sports that is viewed as an opponent to the athlete (for example, the bar in the high jump) (Muller, 2011).

2.2.2. Sports equipment

Following on from the definition of 'sports equipment' provided in the previous section, the utilisation of that equipment will be discussed here. Sports equipment is regarded as "an extension of the athlete's body, enabling a fusion of human and object and allowing the spontaneous generation of new movements" (Muller, 2011). Sports equipment development is an important part of improving athletic performance (Stefanyshyn & Wannop, 2015) and should enable the athlete to undertake their sport, by facilitating performance through the interaction between the equipment and the athlete.

As technology has advanced, there is a growing requirement from athletes for equipment that will enable them to improve their sporting performance, resulting in an increasing need for sports engineering (Jenkins, et al., 2010). In recent years, technological advances in sports equipment have substantially transformed athletic competition due to enhancements in athletic performance, an increase in the durability of the sports equipment due to the introduction of composite materials and a reduction to the risk of injury to the athlete (Stefanyshyn & Wannop, 2015).

> *"A flawlessly engineered mechanical piece of sport equipment can still fail if the athlete-equipment interaction is not properly addressed in the design process"* (Stefanyshyn & Wannop, 2015, p.191).

It is noted that sound engineering does not guarantee the desired interaction between the equipment, the athlete and the action (Stefanyshyn & Wannop, 2015). Stafanyshyn and Wannop (2015) view the equipment (on its own a purely mechanical system) interacting with the athlete as a biomechanical system. The sporting activity is performed by the athlete (regardless of the equipment used) and it is the way in which the athlete uses the equipment that results in the skilled execution of the sport (Muller, 2011). As such, the usability of sports equipment is vital to the athlete and to the overall sporting performance.

2.2.3. Characteristics of sports design

Characteristics are features that differentiate sports design from other design disciplines. Muller, et al., (2007) proposes that for sports equipment, characteristics specific to their design include form, function and materials. For context of use, characteristic features include social aspects and interfaces. As a result, sports equipment differs from other types of products and is unique in terms of their design task (Muller, et al., 2007).

An example of the feedback that is unique to sports engineering is provided by Krueger, et al., (2006): the sound of a tennis racquet at the point of impact with the ball enables the athlete to gain information concerning technique. However, side effects should also be considered in the design process as they can have an undesired effect, such as the vibration of the tennis racquet. When developing sporting equipment, it is vital that sports designers understand this interaction between the athlete and the equipment in order to allow the athlete to perform to their full potential (Stefanyshyn & Wannop, 2015).

In a more recent study (Muller, 2011), 61.2% of athletes that were questioned regarding the characteristics of sports technology replied that specific functionality was the most important characteristic of their equipment. Muller (2011) also states that the emphasis on the athlete's (user's) behavioural aspects is of unique importance compared to that of the design of other technological products. It is apparent that sports design is a highly user focused discipline, where the equipment must aid the athlete in the completion of their sport. Stefanyshyn and Wannop (2015) anticipate that the future of sports engineering is likely to progress to designing for the individual athlete in order to create a solution unique to each individual to maximise sporting performance.

Four types of intended effects have been identified for the function of sports equipment: improvement of athlete performance, improvement of athlete training, improvement of safety, supply of information, or a combination of these (Krueger, et al., 2006). In competitive sports, the effect of 'improvement of athlete performance' is vital in gaining a competitive advantage and ultimately, better results in competitions (Krueger, et al., 2006). Examples given within the paper include the optimised swim suits as a means of gaining better results in competition and a cycling helmet, which provides protection and reduction of wind resistance.

In addition to the intended effects of sports equipment, there are a number of subjective effects that can affect an athlete. Perception, emotion, status symbol and trend-setting are included as subjective effects and can have a large impact on sales volume (Krueger, et al., 2006). It is therefore necessary to take these into account during the design process, particularly for performance orientated sports products. However, these aspects are harder to define in terms of requirements as subjective factors vary between users. Krueger, et al., (2006) recommend that precise requirements should be considered in all phases of the design process, particularly during product planning and the conceptual and embodiment design phases. These can then be used as criteria to evaluate the quality of the design proposal and evaluate the concept or prototype.

2.2.4. Sports designers

Despite a lack of literature into the process of sports equipment design, there are several studies (discussed here) that present the core skills of sports designers/engineers and the make-up of their educational background. Sports engineering is a specialised field, with programs typically made up of a combination of existing courses in broad fields of mechanical and electronic engineering (Medwell, et al., 2012) with a number of other courses and skills added to the program. These findings are in agreement with Wodehouse, et al. (2011), who state that sports engineers can also bring an understanding of physiology, anatomy and biomechanics to the design of sporting products. As previously discussed, Jenkins, et al., (2010) report that sports engineering is the link between classical engineering, sports science and medicine and product design. Core elements from each of these subject areas that combine within sports engineering are summarised in Table 2.1.

Classical Engineering	Sports Science and Medicine	Product Development
Math	Sports	Creativity
Science	Athletes	Innovation
Problem Solving	Functions of the body	Customer service

Table 2.1 - Core components of sports engineering. Data taken from Jenkins, et al., (2010)

Medwell, et al., (2012) state that sports designers must have developed core fundamental skills in both mathematics and dynamics to enable them to apply the equations of motion in a sporting context. Sports designers must also have the ability to interactively process and analyse data, which is not always covered in traditional engineering subjects (Medwell, et al., 2012). Another skill that is unique to sports designers is the ability to interact directly with athletes and coaches. Biomechanics testing also plays a major role in many sports engineering university programs (Medwell, et al., 2012) – before developing sporting equipment, sports designers must have a good understanding of the biomechanical variables that can influence sporting performance (Stefanyshyn & Wannop, 2015). As discussed by Wodehouse, et al. (2011), participation in sports by sports designers is encouraged, with the insights gained as a result beneficial within the sports design process.

In an educational context, sports engineering courses are intended to train future designers of sports equipment. A paper by Medwell, *et al.,* (2012) discusses the development of sports engineering education. While the paper focuses on Australia, the courses specific to the sports engineering degree are unlikely to vary significantly in other countries. Core subject areas include biomechanics, sports design and testing, sports materials and the structure and mechanics of the musculoskeletal system, in addition to the development of computer graphical user interfaces (Medwell, et al., 2012).

2.2.5. Sports design process

As is discussed within the sports design literature, there is a lack of literature into the sports design process. To identify literature relevant to the sports design process specifically, a systematic literature review was conducted using combinations of key words to search internet databases and identified key papers relating to the research. Key words used in the search included ‘sports design’, ‘sports engineering’, ‘design processes’, ‘process models’, ‘sports equipment design’ used in a variety of combinations. The search resulted in 626 results once filters were applied within the data bases. This was reduced to 25 articles once duplicates were removed and titles and key words were read to identify potential relevant papers. Of the 25 articles, 9 were found to be of direct relevance to the research. The reference lists for these relevant papers identified additional literature and this process was repeated to a point of saturation. Key journals and conferences to the sports engineering field (for example: the Journal of Sports Engineering) were also searched to identify existing work into the sports design process. No date was used for exclusion criteria as the core purpose of the search was to identify the existence of a sports design process model, regardless of publication date. In addition to searching for work specific to sports engineering, the literature reviewed a range of design process models across various design disciplines.

Following the literature review there was no evidence found of the whole design process behind sports equipment having been studied. This is surprising on two counts. Firstly, with the increasing demand in the world of sport to continually improve sporting performance, it would be expected that more interest would have been taken into the process of designing sports equipment and secondly, from the increase in awareness in inclusive and user centred design it could be expected that lessons could be learnt from what is also a highly user focused discipline. Although no study has been found that investigates the sports design process as a whole, there are a small number of studies that have investigated certain areas of sports equipment development. These will be discussed here and provide an insight into what differentiates the sports design process.

A PhD thesis (Muller, 2011) proposes a prescriptive model that illustrates the relationship between sport activity and sport context instances. It is developed based on earlier research within the thesis with a leisure sports research perspective, focusing on sports activity and the functional aspect of sports technology. The model, illustrated in Figure 2.5, is intended for use in clarifying input parameters for new design work and for the evaluation and comparison of existing products.

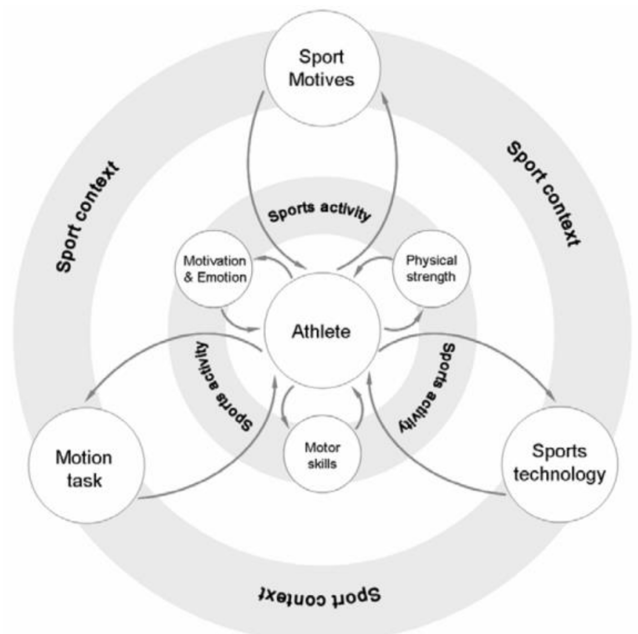


Figure 2.5 - Sports model illustrating the relationship between sports activity and sports context instances (Muller, 2011)

The model in Figure 2.5 is intended to aid in task clarification, determination of functions, design of separate modules and design of the entire product, which are illustrated in darker shading in Figure 2.6 within the context of the design process. Although the model may be of use to sports designers in their understanding of sport and sports technology, there is no evidence of validation of the model within an industry context or of what its benefit may be to designers (in terms of costs, time, design outcome, etc.). While the model may be of use within certain phases of the design process, it does not illustrate the sports design process as a whole – rather it highlights areas of focus within a generic design process.

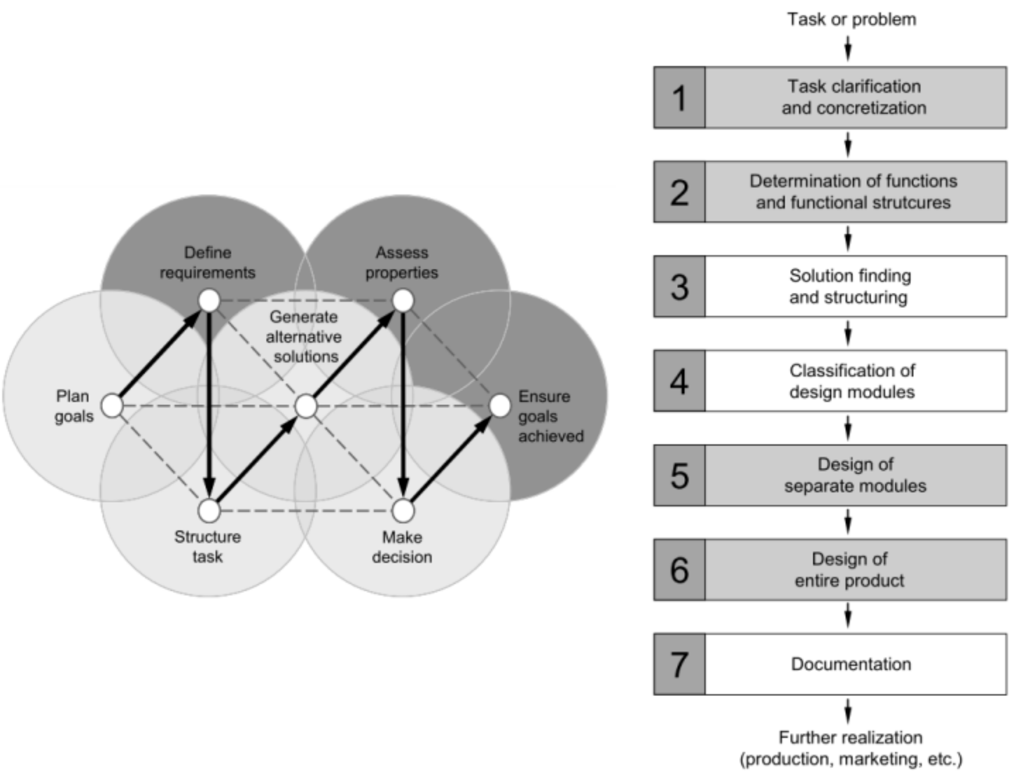


Figure 2.6 - Impact of Muller (2011) research on areas of the design process

An older study into the interaction between the athlete-sports equipment-system (Krueger, et al., 2006) aimed to produce a model that would assist sports designers involved in the design of performance orientated equipment. This is in contrast to the study undertaken by Muller (2011), which focused only on leisure sports. The model describes the interactions between the athlete, the sports equipment and the environment, as shown in Figure 2.7 and is modified according to the VDI guideline 2242 (VDI 1986).

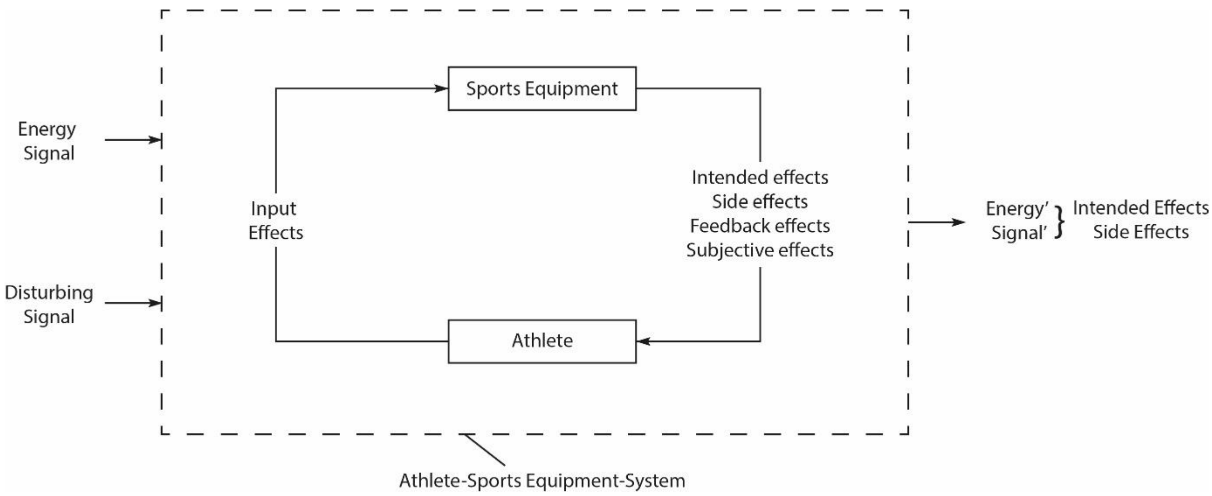


Figure 2.7 - A model for the interaction between the athlete-sports equipment-system and the environment (Krueger, et al., 2006)

The model shown in Figure 2.7 is applied to illustrate an athlete-shoe system within the paper (Figure 2.8) to demonstrate the practical application of the model. When the athlete uses the shoe to run, there is a mechanical load placed on the shoe – the input effect. Dampening of the shoe softens the heel strike, providing cushioning (safety) and improves energy return (performance), which are the two intended effects of the shoe. Sensory information is also returned to the athlete concerning technique. Side effects of the product in competition could be time loss due to over-dampening. However, the while the authors claim that the paper has "shown that the model can be used to assist the designer of performance orientated sports equipment and thus to support a systematic product design process in sports," there is no evidence in the paper of the practical implementation of the model in industry. Like the model presented by Muller (2011), which is intended to aid task clarification, determination of functions, design of the product at specific stages of the design process, this model provides a representation of the athlete interacting with the equipment in the sporting environment/context, which may again aid designers at certain stages of the design process. However, neither model is representative of the sports design process as a whole.

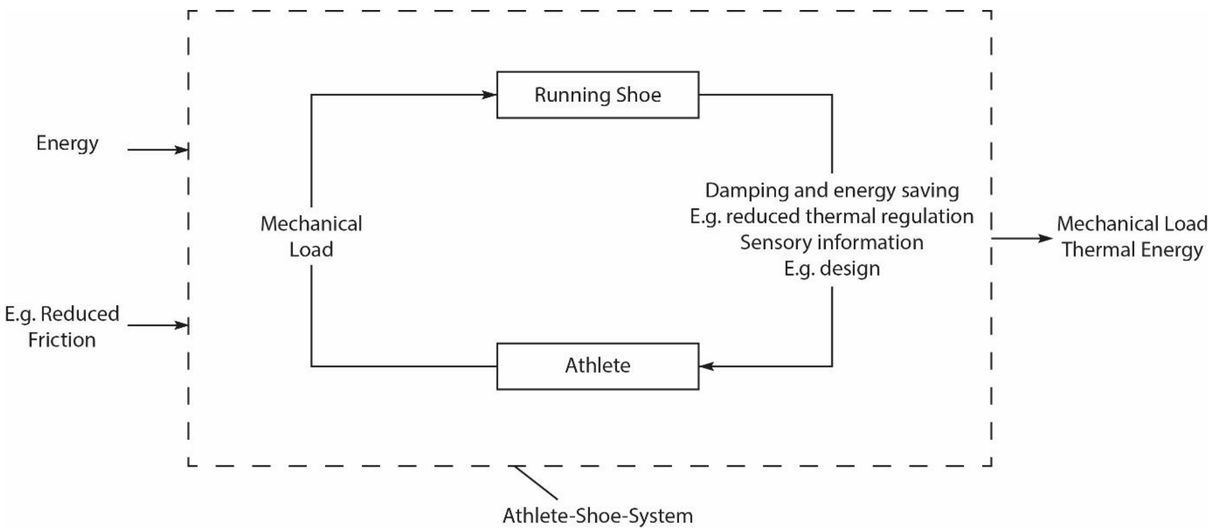


Figure 2.8 - Interaction between the athlete, shoe and environment (Krueger, et al., 2006)

The impact of the characteristics of sports equipment on the design process is summarised by (Muller, et al., 2007) and is illustrated in Figure 2.9. The characteristics of sports equipment provide a pool of information between the initial design process steps of 'new product ideas' and 'design tasks' and the later stages of 'task clarification' and 'conceptual design'. The paper states that the benefits of knowing the characteristics of sports equipment on the design process would include:

- Estimation of testing to assess design parameters (e.g. biomechanical loads).
- Assessment of boundary conditions or limiting factors (e.g. legal restrictions).
- Supporting task clarification with specific facts.
- A structured overview of relevant design aspects for embodiment design.

The paper documents the process undertaken to create the model. However, there is no record of implementation of the model to aid in a design task. The model in Figure 2.9 illustrates the effects of sports specific characteristics on the early stages of the design process but does not illustrate the effect of these on later stages. It could be expected that sports specific characteristics would play a key role throughout the later stages of the design process, although there is no justification given within the paper to explain why only the initial stages of the design process were included in this model.

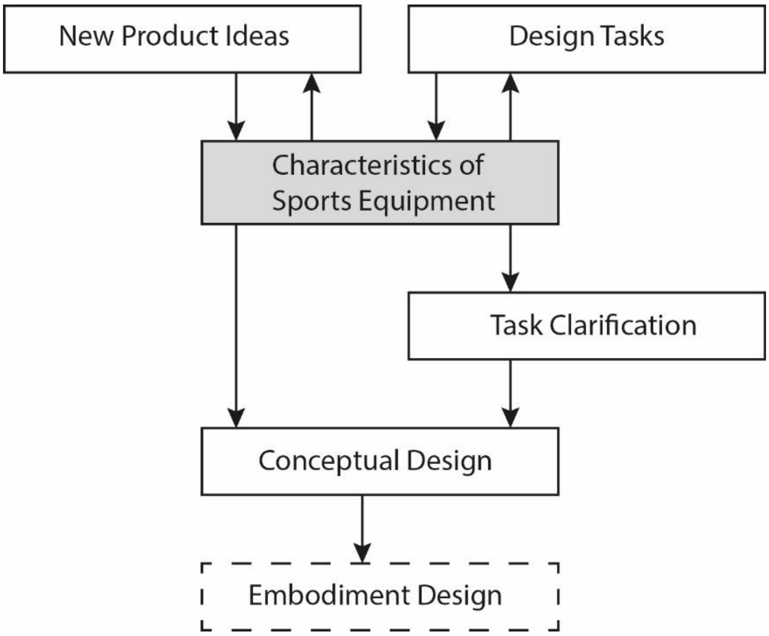


Figure 2.9 - Impact of the characteristics of sports equipment on the design process (Muller, et al., 2007)

There are variations in the models presented here, with the Muller (2011) model focusing on leisure sports, while Krueger, et al. (2006) describes a performance sports model. The model described by Muller, et al. (2007) does not indicate which aspect of sports design the model is targeting – it appears to be a general overview of sports engineering as a discipline. The sports design process is described as being user centred (Kranz, et al., 2007). From the models described in this section, it is apparent that the athlete's interaction with their equipment is a core characteristic of sports design. However, none of the models presented here illustrate the sports design process as a whole. As stated by Ielegems, et al. (2015), "every design aspect needs a different approach, specific to its characteristics, scale and timing throughout the process" (Ielegems, 2015, p.4).

2.2.6. Discussion

This section has presented the findings from the literature review undertaken into the field of sports design. It is acknowledged that this is a small, but emerging field within the design discipline as a whole. However, with the growth of the sports design field discussed in Chapter 1, it is essential that the research associated with it continues to expand. The terminology used within sports design research shows some variation, which has been standardised within this section. These definitions will now be applicable throughout the remainder of this thesis.

This literature review has identified characteristics that are specific to sports design and differentiate it from other design fields. This includes a combination of usability and performance of the equipment, the interaction between the athlete and the equipment as a system, and other areas such as perception and emotion associated with the product. Testing plays a key role in the sports design process in practice to enable designers to gain feedback that would not be achievable without athlete involvement, in addition to sports designers engaging directly with coaches and athletes and an ability to understand biomechanical analysis in relation to athlete performance. There is therefore a differing skill set between sports designers and product designers that facilitate a deeper understanding of the athlete (user).

The models presented in this literature review, which illustrate areas of the sports design process, lack validation regarding the applicability of the model to industry and the benefits the sports designers themselves would gain from using such a model (with the exception of Muller (2011), where the model was demonstrated within an example design application). As identified in this research, there is an absence of a study that has assessed the sports design process as a whole. It is vital that any model of the sports design process is representative and applicable to industry to ensure that there is value in the output of the work. This lack of a sports design process model indicates a knowledge gap that this research will aim to fill and introduces the first of the research questions that this thesis will address – **what is the sports design process?**

The next section will present the literature on design process models, emphasising the importance of a defined design process to business success, and provides a summary of a number of published design process models.

Section summary:

- Sports design is an emerging field within the design discipline as a whole.
- Terminology relating to sports design is defined within this section.
- Sports design possesses characteristics that differentiate it from other design fields.
    - The athlete and the equipment operate together as a system.
    - Sports designers deal directly with coaches and athletes.
- There is no study that has investigated and defined the sports design process as a whole.
- Research question: what is the sports design process?

2.3. Design Process Literature Review

The literature relating to the design process has been identified as falling into several key areas as illustrated in Figure 2.10: an introduction to design and the design process, an overview of a range of existing design process models (across a range of disciplines) and the application of design process models in industry. As identified in Section 2.2 there is a lack of a design process model specific to the discipline of sports design. This section will make the case for the importance of companies following a design process model in terms of business success and will review a number of design process models, focusing on the foundation process models for the design discipline as a whole as well as new, proposed process models that are of relevance to this research.

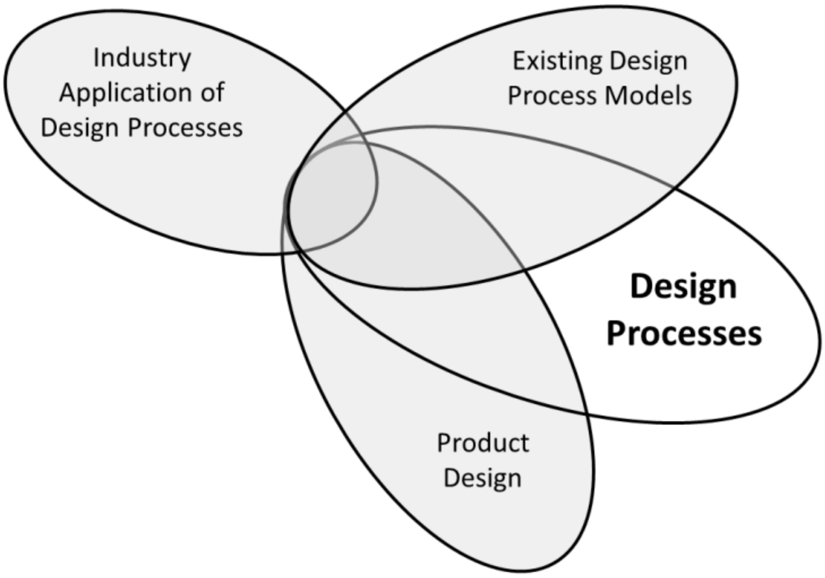


Figure 2.10 - Breakdown of key areas within the design process literature

2.3.1. What is design?

Design is concerned with problem identification and solving (McGinley & Macredie, 2011), with total design defined by Pugh (1990) as, “the systematic activity necessary, from the identification of the market/user need, to the selling of the successful product to satisfy that need”. Haik (2003) identified three levels of design:

1. Adaptive design: the adaption of existing designs.

2. Development design: the designer starts from an existing design but the final outcome may differ markedly from the initial product.
3. New design: only a small number of designs are new designs.

The field of design is broad – people are now associating the word 'design' with the experience of using a product rather than just the physical product itself (Formasa, 2009). As stated by Formosa, (2009), for a product to be successful, it must now exceed expectations rather than simply meet them. The inclusion of user requirements and concerns has added to an already extensive list of factors that designers must consider when developing a product (Margolin, 1997) making the job of the designer far more complex than before. The designer now has the task of meeting user needs that the user themselves may be unaware of.

Designers often work within a company or for a design consultancy. Within a company, product development projects are typically undertaken by multi-disciplinary teams, including members from design, marketing, engineering, manufacturing and other fields (Formasa, 2009), although this is often dependent on company size. In contrast, designers within a consultancy receive the design brief from an external client, and as with large companies, consultancy designers can also work in teams.

Few products are new designs – the majority of design work focuses on the redesign of existing products (Margolin, 1997). This already highlights issues with current design processes as many support new product development rather than the development of existing products. This research aims to be reflective of real-world design, ensuring that findings are relevant to current design practice.

2.3.2. What is the design process?

The design process is defined as "a rigorous, cyclical process of enquiry and creativity… consisting of a series of methods that are put together to suit the nature of each design project" (Best, 2006). It is made up of a series of stages that are undertaken in order to design and commercialise a product (Ulrich & Eppinger, 2012). The design process should highlight which methods and activities are critical to companies and how they interact (Unger & Eppinger, 2011). They can be used to prescribe core activities and outputs that need to be achieved at each stage to allow planning, scheduling, resource allocation and monitoring throughout the process (Tahera, et al., 2015), in addition to supporting problem solving, aiding decision making, providing a common platform for communication and for use in project visualisation, planning and execution (Maier & Storrle, 2011).

The activities of the design process should be brought together in a way that meets the requirements of a problem or a project (Design Council, 2007a). It is therefore difficult to standardise the design process as the process is reflective of the designer and adapted to suit the individual needs of the design project. However, Best (2006) found that although there is no best practice design process that is applicable to all problems, there are a series of core activities that can be adapted to fit individual problems. Gericke and Blessing (2012) studied design processes from across a number of design disciplines and found similarities in the core stages and the stepwise, iterative process. Core stages of existing design process models include need recognition, task analysis, conceptual design, embodiment design, detail design and implementation (Gericke & Blessing, 2012). Problem structuring occurs mainly in the beginning of the design process but also reoccurs periodically as the design activity progresses (Restrepo, 2004).

There are reports throughout the literature that emphasise the advantages associated with implementing a design process – "companies that follow a reference process are usually more successful" (Costa, et al., 2015). This is evidenced by reports of product successes and failures that are linked to the use or absence of a design process. Haik (2003) stated that: "a successful design is achieved when a logical procedure is followed to meet a specific need". While it cannot be guaranteed that following a design process will result in a successful design solution, there is evidence to suggest that the more time and effort an engineer spends on articulating the problem definition and understanding the needs statement, the less need there will be for frequent iteration (Haik, 2003).

The Design Council (2007a) reported that there is a direct correlation between business success and the use of a formalised design process, which is in agreement with earlier case studies carried out by Cooper (2001), where it was found that companies that implemented a design process were more successful. Pugh (1986) found that the Total Design model has enhanced understanding, improved teaching and practice and has resulted in better designs. Howard *et al.* (2008) state that a full understanding of the design process is of great interest to individuals and organisations. However, case studies (Cooper, 2001) based on industrial projects show a lack of consistency in the design processes followed by companies in practice – in some cases no process was followed at all – resulting in the failure of new products in the market. It is therefore apparent that an accurate representation of the design process is needed to aid the continuous improvement of design practice.

> *"Fierce competition has put pressure on companies to develop cheaper products of higher quality in less time and to fulfil specific and rapidly changing customer needs… This has drawn much attention to the management of design processes"* (Shapiro, et al., 2015, p.2).

When designing complex products, it can be difficult to assess inefficiencies and specify improvements in the design process (Pepe, et al., 2011). "Engineering design processes are central for product development and design," (Gericke & Eckert, 2015) therefore without a design process that is reflective of company practice, it is challenging for businesses to highlight areas of improvement. Modelling the design process allows clear identification of areas for improvement, ensures the design team understands the decision process and improves the overall efficiency of the company to allow scheduling of people, procedures, methods and tools. In the product development process, the knowledge of the problem is limited in the initial stages, only growing as the project progresses. However, there is less scope to implement design changes as the project progresses. A comprehensive understanding of the design process will also allow for unexpected challenges to be accommodated, although it is recommended (Bruseberg & McDonagh-Philp, 2000) that there is a need for more flexible design methods due to the diversity of design practice. Although it can be argued that there is no single model of the design process that is universally accepted, it is apparent that the continual development and refinement of design process models will further aid and improve current design practice within design disciplines.

2.3.3. Existing design process models

> *"Despite the extensive research undertaken since the 1950s, there is no single model which is agreed to provide a satisfactory description of the design process"* (Clarkson & Eckert, 2005, p.35).

There has been extensive work carried out by design methodologists to map and illustrate the design process since the 1960s (Cross, 2000), (O'Donnell & Duffy, 2001), (Roozenburg & Cross, 1991) and (McGinley & Macredie, 2011), resulting in many representations of the design process – a study by Gericke and Blessing (2012) found 124 design process models in the literature. The quantity of design process models presents the challenge for organisations of how to select the most appropriate model – however, to make an appropriate selection, a good understanding of the available models is required (Costa, et al., 2015).

The average age of a design process is around 24 years (Gericke & Blessing, 2012) with many newer processes based on existing models. It is surprising that with the developments in product design in recent years there have not been similar developments to the overall structure of design practice. There is therefore a need to continue research into the design process with the aim of improving current practice. As stated by Pugh (1986) a new design process must not only critique existing models, but must also provide an alternative that will aid the communication and understanding of the design process.

Design process models can be descriptive or prescriptive. Descriptive models represent how design actually takes place – in particular the studies that focus on successful processes and products are relevant to the aim of improving design practice (Blessing, 1996). Prescriptive process models are considered to represent effective and efficient practice and often provide a systematic sequence of stages or activities and recommend certain methods for specific stages in the process (Blessing, 1996). However, prescriptive models tend not to be based on extensive descriptive studies – they are usually based on the practical experience of the authors (Blessing, 1996).

Many design process models share similarities in their structure and appearance. Early representations of the design process suggested a linear progression between stages suggesting that design problems are solved progressively in one go. It is proposed (Lindemann, 2003) that the design process could be split into three basic elements: clarify the target, find solutions and select the solution. However, there is much overlapping between each of these elements. Most design process models follow a step-wise, top-down, iterative approach to allow monitoring of the design process and ensure that the problem is understood before developing solutions (Blessing, 1996), although it can be argued that over-complicating the process alienates many practitioners and limits creativity. Pugh (1996) identified that many assume the design process to be linear with iterations between stages when in reality there are regularly overlaps, with many stages often running concurrently. This is supported by more several more recent studies. A study by Maier and Storrle (2011) found that experts emphasised the iterative nature of the design process as it would be impossible to find the optimal design solution first time and design requirements were constantly updated. An earlier study (Bruseberg & McDonagh-Philp, 2000) reported similar findings following interviews with five designers to understand the design methods used in practice – designers emphasised the iterative nature of design due to repeated generation and evaluation of concepts. Sims (2003) also reports on continuous iteration of prototyping, testing and evaluation used to improve the design while Tahera, et al. (2015) states that the product development process is not a linear process of 'design-build-test', but that the design and testing stages are closely integrated. Studies conducted by Lawson (2006) and Choueiri (2003) are less conclusive regarding the structure of the design process, finding that the way in which designers work in practice is often unclear, with overlapping phases. The studies discussed above used different approaches, including questionnaires and face-to-face interviews. While it can be argued that the results of a survey may be too general, the interview-based approach used in other studies would gain more detail. It is therefore concluded that the design process in practice is highly iterative, consisting of activities that are often less well-ordered than is indicated within process models.

Table 2.2 presents an overview of a combination of some of the more well-known design process models, including foundation process models on which many newer models are based (e.g. Pugh's model of Total Design). In addition, some more recent models that are directly relevant to the field of research discussed in this thesis are included. This list is not exhaustive and there are many more design process models that are not discussed here. For the processes discussed here, it is noted that the sequence of core activities shows little variation between models although there are some differences in the terminology of naming the core stages. The major differences between design process models are the emphasis on the problem or product, the level of detail (Blessing, 1996) and the linear, sequential nature of some models compared to the spiral, cyclical nature of the others (Roozenburg & Cross, 1991). Table 2.2 is adapted from a table produced by Howard, *et al.* (2008) and allows a comparison of the core stages of the design processes with some

	Problem Definition	Formation of the Brief	Conceptual Design	Design Development	Design Refinement	Implementation	
Cross (2000)	Exploration	X	Generation	Evaluation		Communication	
Boehm (1988) Design Spiral	Task Identification		Evaluate Alternatives	Evolutionary/Incremental Development		Review	Implementation
Double Diamond (Design Council, 2005)	Discover	Define	Develop			Deliver	
French (1985)	Need	Analysis of Problem	Conceptual Design	Embodiment of Schemes	Detailing	X	
PDP Model (Tahera, et al., 2015)	Planning/Requirement Analysis		Concept Demonstration	Design Verification	Product Validation	Production Release	
Pahl & Beitz (1984)	Planning	Clarification of Task	Conceptual Design	Embodiment Design	Detail Design	X	
Pugh's Model of Total Design (1990)	Market	Specification	Concept Design	Detail Design		Manufacture	Sell
Stage Gate (Cooper, 2001)	Discovery	Scoping/Build Business Case	Development		Validation + Testing	Launch	Post-Launch Review
Ulrich & Eppinger (1995)	Strategic Planning		Concept Development	System-Level Design	Detail Design	Testing + Refinement	Production Ramp Up
VDI 2221 (Beitz, 1985)	Clarify Task	Define Functions	Search for Solution	Divide into Modules	Develop Layout	Prepare Production + Operating Instructions	
V-Model for More (Ielegems, et al., 2015)	Preceding Knowledge	Preparation + Brief	Concept Design	Developed Design	Detailed Design	Construction	In Use

Table 2. 2 - Summary of published design process models. Adapted from Howard, *et al.* (2008)

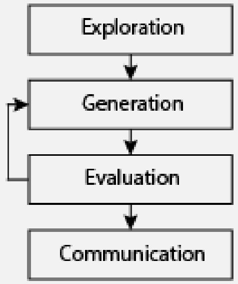
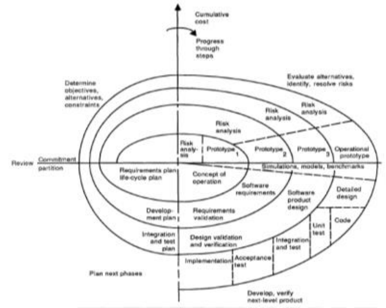
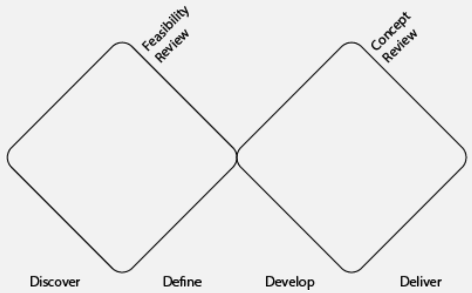
differences noted in breaking down of some sections (predominantly the implementation phase) into sub-sections.

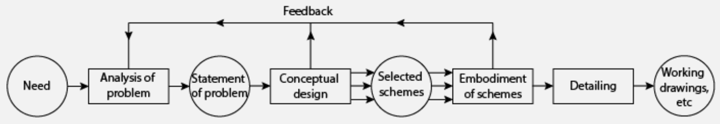
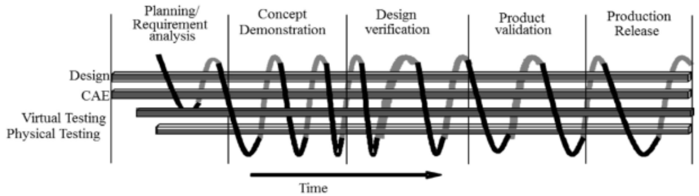
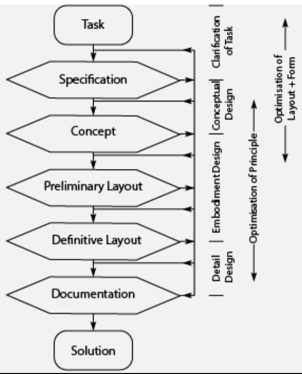
Table 2.3 is adapted from Gericke and Blessing (2012) to describe the activities carried out during each stage of the design process. The name of each stage is taken from the column headings in Table 2.2 to allow standardisation of the process. As stated by Clarkson and Hamilton (2000) the main activities of the design process can be broken down further into a series of tasks that must be completed in order to progress through the design process.

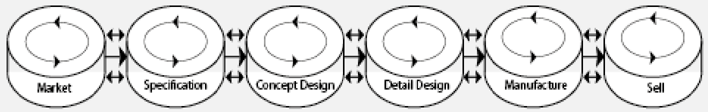
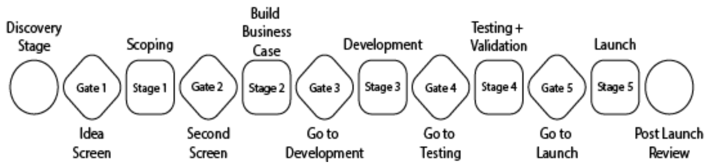
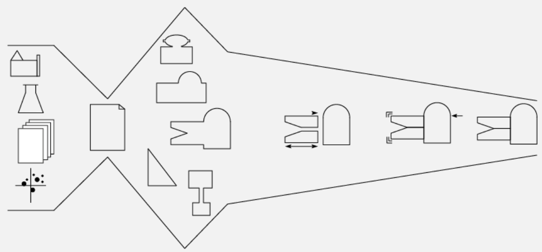
Stage	Description
Problem definition	Initiation of the design process by a product idea, or the identification of a need or problem.
Formation of the brief	Detailed analysis of the initial description of the task, need, idea. Additional information gathered.
Conceptual design	Development of abstract/principle solutions (concepts) which solve the problem.
Design review	Assessment of progress in relation to objectives and specification targets with key stakeholders within the company.
Design development	Detailing the conceptual solution.
Design refinement	Integration of sub-solutions, refinement and finalisation of the solution. Formal communication of documents for manufacture.
Implementation	Productions, selling and marketing of the new product.

Table 2.3 - Breakdown of the core stages of the design process. Adapted from Gericke and Blessing (2012)

More detail on the individual characteristics of the models discussed in Table 2.2 is provided in Table 2.4, which presents the key features of the models and their associated strengths and weaknesses. For some of the well-known, established design process models presented here, many have been implemented and evaluated extensively. Some of the newer models are fairly obscure and are yet to be implemented and validated. All the design processes presented here are high level processes – it is noted that none illustrate a user centred approach throughout the design process within the model itself.

Process Model	Features	Strengths	Weaknesses	Process Diagram
Cross (2000) Design Process	Simple four step process, representing the iterative nature of generation and evaluation of concepts.	The basic nature of the process provides a foundation for designers to construct their own process.	The model lacks sufficient detail to provide an accurate representation of the design process.	
Boehm's (1988) Design Spiral	"Aims to determine the order of the stages involved in software development and establish the criteria for progressing from one stage to the next" (Boehm, 1988).	Represents the cumulative costs throughout the project and is flexible, incorporating iterations across different stages of the process.	Although the process represents iterative loops of the process, building multiple prototypes can raise the development cost significantly.	
Double Diamond (Design Council, 2005)	Illustrates the convergent and divergent nature of the design process.	The process can be skewed to reflect the needs of the project. Offers flexibility as a foundation to designers to construct their own process.	Difficult to follow and interpret by those unfamiliar with the process. Unclear where methods feed in, when iterations occur and how feedback and evaluation shape the process.	

Process Model	Features	Strengths	Weaknesses	Process Diagram
French (1985) Design Process	Circles represent outputs and rectangles represent activities.	Evaluation is carried out continuously with feedback on solutions key to the model.	Model stops with the output of design drawings – no manufacture or production stages. No indication of user involvement or focus on meeting customer needs.	
Product Development Process Model (Tahera, et al., 2015)	Illustrates the sequence of activities from analysis to virtual and physical testing, showing iterations and progression of work leading to product improvements.	The model is based on case studies from industry.	Not intended as a prescriptive model – only to encourage consideration of product testing throughout the process. No evidence of process implementation.	
Pahl and Beitz (1984) Design Process	Focus is on mechanical engineering and developed in line with the VDI guidelines. Emphasis is on layout and production.	Provides a prescriptive step-by-step approach, focusing on the output in relation to the design task.	Prototyping is not illustrated within the process. No indication of customer involvement – due to mechanical engineering emphasis.	

Process Model	Features	Strengths	Weaknesses	Process Diagram
Pugh's (1990) Model of Total Design	Consists of the six core stages of the design process – different versions of the model provide alternative representations of process details.	The process appears linear but arrows between stages represent the iterative nature of the core stages.	Gives a false impression of only moving between consecutive steps. Not apparent from the model that user involvement is a core aspect of the process.	
Stage Gate Model (Cooper, 2001)	"Intended as a blueprint for managing the product innovation process to improve effectiveness and efficiency" (Cooper, 2001). The gates provide quality control.	Provides a controlled and rigid structure for developing new products. Aims to decrease time to market and product failures.	Few products are new product developments. Not apparent from the process model that it is customer focused and where these need fit into the process.	
Ulrich and Eppinger (1995)	A wide range of concepts are created in the early stages, and narrowed down until the product can be reliably and repeatedly manufactured.	Emphasis is on early planning to save time and money later by identifying potential faults early.	Not apparent from the model the process is intended to be sequential with overlap and iterations between stages. Designers are not encouraged to play an active role in user research.	

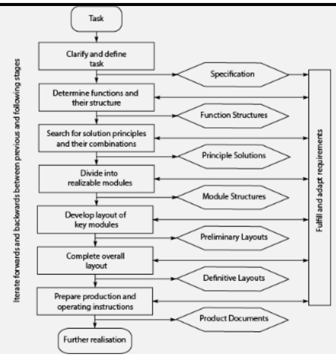
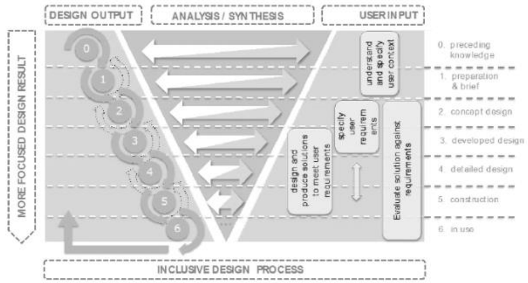
Process Model	Features	Strengths	Weaknesses	Process Diagram
VDI 2221 Guideline (Beitz, 1985)	Provides a methodology for design of technical systems and products to ensure a more efficient way of working.	Emphasis on the iterative nature of the process and the output of each stage. Emphasis on company-orientated rather than individual thinking.	The scientific foundation to the design process will not be applicable to all projects. Not reflective of real-world practices where few designer have an understanding of the literature.	
V-Model for More (Ielegems, et al., 2015)	The model aims to analyse how the inclusive design process can address and anticipate practical constraints.	Emphasises the implementation of user information as an equal and continuous task. The process is flexible in terms of managing the process.	Difficult to initially interpret. Although focus is on inclusive design, diversity of users is not apparent.	

Table 2.4 - Summary of key features of design process models

Despite the advantages to following a design process, there are a number of problems that have been highlighted with existing models. Maffin (1998) states that a more detailed design process model is needed as many designers do not have a more than a basic understanding of published models. This is supported by Pugh (1996) who added that few design processes are self-descriptive, making them difficult to use without experience. Although there is often supporting discussions of design process models, it is apparent that many design practitioners may never read this and much of the detail is not visually represented in the models. Choueiri (2003) states that drawings of the design process allow a more complete understanding of the process, whereas verbal expression of the design process are much more imprecise. Although a design process cannot reflect every designers individual methods, a structured process should allow flexibility for individual project and designer needs.

It is also noted that many design process models are intended for new product design, which is in contrast to the reality of most design projects (Gericke & Blessing, 2012) and (Pepe, et al., 2011). In development projects requiring only minor changes to existing designs, there is often little or no conceptual design stage required. The Design Council (2007b) found differences in the approach to new product design or development design, with higher risk involved in the development of new technology and a greater need to understand how user requirements are fed into the design process. Tahera, et al. (2015) state that most process models represent testing activities at the end of the design process as part of product validation. The study claims that many current design processes in the literature do not reflect the importance of testing and recommended that product testing should be integrated throughout the design process in parallel with other design activities. These findings are in agreement with Isa, et al. (2015), who found that designers who used physical modelling to understand problems with ideas and concepts in the early stages of the design process were able to gain a much clearer understanding of the form, function and construction compared to designers who did not.

2.3.4. Design process in practice

> *“Design practice in industry is clearly in sharp contrast with the abstract definition of requirements recommended by most of the engineering design models”* (Maffin, 1998, p. 319).

It is difficult for designers to describe their own design process – partly because it varies from project to project, but mainly because intuitive processes are difficult to articulate and analyse, as they happen largely subconsciously (Bruseberg & McDonagh-Philp, 2002). Design processes also vary substantially between different design disciplines, product types, design tasks and individual approaches due to experience and training. It was noted by Maffin (1998) that most design practitioners in industry develop their own procedure to deal with design projects as many design processes do not take into account constraints such as time, resources and management. There are also reports (Costa, et al., 2015) that many published design approaches have not been adopted in practice, due to a lack of guidelines and support to implement them. A study by Choueiri (2003), interviewed industry designers and students to understand their representation of the design process. Although a theoretical approach to the design process is taught in the academic setting, in practice it is more flexible and subjective. One designer reported: "there are theoretical steps in the design process that we teach in an academic setting… Once actually designing, the process becomes more loose, more subjective, more inter-looping" (Choueiri, 2003).

It is apparent that design processes in practice are made up of much iteration, showing continuous design evaluation and improvement until a viable solution is found. This iterative approach allows several ideas to be considered together (Design Council, 2007a). It is suggested (Sims, 2003) that designers arrive at their final solution by new insight, redeveloping existing designs, utilising previous experience, or by trying various possible solutions until the best is found. This approach to design is clearly based on designers own ways of working and is dictated by the timescales of the project and individual project requirements.

In a case study (Goodman-Deane, et al., 2010) it was found that all the companies interviewed structured their design process using stages including idea and concept generation, design development and manufacturing or production, similar to the core stages of the published models discussed in Section 2.3.3. However, there was variation in how the design process was implemented with reported differences in focus and the level of detail followed in each of these steps. Some companies used a formal approach made up of main stages and smaller steps, which were reported to be flexible in practice and used as a general guide. However, the degree of flexibility was limited by constraints – particularly by timescales and client involvement – with designers reporting that they would prefer a more flexible approach than is allowed in practice. It is noted that these findings are only applicable to design consultancies – in-house design companies were not involved in the study. The study also only involved one expert from industry, therefore the views expressed are of limited scope. However, the key findings from the study are evidenced by other research, discussed earlier in this section.

2.3.5. Discussion

The design process models presented here show similarities in terms of the core stages of the process. However, based on the findings of the sports design literature review, there are a number of characteristics that differentiate sports design practice from traditional product design, including the emphasis placed on the performance output of the equipment and the interaction between the athlete and their equipment. While none of the design process models discussed in this section are specific to sports design, there are none that communicate within the design process model itself those characteristics that were identified in Section 2.2 as representative of sports design practice.

The results from the literature review highlight that there is a substantial difference between existing models of the design process and what actually occurs in practice. The core stages of many theoretical design process models do not show much variation and appear to be reflective of the core stages of design practice. However, it is reported that in practice, designers rarely follow a structured approach with their design process being highly flexible and imprecise. The design process is also reportedly different between companies, designers and projects, making it difficult to precisely map. It is therefore apparent that there is still much to be learnt about design processes in practice. There is also a need for design processes that are not only reflective of design practice, but have their foundations in design practice, rather than based on "best practice".

Section 2.2 highlighted that sports design has many characteristics that differentiate it from other design disciplines. This section of the literature review has highlights the evidence to support the benefits of implementing a design process in practice and has identifies that many existing design process models are not reflective of everyday design practice in industry, or of sports design practice. There is therefore a need to understand exactly what differentiates sports design practice from product design practice in industry. This proposes the second research question for this thesis: **what differentiates the sports design process from the product design process in practice?**

In order to further investigate the research aim presented in the introduction ("**to investigate how the sports design process can be used to improve inclusive design practice?**") the following sections of this literature review discuss the nature of user centred design, which is directly applicable to the sports design discipline being entirely focused on the athlete, and the area of inclusive design by identifying how sports design can be used to aid inclusive design practice.

Section summary:

- Existing design process models show similarities in terms of core stages.
- No design process model has been found that communicates the characteristics specific to sports design practice as a whole.
- There are key differences between design process models and what occurs in everyday design practice.
- There is a need to understand what differentiates the sports design and product design processes in practice.
- Research question: what differentiates the sports design process from the product design process in practice?

2.4. User Centred Design Literature Review

This section of the literature review presents work relating to the field of user centred design. The literature is spilt into the following key areas, as illustrated in Figure 2.11: what is user centred design, the importance of user understanding, user information and user involvement within the design process, designer involvement in the design process and the design brief. As discussed within the sports design literature, sports design is highly user centred – if the equipment and the athlete do not interact properly, then the equipment will fail, regardless of how well it has been designed. The athlete (or user) is therefore central to sports design practice. User centred design will be discussed here specifically in relation to product design, to highlight the potential for aspects of the sports design approach to be transferred to the product design discipline.

Within this section, the term "user centred design" is defined and the case for the approach is made. This section also covers the importance of user understanding to ensure that the needs of the user are met, the use of user information with the design process and specifically the involvement of the users themselves within the design process. The level of designer involvement (within typical product development processes) is also discussed in relation to designer understanding and empathy for those they design for – in particular, diverse user groups – in addition to designer preference for the presentation of user data.

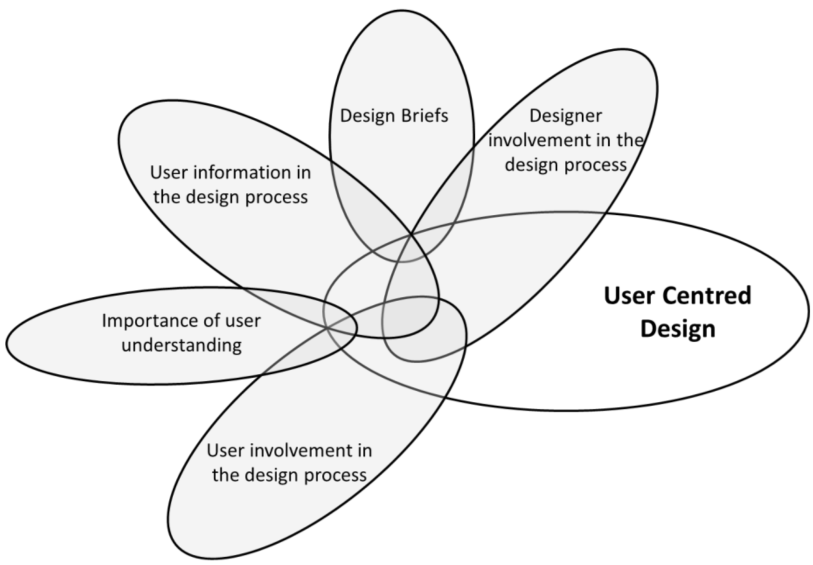


Figure 2.11 - Breakdown of key areas within the user centred design literature

2.4.1. User centred design

User (or human) centred design is defined by Clarkson *et al.* (2003) as a "design approach that places the user at the heart of the design process and often involves and engages with users in ways that make them part of and integral to the process itself". In order to be people-centred, the user must be considered throughout the design process, from the initial identification of the problem to refinement to the final solution (McGinley & Macredie, 2011). Design for usability aims at improving the user's operating experience with a product (Li & Gunal, 2012) – in ISO 9241-11 (1998) usability is defined as "the extent to which a product can be used to achieve specific goals of a user effectively, efficiently and satisfying". Human factors engineering is aimed at improving interactions between the user and the product interface (Li & Gunal, 2012). User centred design can be applied as an approach to inclusive design (Keates & Clarkson, 2003), on condition that the user to be addressed is the widest possible diversity of people and not merely as one specific target group (Ielegems, et al., 2015).

> *"Even a user centred approach to design is no longer focused on issues of usability alone, but on the overall experience being created"* (Pullin, 2009, p.137).

Competition between products and brands is increasing with customers becoming more selective, therefore it is essential that design satisfies the root of the design problem – "to serve the user with the best performance and superior experience" (Li & Gunal, 2012). All users are different and can be categorised by any number of variables. It is important that the designer understands the needs of those they are designing for so they can create a product that will be in demand. Figure 2.12 illustrates the three design dimensions that should be covered within user centred design (design alternative, user category and usage context) with the aim of finding a product with optimal usability performance by a specified user category within a given context (Li & Gunal, 2012). However, there is also a wariness towards user research as it can be considered a limiting factor to creativity (McGinley, 2012). A lack of financial resources and tight time-scales has resulted in too much focus being placed on the end product over the end user (McGinley, 2012). While barriers to user involvement are touched on in this section, a more comprehensive overview of a range of barriers to inclusive design uptake specifically are discussed in Section 2.5.4.1, many of which will also be applicable here. It should be noted that while user information is a vital part of the design process, there are many other factors in design that need to be considered and communicated throughout the process.

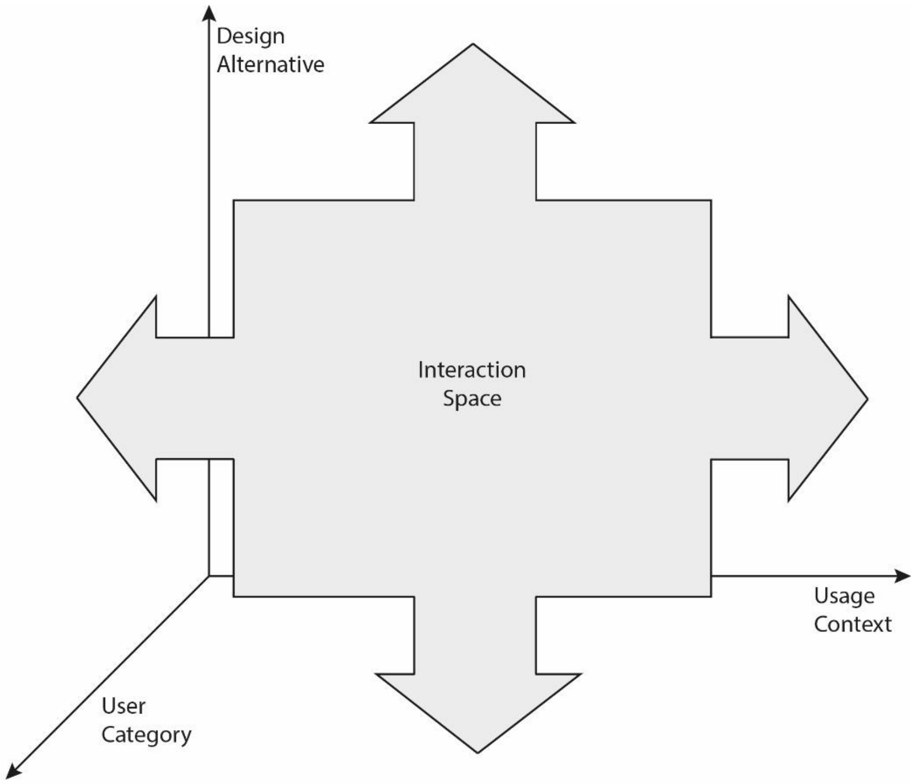


Figure 2.12 - Interaction space in user centred design (Li & Gunal, 2012)

2.4.2. Importance of user understanding

A user centred design approach can enhance user experience, taking a product beyond being purely functional. Supporting designers in their use of and reflection on human information can help them to design in more innovative and people-centred ways (McGinley & Macredie, 2011). A recent study (Dong, et al., 2015) states that there is potential for designers to gain a more detailed understanding of those they design for through using a wider variety of sources to aid in a user centred design approach. In the past, industrial designers have focused on the functionality of the product. Pugh (1996) highlights that many design processes are mechanically orientated making them unsuitable for the design of many consumer products. However, the future of design rests on understanding people (Formasa, 2009). This has resulted in a need to understand the wider environment in which the product is used and the characteristics and needs of those who use it. Human information has to sensitise designers to a range of varied users that are representative of global demographic shifts such as increasing ethnic diversity, multi-cultural societies and ageing populations (McGinley & Macredie, 2011). As designers increase their understanding of how products contribute to the social and environmental problems of the world, the question of what users do with products becomes more important (Margolin, 1997). It is important that designers are aware that users do not consider a product in isolation but are influenced by their own environment and experiences. Designers have to design products that are in-keeping with these environments and will improve or aid the everyday lives of the user, rather than becoming too advanced and limiting user satisfaction.

Design practice is flexible and varies greatly between projects, companies and designers, therefore designers cannot be expected to have a thorough understanding of every user they design for (Bruseberg & McDonagh-Philp, 2001). However, the importance of user involvement in the design process has been highlighted consistently throughout literature – as stated by Haik (2003): "the most important step of the design process is identifying the customer need". Ielegems, et al. (2015) also note that user information from a range of different sources would significantly enrich the design process.

Understanding people is increasingly vital to design (Formasa, 2009) as it ensures companies maintain a competitive advantage and are able to gain entry into more lucrative markets (McGinley & Macredie, 2011). Companies aim to increase customer value through new product design, which is created when the benefits of the product to the customer exceed the products life-cycle costs to the customer (Slater & Narver, 2000). Although value to the customer is difficult to quantify or measure, it is becoming more apparent that usability is dictating the success or failure of a product on the market (Bruder, 2000). Users have a choice between available products, therefore it is important that user needs are met and exceeded to ensure a product stands out from the competition. Failure to consider the user during the design process can cause discomfort, frustration and even injury (Sims, 2003). It was found (den Ouden, et al., 2006) that one of the main causes of customer dissatisfaction was due to a product failing to meet user requirements, rather than the product failing to meet the functional specification. Customers often make assumptions regarding the performance or functionality of a product based on its appearance (Mugge &

Schoormans, 2012). Companies with proactive approaches to understanding users' needs benefit from better products and therefore profitability and customer loyalty (Topalian, 2005).

Many designers base their work on intuition and observations. However, the typical designer in the UK is mid-thirties, Caucasian and male (McGinley & Macredie, 2011), therefore this can result in a limited understanding of diverse users. The designer is clearly not representative of the UK population as a whole and many designers will never have encountered the problems faced by those they are designing for or have experienced their everyday lives. However, Goodman-Deane, et al. (2010) found that designers can consider themselves to be representative of the target market, therefore would design for someone with physical and skill capabilities similar to their own, without coming into contact with other potential end users (Crilly & Clarkson, 2006). This therefore makes it difficult for designers to empathise with user needs (Sims, 2003). It is important that designers verify what the customer expects in terms of product performance as this may not align with the designers predictions (Mugge & Schoormans, 2012). Designers also tend not to notice poor designs as they are often assessed by fellow designers who again are not typical end users, therefore are unable to identify problematic features of a product. Significant room therefore remains for designers to improve their understanding of the user (McGinley, 2012).

It is apparent that as awareness and uptake of user centred design increase, the awareness and understanding of the user themselves has to also develop. Those practicing user centred design have to accommodate a broad diversity of users rather than cater for the mainstream. It can be argued that the term "user" is too broad, and should be more specific to those targeted by a product. The design of products for older adults and the disabled needs to be based on a thorough understanding of the population needs and expectations with user centred approaches (Lee & Coughlin, 2015). A study by Wilkinson and Angeli (2014) found that wheelchair users were aware of the problems associated with existing technology and that including these people in the early discussion and design stages facilitates new concept generation. It is therefore vital to the success of the product, particularly for diverse user groups that the needs and abilities of the user are understood by the designer.

2.4.2.1. User information within the design process

User needs should be considered as early in the design process as possible (Bruseberg & McDonagh-Philp, 2000) where they will have a more effective influence (Warburton, 2003) – design changes later in the design process can be expensive and time consuming (Sims, 2003). Considering the user in the early stages of the design process allows the greatest potential for user-based information to shape the project (McGinley, 2012). However, if designers are not provided with appropriate user data in the design brief, the needs of the user are often left underexplored (McGinley & Macredie, 2011). It can often be difficult to know what to ask and how to involve the customer in the early stages of the design process, although the way in which the user reacts to existing products can be translated into product requirements that will direct the design process. Van Kleef, et al. (2005) highlights that involving users too early in the process can kill creativity although it can also be argued that understanding user problems can stimulate creativity and identify potential projects and solutions.

The need for user information moves though peaks and troughs over the course of a design project (McGinley & Dong, 2009) as illustrated in Figure 2.13. It is common for a high level of user information to be required during the initial discovery phase, with this information becoming more specific as the project progresses and user needs are understood. However, this decrease in the amount of data required does not mean that users are any less important throughout the remaining stages of the design process. Important design decisions are made throughout the design process that affect the direction the project will take and the final outcome. It can be argued that user input at these decision making stages is vital to ensuring that user needs are met by the final product. Lindemann (2003) notes that when little is known about the target user, the design process can often be reversed, with a solution found early on and then analysed in order to learn more about the problem and market. However, this can be expensive and time consuming if the solution is found not to satisfy the problem as redundant actions are frequently carried out.

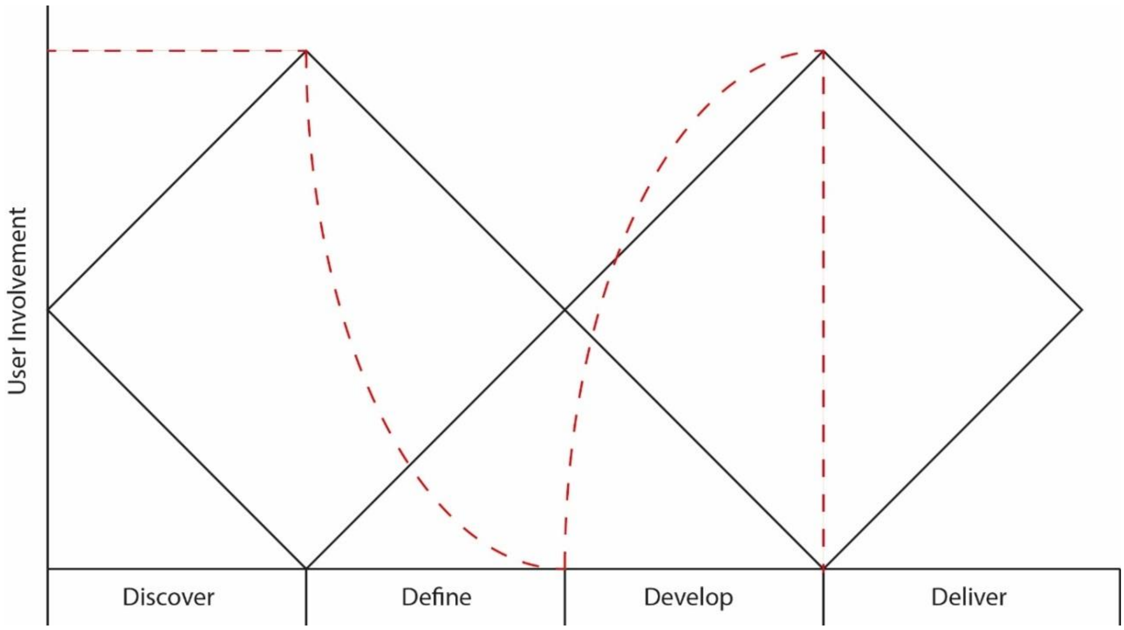


Figure 2.13 - The Double Diamond design process highlighting levels of user data input (McGinley & Dong, 2009).

There appear to be similarities between the suggested approach for user centred design (with user involvement throughout the design process) and the findings from the sports design literature review in Section 2.2, which indicated that the athlete was often involved extensively throughout the sports design process. However, no published work that has been found that studies the similarities between the sports design and user centred design approaches and whether lessons are transferrable between the two.

Despite the emphasis on the importance of considering user needs within the design process, there are reports throughout the literature of a lack of user involvement in the design process as a whole in design practice (Bruseberg & McDonagh-Philp, 2002). A recent study (Li & Gunal, 2012) found that many design activities are not primarily user focused, with user evaluation undertaken too late in the design process, often during prototyping and testing. Continuation through the design process without considering the needs of the end user can result in a prototype or final design having to be altered late in the design process (Sims, 2003), which is often an expensive and time-consuming option. Wilkinson and Angeli (2014) state that the lack of user involvement in the design and evaluation stages of the product development process may be responsible for excluding elderly and disabled users from many modern technologies. Maffin (1998) lists some of the most commonly used methods within the product design process – user needs were mentioned in the early market research stages but were otherwise not considered within the list of 50 methods. Pugh (1996) also lacks emphasis on the importance of the user early in the process and the inclusion of the designer in collecting this data, while Bruder (2000) reports that ergonomic factors are frequently left out of the design process. There are variations in the literature as to whether user information in the design brief comes directly from the client (Goodman-Deane, et al., 2010) or from an external agency (Bruseberg & McDonagh-Philp, 2002) and (Crilly & Clarkson, 2006). Figure 2.14 is taken from Wilkinson and Angeli (2014) (original text Wilkinson 2011, unpublished PhD thesis), and illustrates the cycle of design oversight that results in a lack of appropriate designs to accommodate older and disabled people. The paper discusses the concerns that are raised by designers assuming that all users have the same capabilities as themselves, resulting in the design of products that exclude many users.

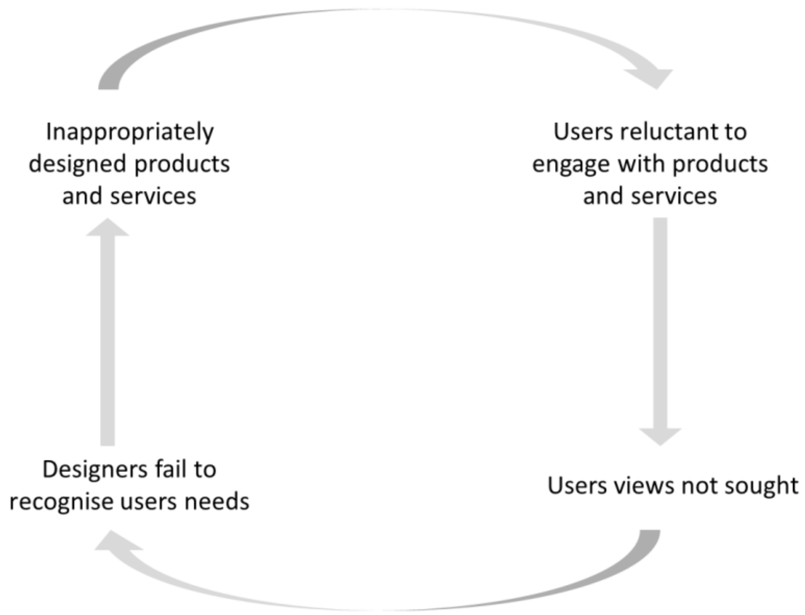


Figure 2.14 - Cycle of design oversight. Adapted from Wilkinson and Angeli (2014)

It is surprising that there appears to be a lack of inclusion of the user at all stages of the design process when it is well documented that users provide a source of primary information that can lead to commercial success (Bruseberg & McDonagh-Philp, 2001). It is becoming more apparent that consideration of user needs is required earlier in the design process. In practice, it has been found that information about end users is used too late in the design process (Sims, 2003) for changes to be made without excessive costs in time and money. 81% of those interviewed by Sims (2003) felt it was possible to consider the end user earlier in the design process. The same study found that user trials were the most popular method of user involvement. This is in agreement with McGinley and Macredie (2011) who state that human information plays a key role from the outset in anchoring the constraints of the design problem. During the early analysis stages of the problem, it is often beneficial to observe users as they interact with existing products in real and novel situations to find out how users currently interact with products and what problems they have with them (Kahmann, 2000). In order for the solution to be truly user centred, user information should be available early on rather than added in as an afterthought once other main principles of the design are in place (McGinley, 2012). It should be noted that while it is highly beneficial and inspiring for designers to involve the user during the design process, this approach is not always feasible in everyday design practice (Cardoso & Clarkson, 2012).

2.4.2.2. User involvement in the design process

> *"Common development practice promotes user consideration once in the requirements list. This normally happens at the very beginning of the product development process and then the developer sticks to this information. There is hardly any product developer integration in the user characterisation process, which is commonly carried out by third parties. It seems quite obvious that this does not always lead to an adequate result"* (Kett & Wartzack, 2015, p.3).

The user has to be considered continuously throughout the design process (Kett & Wartzack, 2015) as designers cannot rely on their own skill sets or experiences to design for the wider population (Wilkinson & Angeli, 2014). It is stated (Kahmann, 2000) that user involvement in the early stages of problem analysis can give the designer inspiration. Throughout the concept evaluation stage, user involvement can be used to aid the evaluation of concepts and prototypes. A final evaluation can be undertaken by comparing the developed product to existing products in the intended environment of use – "critical users are the starting point to test or evaluate products" (Kahmann, 2000).

It is critical that there is information about the end users available, particularly when designing user centred or accessible products (Goodman, et al., 2007). However, the level and nature of user involvement within the design process will be dependent on the nature of the project. As stated by Ielegems, et al. (2015), “direct user involvement generates new data. Indirect user involvement relies on available knowledge to gain more insight”. Designers typically consult a variety of information sources to gain an understanding of the design problem. In relation to criteria of the end-user this can involve (McGinley & Macredie, 2011):

- Client provided data (brief, internal reports).
- Internal knowledge (tacit knowledge, previous work).
- Primary findings (experiment, testing).
- Secondary data (anthropometrics, marketing reports).

Customers are now more informed than ever before (Ramaswamy, 2008) and (McGinley & Macredie, 2011). As a result, leading companies are starting to engage customers in the co-creation of value in order to gain a competitive advantage. The assessment of existing products by customers can provide a platform on which to base new product development (Bruseberg & McDonagh-Philp, 2001).

> *“Smart firms now recognise that customers are a source of competence which they can tap into”* (Ramaswamy, 2008, p.12).

While clearly beneficial to include the user within the design process, it is not up to designers to ask the user what product they want or how their life could be made easier. Often, the users themselves have become so accustomed to making allowances for poor or complex products that they are unaware of the potential for new products and the benefits they could gain (Leonard & Rayport, 1997).

> *“Traditional design approaches have been accused of failing to engage with users in the design process, compromising commercial opportunity and the interactional experience of users”* (Wilkinson & Angeli, 2014, p.614).

There are a number of barriers that limit user involvement within the design process in practice. Timescales and resources are often cited as the main barriers to user involvement within the design process (McGinley, 2012) – with time constraints and customer demands, the product development process is required to be shorter (Eckert, et al., 2015). Many commercial projects are run on the basis of launching products quickly, ahead of the competition, resulting in little emphasis placed on reflecting on the users themselves (McGinley & Macredie, 2011). Designers are often set strict project deadlines, limiting the time allocated to allow the designer to interact with the user and allocating resources to other areas of the process. In practice, there are often several projects running concurrently, meaning little time to reflect on what has been learnt about the user (McGinley, 2012). This is in agreement with Warburton (2003), who state that in reality, the level of user involvement in design projects is dictated by the availability of time and money. It can also be difficult to recruit user groups (Bruseberg & McDonagh-Philp, 2002) therefore they are not used as often within the process.

Clients are generally responsible for providing the design brief and for commissioning any user research, with McGinley and Dong (2011) stating that although direct interaction between the designer and the user allows a greater understanding, it is often not possible due to time and money constraints – "you need a reasonably enlightened client to allow user research to happen" (Goodman-Deane, et al., 2010). Although designers appreciate the importance of understanding the user, this view does not appear to be shared by the client. There is a perception that consulting external users drains expensive resources and involves skills out-with the remit of designers (Warburton, 2003), with client and management expectations that the project time allocated to designers is spent designing (McGinley & Macredie, 2011). However, without adequate knowledge of the end user and their requirements, the process of designing can often become lengthy, with designers relying on prior knowledge which may not be reflective of those they are currently designing for. The challenge is therefore convincing clients of the value of user centred design.

2.4.3. Designer involvement

> *"Designers need to be knowledgeable about the broad range of user types whom they are tasked to design for"* (McGinley & Macredie, 2011, p.4).

As discussed in the previous section, the designer is rarely representative of those they are designing for, therefore often has a limited understanding of diverse user groups (McGinley & Dong, 2011). McGinley and Macredie (2011) question how closely the designers' perception of the user matches up to the reality of those they are designing for. Many designers are trained as problem solvers rather than problem definers (Margolin, 1997). They are highly visual by the nature of their profession (McGinley & Dong, 2011), often prefer to gather their own primary data through exploration, and depend highly upon intuition and tacit knowledge (McGinley & Macredie, 2011). Designers continuously learn on the job, broadening their skills and expanding their emphatic horizon (Bruseberg & McDonagh-Philp, 2001), gaining more knowledge as they complete more projects (Lawson, 2006). This allows them to tackle future problems by drawing parallels from previous experiences (McGinley, 2012). Designers must know how to design, but they must also know for whom they design and why (Margolin, 1997).

The importance of the designer conducting their own user research must be emphasised. Designers cannot be expected to be knowledgeable about every user they design for, therefore it is essential that the designer engages with the user to enhance their understanding and experience. It is apparent that the best way for designers to get to know those they are designing for is to interact with them in their own environment. Observing the user interacting with a product in a natural environment can highlight previously unknown product difficulties and coping mechanisms that were unknown to the designer and can spark creativity.

Despite evidence already reported in this literature review of the benefits of using primary user data, it is common practice for the designer involvement in user research to be limited (Bruseberg & McDonagh-Philp, 2001). Goodman-Deane et al. (2010) found that designers often place a high reliance on clients for user information, although the study also reported that user data can often be based on supposed trends, making it highly erroneous. In practice, the collection of user information, including the identification of the context of use of a product and the needs of the target users, is often undertaken by the sales or marketing division (Bruder, 2000), with reports (Formasa, 2009) of designers and marketing teams working together with users. However, the benefits of this practice are questionable due to differences in the role of the designer and the marketing team. While both departments could work with the same group of users independently, both should be allowed their own time with the user in order to gain the understanding and information that is relevant to their own field of work. Designers receiving secondary data from the marketing department will lack the raw details and creative spark that could be observed by the designers themselves. Designers need to have empathy with those they are designing for – as stated by Marshall, et al. (2010); “abstract representations of people based information does not inspire designers”. A study by Goodman-Deane, *et al.* (2010) interviewed designers on user consideration in design practice and found that user research was often not considered part of the designer’s role. Sims (2003) added that only 34% of designers involved the end user if the client had not requested it in the brief.

Designers are aware of the shortcomings of designing for users without specified end user requirements (Sims, 2003), although often rely heavily on intuition and prior knowledge to guess at what user requirements might be (Restrepo, 2004), (Goodman-Deane, et al., 2010). While designers can build up experience, this is only beneficial when designing for those they already have an in-depth understanding of. However, even within known groups, customer preferences can change.

Figure 2.15 (adapted from McGinley, 2012) illustrates how designers experience moves outwards to consider colleague’s experiences, external relationships and then onto new and unfamiliar user domains. This process widens the designer’s knowledge of potential users. Goodman-Deane *et al.* (2010) also found that designers are more likely to involve the target user selected by the client or those within easy reach, such as relatives or neighbours.

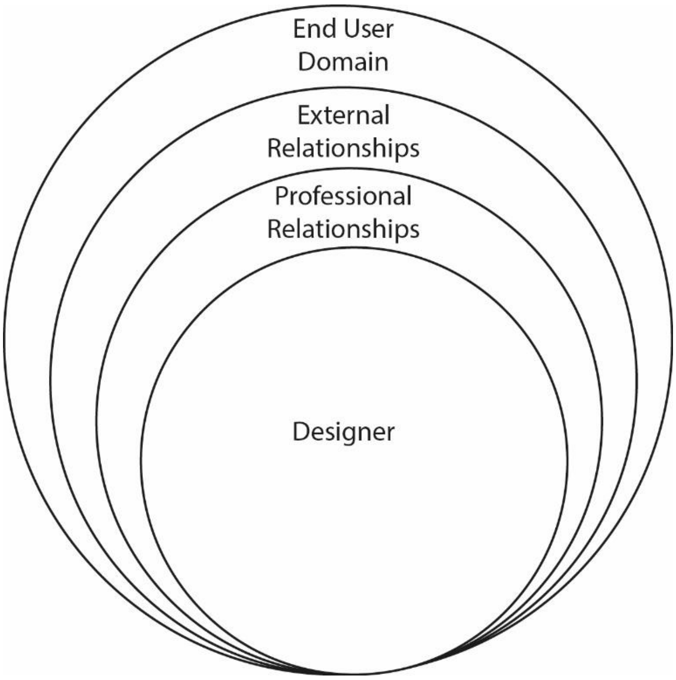


Figure 2.15 - Designer's field of experience. Adapted from McGinley (2012)

The benefits of involving designers closely in the user research stage include (Design Council, 2007b):

- Designers creative skills can be used to identify problems and potential solutions as user research is undertaken.
- Having designers involved directly with other teams in the analysis of data involves multi-disciplinary working, giving other teams an insight into the skills that designers bring to the process.
- Multi-disciplinary working helps to clarify project objectives at an early stage.

2.4.3.1. Design briefs

> *"Most designers regretted that they lacked detailed user information as it is often not provided by the client or market research departments"* (Bruseberg & McDonagh-Philp, 2000, p.5).

Early research often forms the initial stage of the design process with findings feeding into a design brief document, which defines the problem or opportunity to be addressed (Goodman-Deane, et al., 2010) and usually specifies the target user (Bennett, 2002). The design brief is frequently a dynamic document, negotiable between the designer and the client. The designer can use their skills and insights to modify the brief in a way that they believe will best benefit the client and target customer (McGinley & Macredie, 2011). The content and format of the brief varies between projects and companies (Cross, 2000), with the level of detail of information provided varying between clients (McGinley & Dong, 2009). Goodman-Deane, *et al.* (2010) found that the project brief could contain detailed information such as design constraints, the desired look and feel of the product, branding, legislation and the results from market research, with Bruseberg and McDonagh-Philp (2002) adding that market and user research is often included. McGinley and Macredie (2011) found that client data accompanying the brief could also vary immensely, although this was sometimes due to the nature of the data, influenced by the project. It was stated (Pugh, 1996) that a project brief constructed by the client often lacked detail of user research and competitors. This results in a poor foundation for the project, with effects seen in the overall outcome. As stated by Choueiri (2003), “the importance of trying to define the problem that needs solving cannot be overstated.” However, there is no suggestion of how to collect missing data or how the design process could be altered to emphasise the need to focus on these inputs in the early stages of the design process.

Goodman-Deane *et al.* (2010) found through interviews with designers that it was rare for designers to challenge the design brief. However, it was reported that designers would sometimes modify the brief to improve it. It was also found that the client was often a major information provider and many designers relied primarily on the brief for information, which was not always reflective of actual user needs. Sims (2003) interviewed a number of design professionals and found that for many of them, the client was the first reference point for additional information. It was also found that designers frequently rely on secondary data sources (Bruseberg & McDonagh-Philp, 2000). However, designers complain that abstract data gives them no inspiration or feeling for the users’ situation and experience (Marshall, et al., 2010). It is therefore apparent from the literature that the majority of user data is found within the design brief, with little primary user data gained and limited contact between the designer and the user.

2.4.4. Discussion

This section has highlighted that while user centred design is highly important and should be aimed for in practice, there are also barriers that have to be overcome in order to adopt the approach. There is a need to raise awareness that user involvement should play a key part in the designers' role within the design process. Secondary data from clients or marketing teams does not provide the creative setting for a designer to work in and it should be acknowledged that nothing will give user feedback in a more beneficial way than by interacting directly with the user. Most design process models appear to focus on mechanical function, the product and in some cases the wider business issues. However, none place the user at the heart of the design process and represent this within the design process model. It is apparent that a user centred approach is vital to product success as it focuses on improving user experience rather than the purely functional aspects of the product. However, there is a gap in the literature as to how to address the need for greater user/designer involvement. Before user centred design is more widely adopted, the barriers to the approach have to be overcome.

The findings from the user centred design literature review draw parallels with many of the characteristics identified within the sports design literature. Sports designers are required to consider the system that is formed between the athlete (user) and the equipment (product) and the resulting sporting performance. As a result, sports design is clearly a highly user focused design discipline, with the user central to the design process. This emphasis on the user and the evident interaction between the designer and the athlete within the sports design process appears to represent potential "best practice" for user centred product design. As identified from the sports design literature review, there is a lack of a formalised sports design process model. This research suggests that if this sports design process is defined, capturing the characteristics that are central to sports design practice, there is the potential for other user centred design disciplines to benefit from that process. The conference report from the Royal Academy of Engineering's "How can sports drive engineering innovation?" conference (2012) indicates that there is the potential for the innovation found in sports engineering to have a wider application.

Inclusive design is a highly user centred design approach, which considers the needs and capabilities of a diversity of users throughout the design process. Given current population ageing (a pressing global issue that inclusive design can address), this research will focus specifically on inclusive design, as a prominent area of user centred design. The final section of the literature review presents research relating to the field of inclusive design, focusing specifically on the drivers and barriers to the approach, with a view to identifying how the approach to sports design could improve inclusive design uptake in industry. It should be noted that while similar in many respects, user centred and inclusive design are separate design approaches. While user centred design aims to place the user at the heart of the design process, there is no stipulation on which user group is targeted or whom that would include. The inclusive design approach also aims to place the user at the heart of the design process, but goes further in that the target user group aims to address as wide a range of user capabilities as possible. More detail on the inclusive design approach is provided in the next section.

Section summary:

- User centred design is vital to ensure user needs are met in the design process.
- Designers require user information to enable them to understand and empathise with the target user.
- User involvement and information should occur early in the design process and be continued throughout, drawing parallels with sports design.
- There are a number of barriers to user involvement with many coming from the client. As a result, designers are often only provided with secondary user data.
- There are apparent similarities between the sports design approach and user centred design.

2.5. Inclusive Design Literature

As discussed in the previous section, there is a need to ensure that the user is central to the product design process to ensure that user needs are met. However, as will be discussed in this section, there is an increasing drive for inclusive design, which is a prominent area of user centred design. The literature relating to inclusive design is split into key areas as shown in Figure 2.16 that include the drivers for inclusive design, the inclusive design process, methods and tools available to aid its implementation in practice, the uptake of inclusive design in industry and a discussion of some of the barriers to inclusive design practice.

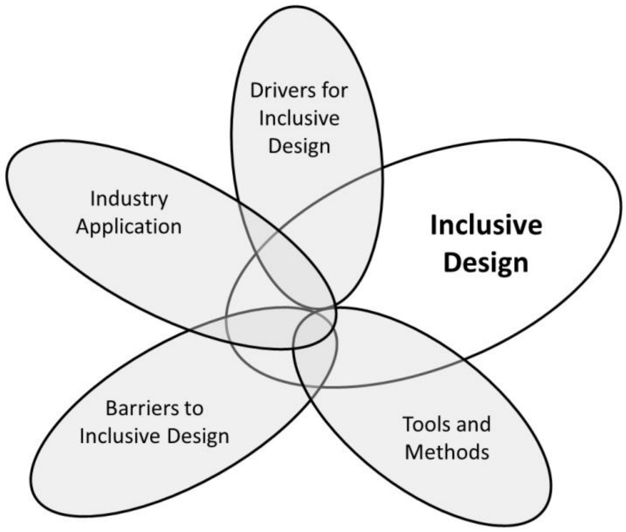


Figure 2.16 - Breakdown of key areas within the inclusive design literature

> *"It is no longer an individual's quest to be able to take part in everyday living and be integrated into society, but rather the other way around. Our living environment is obliged to allow us to be different… In dealing with the claim for a stronger integration of people with all kinds of abilities and needs, user centred approaches in product development need to be better established"* (Kett & Wartzack, 2015, p.2).

2.5.1. What is inclusive design?

Inclusive design is a design philosophy with the aim of considering the needs and capabilities of the whole population during the design process (Johnson, et al., 2010), (Persad, et al., 2007). It is defined by Foresight (2000) as a process where:

> *Designers should ensure that their products and services address the needs of the widest possible audience”* (Foresight, 2000, p.21).

Inclusive design is seen as a progressive and goal-orientated process, combining business strategy and design practice (Clarkson, et al., 2003) that aims to design products that are accessible to as wide a spread of the population as possible without the need for adaptation or compromise of aesthetics (Persad, et al., 2007), (Dong, 2004). It concentrates on ensuring that decisions made during the design process maximise the success of the product in a specifically selected target market population (Waller, et al., 2013).

> *“Where inclusive design is concerned, the underlying philosophy considers the needs of those that are often overlooked in the design process”* (McGinley & Dong, 2009, p.116).

A range of capabilities must be accounted for in good product design and inclusive design aims to increase awareness of the diversity of user capabilities (Johnson, et al., 2010). As a result of considering a greater range of diversity of potential users, it is likely that the final product will be improved as all users will benefit from the enhanced usability. Inclusive design can therefore be considered as good product design.

Mainstream products are often targeted the younger, able-bodied market, while existing segmentation models often omit the older market (Waller, et al., 2013). Figure 2.17 shows an extension to the Population Pyramid model, which was developed to illustrate the full range of ability variation within the population and aims to “challenge the designer to address user needs from higher echelons of the pyramid rather than the average target user group” (Clarkson & Coleman, 2015). The pyramid acts as a sliding scale – those with almost full capabilities are shown as the broad base of the pyramid with the level of capability deteriorating moving up the pyramid. Johnson, *et al.* (2010) defines user capability as “an individual’s level of functioning, along a given dimension from very high ability to extreme impairment, which has implications for the extent to which they can interact with products”. It is expected that if a product is designed to be usable by a particular layer of the pyramid, then it will also be usable (without difficulty) by those in the layers below.

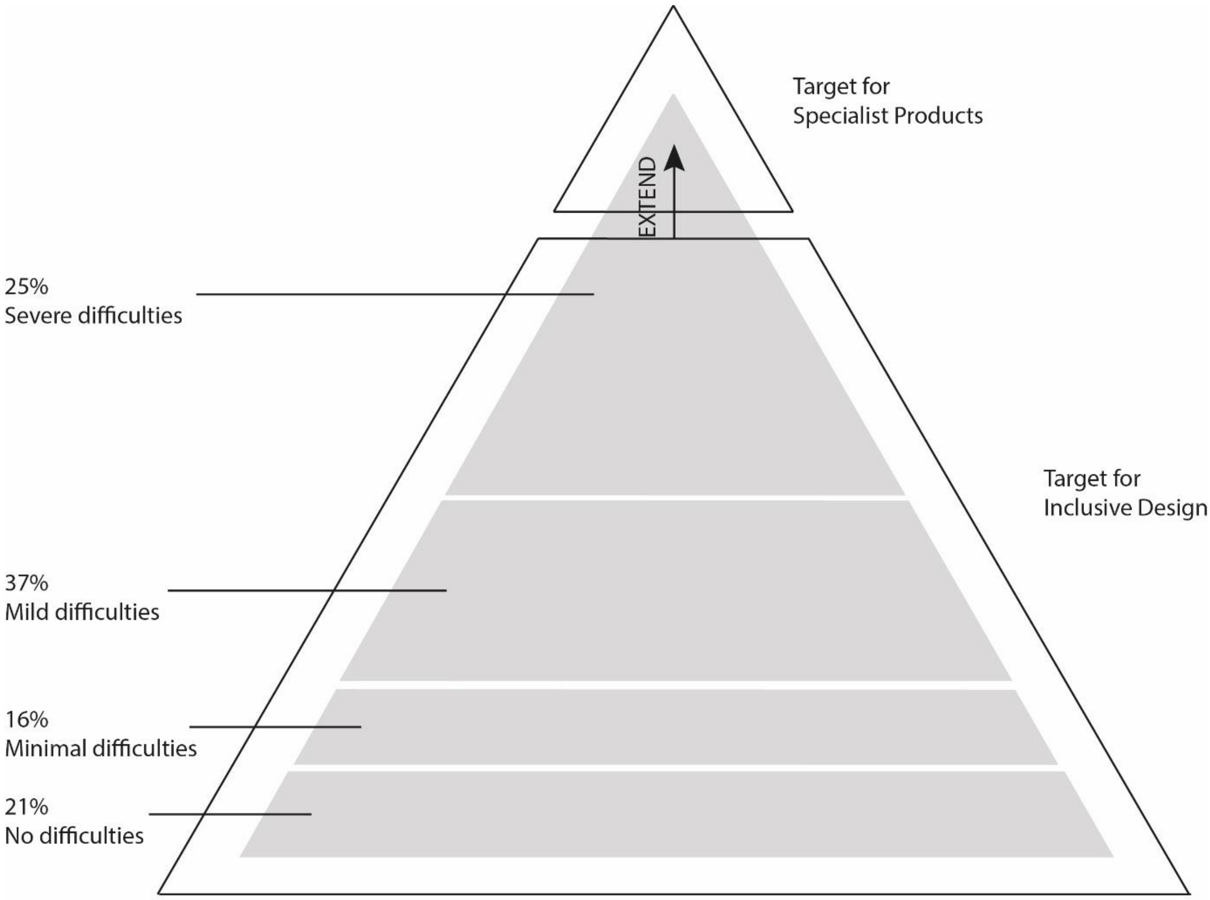


Figure 2.17 - The population pyramid (Waller, et al., 2013)

> *"Inclusive design does not suggest that it is possible to design one product that addresses the needs of the entire population. A strategy of targeting specific products to particular market segments is a commercially successful approach for satisfying conflicting user needs"* (Waller, et al., 2013, p.3).

It is accepted that specialist solutions will be required to satisfy the needs of those at the very top of the pyramid, who have severe capability limitations. It is the aim of inclusive design to ensure a greater understanding of diversity to ensure mainstream products satisfy the needs of a greater number of people (targeting a larger proportion of the pyramid shown in Figure 2.17).

Inclusive design, universal design, design for all, gerontechnology and transgenerational design are all terms that describe the inclusion of the disabled community within mainstream consumer society (Clarkson & Coleman, 2010), (Goodman, et al., 2006) and encourage the consideration of the needs of older and disabled people. The terms "universal design" and "inclusive design" are often used interchangeably and relate to a design approach that implies equality and social justice in design (Ostroff, 2011). Unlike transgenerational design, inclusive and universal design focus on social inclusion. "Design for all" is a design philosophy which aims to produce products, environments, services and systems that are usable by everyone, whatever their age, size and abilities (Sims, 2003). It is a holistic and innovative approach that aims to give all people equal opportunities in all aspects of society. Inclusive design differs from user centred design in that it goes beyond designing for specific user groups and focuses instead on meeting the needs of the wider population. For the purposes of this literature review, the terms "universal design" and "inclusive design" are used interchangeably, with the terminology taken from its original context. The remainder of this thesis will use the term "inclusive design".

2.5.2. The need for inclusive design

> *"In addition to those excluded from using a product, many more people will experience difficultly or frustration, so reducing the number of people excluded can improve the experience for a wide range of users"* (Waller, et al., 2008, p.3).

Disability can create problems in people's lives, either directly or indirectly (Pullin, 2009) – it has been suggested that people are disabled by the design of the environment around them, which does not take into account the full range of human capabilities (Clarkson & Coleman, 2010). Despite motivators for the use of inclusive design and the appropriate design approaches and methods that exist, many older and disabled people continue to find products difficult to use (Goodman-Deane, et al., 2010). The elderly and disabled form two distinct groups outside the able-bodied population. However, it is argued that a change in physical abilities is experienced by all at some point in our lives (Huppert, 2003), which can be as a result of old age, illness or an accident. In some cases this may only be temporary, but it introduces new challenges in everyday life. This change in physical ability can make everyday tasks more challenging and many products become inaccessible. Design exclusion occurs when a product requires certain capabilities that the user is unable to meet (Clarkson, et al., 2003). No one is fully able, as everyone will experience some activities that they have difficulty with or cannot accomplish as well as others. Ability is a broad scale, from the almost fully able at one end to the severely disabled at the other (Sims, 2003), as illustrated in the Population Pyramid (Figure 2.17). However, many products fail to take into account the capabilities of all potential users. The consumer is the ultimate judge of how successful a product is, therefore a good product has to meet the needs of as wide a range of users as possible to improve the overall product experience. It should be the aim of designers to reduce the frustration caused to all users, improving the overall product experience.

Changing attitudes have created a framework for a more inclusive society, moving away from specialist solutions and increasing inclusivity in mainstream design – for example, the Queen Elizabeth Olympic Park in London. Usability is defined as the extent to which users can achieve goals with the product with effectiveness, efficiency and satisfaction in real world situations (Waller, et al., 2013). However, many design approaches aimed at improving usability focus on the disabilities of the target user group – the primary concern for a designer should be the physical capabilities of the user rather than disability (Keates, et al., 2000a).

It is common practice for designers to accommodate users within the 5^{th} and 95^{th} percentile of ability (Johnson, et al., 2010). This can exclude up to 5% of the population for each capability requirement of the product. As many products require multiple capabilities (strength, vision, hearing), such products will exclude an even greater range of potential users (Johnson, et al., 2010). Many everyday products are designed and marketed primarily for young, able-bodied users, despite their potential to improve older people's quality of life (Dong, 2004). However, Clarkson, et al. (2003) found that many consumer products exclude those with both moderate and severe disabilities, while Microsoft (2004) reports that 57% of working age Americans are likely to benefit from the use of accessible technology. Special needs products that focus on narrow markets with low turnover and profits do not justify investment (Clarkson, et al., 2003). There is therefore a need to focus on designing for a wider spread of user capabilities rather than designing for smaller, specialist target groups.

When designing for non-mainstream groups, designers often design for stereotypes and emphasize function over style (Naess & Oritsland, 2005). Designers are also reported to often design for themselves (Coleman, et al., 2003) as a result of typical design challenges imposed by limited time, budget and logistical requirements which are common of most design projects (Cardoso & Clarkson, 2012). Increasingly practitioners regard inclusive design as part of good design practice (Clarkson, et al., 2003), with the subsequent output being a product that is more successful in the market. There is therefore a need for designers with research skills who are able to design for user experience (Dong, 2010).

2.5.2.1. Ageing population

> *"We live in a world increasingly shaped by human intervention where design can enable or disable people. It is imperative that we design a world that best matches the diversity present within the population"* (Clarkson & Coleman, 2015, p.2).

During the 1990s, there was an increase in awareness of design for disability due to an increase in both the ageing population and the desire of the disabled community for inclusion within mainstream consumer society (Clarkson & Coleman, 2010). This claim is evidenced by Goodman-Deane, et al. (2010) who state that there is an increase in awareness of the importance of considering the older and disabled users and increasing their inclusion in society. A recent study, (Clarkson & Coleman, 2015) notes that there has been a shift from a medical model where people were seen as disabled by physical and mental limitations to a social model where people are disabled by poor design.

Global population ageing is highlighted throughout this chapter as a key driver for inclusive design. Life expectancy is increasing, which has resulted in the possibility of many people working well in to their 70s (Bouma, 2013). Various sources report on the ageing of the UK population specifically – the United Nations (2015a) predict that the number of people aged over 60 will grow by 54% by 2030, while the Office of National Statistics (2015) anticipate that the number of people aged 80 and over in the UK is expected to more than double to 6 million by 2037. Figure 2.18 illustrates the current population (for 2014) for males and females across age categories in the UK (shown in the shaded horizontal lines).

The black line highlights predicted trends by 2039, showing an ageing population. The trend is similar globally, particularly in developed countries. The past 20 years have seen a worldwide movement towards design for inclusion where, in most countries, ageing was identified as the key driver for change (Dong, et al., 2004).

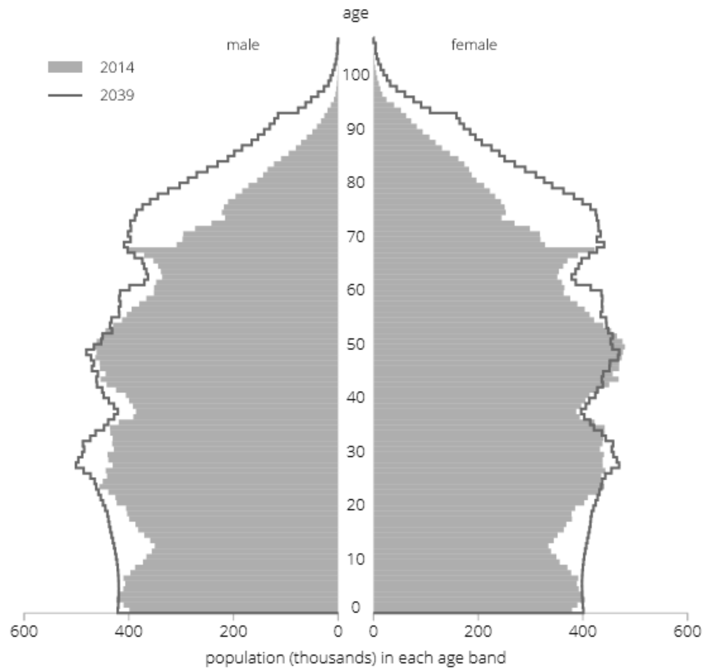


Figure 2.18 - Predicted UK population growth (Office for National Statistics, 2015)

Old age is associated with a decline in physical performance (Langley, et al., 2005). From the age of 30, there is a gradual decrease in speed, force and endurance (Bouma, 2013). Some cognitive processes slow as a person grows older (Fisk, et al., 2009), making the learning process more difficult (Bouma, 2013). This makes it difficult for older users to carry out simultaneous tasks. As a result of ageing, human capabilities start to decrease from around the age of 60 (Bouma, 2013) and (Fisk, et al., 2009), with the term capability referring to an individual's level of functioning. Heterogeneity also increases with age – as the population gets older, the needs and capabilities of the user become more diverse (Johnson, et al., 2010).

An interview survey conducted by Sims (2003), which included 50 older and disabled people, found that nearly all experienced problems completing basic activities of daily life and that improvement to existing design could improve quality of life. A more recent study by Combe, *et al.* (2012) investigates the usability and exclusivity of digital thermostats and concludes that the difficulties found in programming the heating controls were more apparent within the older user group tested. Feedback from those involved in the study indicated that the users would not choose to buy products that placed demands on the mental process, often resulting in frustration. Without an appropriate response to the issues faced by an ageing population there is likely to be an increase in the dissatisfaction and frustration associated with everyday products. There is therefore a need for products that are designed to cater for a wider diversity of user needs (McGinley, 2012). Those that accommodate a greater range of user capabilities are more likely to be successful in the market with inclusive design seen as a possible strategy to address social sustainability in society (Ielegems, et al., 2015).

In addition to global population ageing, inclusive design should also address the needs of less-able users, irrespective of age.

2.5.2.2. Market potential

> *"The business case for inclusive design challenges the myth that it is targeted at a minority of little economic significance, rather it serves older and less able people who effectively constitute a majority with considerable spending power"* (Clarkson & Coleman, 2015, p.2).

The inclusive design philosophy has clear commercial benefits (Clarkson, et al., 2003). As a result of changing demographics, older adults and the disabled now form a large (and expanding) proportion of the population with considerable spending power (Goodman, et al., 2006), creating financial incentives for expanding the market to include them. Design for disability is also under pressure to be universal due to the strong business case not to further fragment the potential market (Pullin, 2009). Understanding the user is becoming more important to designers in an effort to gain a competitive advantage and entry into more lucrative markets (McGinley & Macredie, 2011) as the "age shift" will result in a large percentage of the population who have difficulty using or cannot use existing products.

> *"Developing products that cater more effectively for a larger demographic widens the commercial market, benefits a larger cross-section of society and makes both*

commercial and ethical sense… Products designed in this way will be capable of being used by people with the widest possible range of abilities, reaching most if not all potential end users" (Wilkinson & Angeli, 2014, p.615).

Other developed countries, such as the US, Canada, Australia and those in Western Europe show similar age demographics, therefore opening up a large international market place. If British companies choose to neglect these new markets and potential customers, they are likely to be over-taken by international competitors. Figure 2.19 (Preiser & Ostroff, 2001) shows in the shaded area the market size that the data normally used by designers takes into account. By including less abled users, shown above the dotted line, the potential market size will increase.

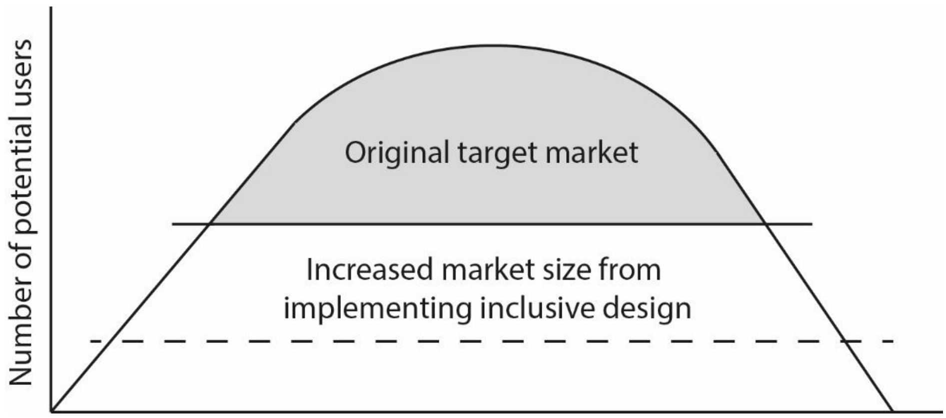


Figure 2.19 - Potential market size as a result of adopting inclusive design. Adapted from Preiser & Ostroff (2001)

It was found through a survey of UK companies (Goodman, et al., 2006) that 69% of the companies that took part felt demographic and consumer trends were a key driver of inclusive design. The study also found that social responsibility and brand enhancement were other factors that promoted inclusive design. Key commercial benefits came from increasing customer satisfaction and producing innovative products. Further evidence of the market potential of inclusively designed products includes the BT Freestyle 700 series, which has seen a 20% increase in sales since its launch in 2008 with a reduced number of product returns, resulting in an increased profitability despite higher manufacturing costs (British Telecommunications, 2010). Other benefits of inclusive design can be found in the workplace where inclusively designed products can enable the possibility of older and disabled people working for longer and therefore, extend independent living (Clarkson & Coleman, 2015). This brings further advantages in the form of lowering care costs and benefitting the economy.

2.5.2.3. Legislation

There is new legislation requiring companies to consider older and disabled users when designing (Goodman, et al., 2006), which are outlined briefly in this section. Current British legislation concerning the needs of disabled people includes the Disability Discrimination Act (DDA) 1995, modelled on the Americans with Disabilities Act (ADA) 1990. Both these legislations have been successful in raising awareness and consideration of user's needs (Goodman, et al., 2006). The UK Disability Discrimination Act (2005) includes items on locomotion, reach and stretch, vision, hearing, communication and intellectual functioning. However, it has been indicated by Sims (2003) that the DDA focuses primarily on disabled people with respect to architectural design and employment discrimination, with little reference made to the design of products.

The Equality Act (2010) defines disability as a "physical or mental impairment that has a 'substantial' and 'long-term' negative effect on the ability to do normal daily activities" (Equality Act, 2010) and has updated, simplified and strengthened previous legislation (Clarkson & Coleman, 2015). The Disability Follow-up Survey 1996/97 (Department of Social Security , 2000) offers the widest range of capability data of all the existing databases (Johnson, et al., 2010). However, some age brackets are known to be underrepresented and the data is not in a format that is accessible to designers. It was also found (Goodman, et al., 2006) and (Dong, et al., 2004) that government regulation was considered more effective in the US and Japan than in the UK. More recently, advances have been made in Japan, the US and Europe that are embedding inclusive design thinking in industry and education, including the introduction of BS 7000-6 on inclusive management and the launch of a Knowledge Transfer program in inclusive design under the UK government-funded EQUAL program (Clarkson & Coleman, 2010). The BS7000-6 (2005) aims to provide a framework that designers can use to aid their understanding and response to the needs of diverse users.

In a survey aimed at understanding company position of inclusive design and the barriers and drivers for it (Goodman, et al., 2006), it was found that only 47% of responses agreed that legislation was a driver for inclusive design. The same study states that 24% felt that British Standard BS7000-6 specifically was a driver for the approach. In contrast, over two thirds of those who responded felt that social responsibility, demographic/consumer trends and brand enhancement were drivers for inclusive design. Although legislation plays a role in the uptake of inclusive design, it is apparent from the above findings that responding to the needs of customers and the ageing population trends are the key drivers for inclusive design in UK businesses. This is likely due to the financial incentives of maintaining customer loyalty and competitive advantage.

2.5.3. Inclusive design process

Inclusive design is a process, not an end product (Vanderheiden & Tobias, 2000). That process is iterative, consisting of gaining new knowledge, which leads to continuous design improvement, increased customer satisfaction and brand loyalty (Clarkson & Coleman, 2015). Inclusive design thinking should play a key role in the decisions made throughout the design process (Waller, et al., 2013) – good inclusive design practice should be used to inform design decisions made in the early stages of the design process to minimise changes later in the process, which can be expensive to implement. To implement good inclusive design practice, user testing should also occur early in the design process. This process of continuous user testing is highly valuable and can significantly reduce the need for re-design (and the associated costs) compared to only carrying out user testing in the later design stages (Ielegems, et al., 2015).

In order to produce an inclusively designed solution, it is necessary to adopt user centred design throughout the design process (Keates, et al., 2000a). Keates, et al. (2000a) describes two approaches that can be used when designing. The first is adaptive – to design for a specific application and to then adapt that solution to different users. The second is proactive – to define the user with a wider range of capabilities at the start of the design process and to design for that wider user group. It is important that the user is placed at the centre of the design development process rather than adapting existing technologies to certain user groups (Bechtold & Sotoudeh, 2013), which is in line with Keates, et al. (2000a) proactive approach. As stated by Ielegems, et al. (2015), in order to realise an inclusive design process, it is vital to continuously generate user information throughout the design process. This link between the designer and the user is essential for inclusive design to provide an iterative process of analysis and synthesis of user information (Ielegems, et al., 2015). It is therefore apparent that the level of inclusivity of the final solution is dependent on the level of inclusivity of the design process itself.

Given the importance of incorporating the end user in the design process, there is a lack of literature outlining the specific inclusive design process. Clarkson, et al (2000) state that given the increasing ageing population, there is surprisingly little industry awareness of the benefits of inclusive design. The paper recommends that there was an “urgent need for design methods based on a better understanding of age and ability related factors, which will lead to a minimising of impairments and thereby extend quality of life” (Clarkson, et al., 2000). A more recent paper (Clarkson & Coleman, 2015) states that in order to design inclusively, a range of practical tools are required to aid the designer and design managers in understanding design issues and to follow an inclusive design process – the Inclusive Design Toolkit (University of Cambridge, 2013), launched in 2007, intends to meet those needs. However, while addressing the needs of the designers and design managers, there appears to be a lack of tools available that address other barriers to inclusive design. Ielegems, et al. (2015) reports that although there are an abundance of existing design process models that highlight the importance of integrating the end user into the design process, there is a lack of guidance on the interaction between the designer and the user information. In addition, there is a lack of solutions to aid inclusive design implementation, with prior research primarily focusing on developing specific solutions for specific problems (Clarkson, et al., 2000).

There are a number of practical studies that report findings into the inclusive design process. Herriott and Jensen (2013) investigated student responses to inclusive design and found that in an inclusive design project, it was vital to gain feedback from users on ideas and to validate solutions throughout the design process. It was concluded that the inclusive nature of the problem resulted in greater integration of users into the students design processes. A study by Goodman, et al. (2007) investigated formats of user data and found the design process to be “variable, informal and flexible, with diverse activities and stages of design mixed together” (Goodman, et al., 2007). An earlier study investigating critical user forums (Dong, et al., 2005) found that the design process described by designers as part of the study showed little variation from a normal design process – receiving the brief from the client, interpreting the brief, developing concepts, selecting a concept, implementing the design. However, it was stated that designers may not count user involvement as a factor within a ‘normal’ design process. A recent study by Dong, et al. (2015) found that designers perceptions of tools were influenced by the visual presentation of the tools – visually attractive tools were perceived as easier to use and more useful. This should be taken into account when developing further tools and processes to aid inclusive design uptake – something that is familiar and well-presented will be better received by designers. It is recommended that “in developing such tools, an inclusive design research methodology should be adopted – involving users (designers) throughout the process” (Dong, et al., 2015).

A paper by Dong (2010) discusses several inclusive design case studies within an undergraduate student environment. It is briefly discussed within the paper that an inclusive design process was produced as an outcome of one of the case studies, showing user involvement throughout the design process. However, this process has not been illustrated nor has it been found in any follow-up papers. It should also be noted that the process was based on undergraduate projects, therefore is not fully representative of industry practice.

2.5.3.1. Inclusive design methods and tools

The remainder of this section will provide an overview and discussion of a number of common (although not exhaustive list of) inclusive design methods, processes and tools. The Inclusive Design Toolkit (University of Cambridge, 2013) will be discussed in detail as it has been identified in this literature review as the main tool available to aid inclusive design. This is identified as a result of number of citations and being one of the most current and up to date methods. However, there are a number of other tools and methods designed to aid inclusive design practice, which will be discussed in this section. Although not exhaustive, a list of several of these methods and tools is shown in Table 2.5.

While each of the tools discussed in Table 2.5 aid designers in many ways – highlighting the potential target market, increasing designer awareness of the diversity of user capabilities, methods on gaining empathy with users, etc. – there is a lack of an overall process model that fully incorporates the user within the inclusive design process. From the range of methods and tools available to designers, it is apparent that there is a clear awareness of inclusive design within the research community. However, from the studies that will be discussed in Section 2.5.4 regarding the uptake of inclusive design in industry, there is a clear gap between the awareness of its theoretical importance and its implementation in industry.

Tool	What it does	Features
Inclusive Design Toolkit (University of Cambridge, 2013)	Answers the questions: 1. What is inclusive design? 2. Why do inclusive design? 3. How to get started?	Provides tools to assist inclusive design and aid understanding of variations in user capabilities.
Exclusion Calculator (University of Cambridge, 2013)	Used to estimate the number of people potentially excluded from a product (included in the Inclusive Design Toolkit).	Takes into account capabilities including vision, hearing, dexterity, thinking, locomotion, reach and stretch.
Population Pyramid (Benktzon, 1993)	Illustrates the full range of ability variation within the population and challenges designer to address the needs of those higher up the pyramid rather than the average target user.	The approach claims that if a product is designed to be usable by a higher layer of the pyramid, it should therefore be usable by those from lower layers.
Inclusive Design Cube (Keates, et al., 2000a)	Aims to provide a framework so designer can understand and recognise the benefits of inclusive design and give guidance to those who manage design on how to implement the approach.	The cube is an extension of the population pyramid by more fully representing the whole population and proposes three related design approaches, which combined can address the needs of the whole population.
Inclusive Design Waterfall Model (University of Cambridge, 2013)	Outlines the design process of transforming an initial need into a solution that satisfies the need.	Part of the Inclusive Design Toolkit. Illustrates the process stages – need, understanding, requirements, concepts, solutions.
Knowledge Loop (Clarkson & Coleman, 2015)	Asks questions about the knowledge needs and characteristics of knowledge users.	Aids knowledge transfer and maps the scope and scale of inclusive design.
Critical User Forums (Dong, et al., 2005)	Involves direct interaction through small focus groups between designers and disabled users.	Interactions with critical user groups forces designers to think differently, triggering creative solutions.

Tool	What it does	Features
Usability, Safety, Attractiveness Participatory (USAP) Model (Demirbilek & Demirkan, 2004)	Aims to develop safe and functionally appropriate products to aid the elderly.	Based on a quality function deployment system to determine the relationship between user requirements in the concept development phase and technical design specifications.
7 Principles of Universal Design (North Carolina State University, 1997)	Helps to guide the design process, educate designers and evaluate the final design result.	7 Principles: equitable use; flexibility in use; simple and intuitive use; perceptible information; tolerance for error; low physical effort; size and space for approach and use.
IDEO Methods Cards (IDEO, 2017)	"A tool to showcase methods used to inspire great design and keep people at the centre of the business" (IDEO, 2017). Intended as a tool to allow designers to explore new approaches and gain new perspective.	Includes 51 cards, each describing a method and how and when to use it. Addresses needs from clients, students and teachers.
Field Guide to Human Centred Design (IDEO, 2015)	A book guide discussing how and why human centred design can impact the social sector. The human centred design process is broken down into three main phases: inspiration, ideation and implementation.	Presents 57 design methods and case studies, focusing on the mind-set of the designer.
Norwegian Design Toolkit (2010)	An online resource providing practical tools to aid in the implementation of inclusive design.	Includes education on inclusive design "myths", checklists, definitions

Table 2.5 - Summary of inclusive design methods and tools

2.5.3.2. Inclusive Design Toolkit

One of the more comprehensive of the inclusive design methods and tools discussed in Section 2.5.3.1 is the Inclusive design Toolkit, created by the University of Cambridge (2013). The Toolkit aims to answer the following questions (University of Cambridge, 2013):

1. What is inclusive design?
2. Why do inclusive design?
3. How to get started?

It provides additional tools to assist designers in implementing inclusive design and to aid understanding of variations in user capabilities. The Inclusive Design Toolkit includes population data taken from the Disability Follow-Up Survey, which represents the UK population. However, as noted earlier in the literature review, some groups are known to be under-represented in the Survey. Figure 2.20 is taken from the Inclusive Design Toolkit and is intended to aid the concept generation stage of the design process. The design process checklist asks fundamental questions of conceptual design and lists principles of inclusive concept generation. It also lists key activities for inclusive concept generation that should be undertaken at various points of the design process. While Figure 2.20 can be used to aid designers as specific points of the design process, is not representative of the design process as a whole. As stated by Waller, et al. (2013) the Toolkit represents a minimum of what is required to design inclusively.

The Inclusive Design Toolkit includes the Exclusion Calculator, which is used to estimate the number of people potentially excluded by a product (Combe, et al., 2012) and takes into account capabilities including vision, hearing, dexterity, thinking, locomotion, reach and stretch. The output is a quantifiable measure of the overall population excluded, which is of great benefit when user testing. Other tools available within the Toolkit include simulation gloves, glasses and software, intended to demonstrate the physical effects associated with ageing. Additional information is provided regarding user capabilities, including vision, hearing, thinking, communication, reach and stretch, dexterity and locomotion.

While the Inclusive Design Toolkit provides a range of tools and methods to support designers in inclusive design practice, it is apparent from the literature cited in this review that it has not been sufficient on its own to significantly increase the uptake of inclusive design practice.

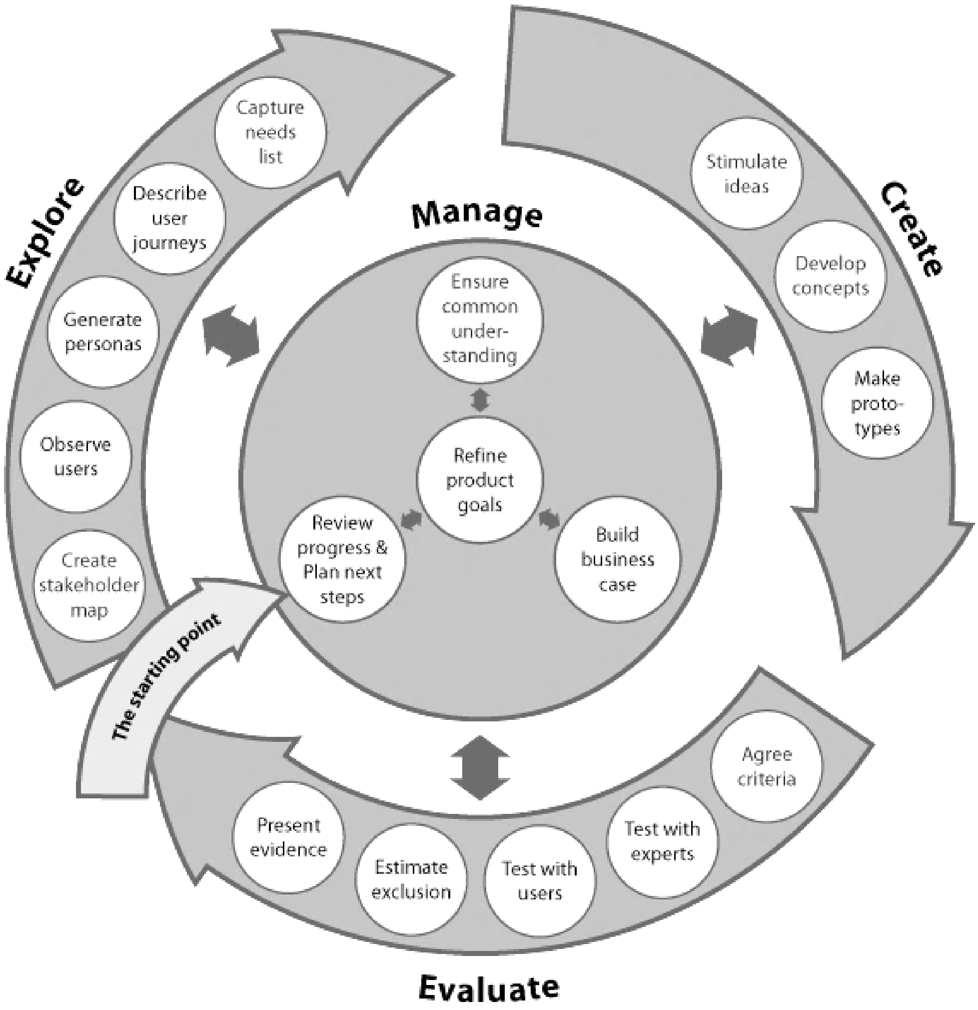


Figure 2.20 - Inclusive Design Toolkit (University of Cambridge, 2013)

2.5.4. Implementation of inclusive design

Despite the introduction of new legislations, financial incentives and the existence of many appropriate inclusive design approaches, many companies are not adopting an inclusive approach to design (Goodman, et al., 2006). As discussed earlier in this review, this results in a large number of everyday products that cannot be used easily by older and disabled users and can also be difficult or frustrating for able bodied users.

Vanderheiden and Tobias (2000) investigate current practices and perceptions of designers, interviewing 26 companies. A key driver for inclusive design was accessibility regulations, although some of those interviewed argue that regulations would set industries at achieving a minimum level, with no incentive to exceed targets. However, others argue that when the benefits of inclusive design are realised, companies will move beyond regulation criteria.

In a study by Sims (2003) a survey of 32 design professionals found that 72% of those interviewed were aware of the philosophy of “design for all” but rarely considered the approach due to perceived time and financial costs. It was also found that designers are not always fully aware of the benefits of end-user consideration. 84% involved the end user in the design process – however, the majority where involved in the later modelling and prototyping stages: “testing at this stage allows for limited changes to be made to the design if problems arise and if trials are only carried out using finished products, the scope for change is almost negligible” (Sims, 2003). There was no comparison made between barriers in different industry sectors. The study also acknowledged that designers themselves may also play a role in influencing clients to consider the end user – however, only 34% of the designers interviewed had tried to influence the client.

These findings are backed up by a more recent study by Goodman, et al. (2006), which investigates 101 UK companies to examine their awareness of inclusive design and identify the barriers and motivators for it. This includes large organisations and SME’s from the design, manufacture and retail sectors and included a range of companies, including those in the telecommunications, IT, consumer electronics and household durables sectors. The study found that 76% of companies had heard of inclusive design, with the majority of the companies involved having a good understanding of what inclusive design was. 16% of companies had not heard of inclusive design, universal design or design for all. Although there has been an increasing awareness of inclusive design in recent years, this could be improved further as 39% of companies still showed low levels of awareness.

However, awareness alone is not enough to increase the uptake of inclusive design practice and a greater understanding of the barriers to inclusive design is needed before a new approach can be proposed. Half the companies that responded (Goodman, et al., 2006) felt that their company was not investing enough effort into inclusive design and a large proportion reported that they were not interested in inclusive design. It is therefore apparent that while the majority of companies are aware of inclusive design, few are taking the steps necessary to implement it. There is also a need to understand why designers and companies are reluctant to undertake an inclusive design approach and why existing inclusive design approaches are not widely used. Although the Goodman, et al. (2006) study provides good insight into the uptake of inclusive design within UK industry, it is worth considering that as surveys were used in this study, the response may be biased as those who adopt inclusive design are more likely to respond to the survey than those who do not.

In a third study (Goodman-Deane, et al., 2010), two of the six companies interviewed reported that they had little prior experience of inclusive design, one had little experience in inclusive design through their everyday work, one often had to consider accessibility and the remaining two were experienced in inclusive design as part of their everyday work. Although a smaller sample size than the other studies discussed here, this agrees with the findings of previous studies that although companies are aware of inclusive design (the six companies involved in this study were taking part in the 2005/06 Design Business Association Inclusive Design Challenge) there is a limited uptake of an inclusive design approach in industry, with only half the companies involved in this study using inclusive design principles regularly in their everyday work.

A recent study (Kett & Wartzack, 2015) aims to contribute to an improved practicability of inclusive design throughout established product development processes. The work looks to improve inclusive design uptake in product development practice by extending existing design process models to integrate inclusive design principles. However, the work focuses on new product design rather than product development and is purely based on theoretical methodologies – there has been no implementation or validation of the approach in practice.

The three studies discussed here – (Sims, 2003), (Goodman, et al., 2006), (Goodman-Deane, et al., 2010) – highlight that the majority of companies that took part in the studies are aware of inclusive design. However, it is apparent from the studies found here and noted in other, recent research (Ielegems, et al., 2015) that more work is needed to take into account the difficulties faced by designers regarding inclusive design practice to ensure that a new inclusive design approach is adopted. As stated by Clarkson and Coleman (2015): “embedding this in a company requires inclusive design champions at all levels of the organisation, including board members, decision makers, design managers and marketeers”. It is apparent that a lack of awareness of inclusive design is not the main issue behind the failure to adopt an inclusive design approach, therefore this research study will not focus on increasing awareness of inclusive design, but will focus on ways to aid the implementation of inclusive design throughout the design process, taking into account the barriers to the approach.

2.5.4.1. Barriers to inclusive design

This section will discuss some of the main barriers to the uptake of inclusive design in industry, focusing on education, perception barriers, the use of inappropriate methods, client barriers, time and cost constraints and the role of the designer. The barriers discussed in this section are summarised in Table 2.6.

Paper	Education	Perception Barriers	Inappropriate Methods	Client Barriers	Time and Cost	Designer
Bruseberg & McDonagh-Philp (2000)		Designers should know who they are designing for – conducting research is a sign of weakness.		Not prepared to pay for additional user research.		Not confident talking to people.
Bruseberg & McDonagh-Philp (2002)	Lack of designer understanding of appropriate methods.	User research is considered out-with the remit of the designer by the client.		The client is unlikely to fund further user research – will not duplicate information already provided to designer; clients assume designer understanding of the user.	Limited time to involve users.	Designer too reliant on user information provided by the client; user involvement methods are not considered part of the designer's role.
Cardoso & Clarkson (2012)			Self-observation approaches fail to identify less obvious problems.		Time consuming and expensive methods are hard to finance.	
Clarkson & Coleman (2015)			Designers do not engage well with conventional data presentation formats which they find hard to interpret.	Designers have to work within company constraints; designers are people orientated while companies are profit orientated.	Design constraints focus on cost, novelty and brand positioning.	Designers are happiest when solving clear cut problems with small user groups they can engage with emphatically.

Paper	Education	Perception Barriers	Inappropriate Methods	Client Barriers	Time and Cost	Designer
Crilly & Clarkson (2006)		Consumer research is not cost-effective; consumer research can stifle creativity.	Designers carry out self-observation, believing they are representative of the target user.	Clients do not perceive inclusive design adds value to the final product; clients promote own aesthetic preference.		Reluctance to ask for funding to carry out user research.
Dong, et al. (2004)	Lack of awareness; lack of organisational policy.	Difficulty in changing business culture to support the approach; sacrifice of aesthetics.	Lack of resources.	Lack of business case.	Increased product development time; lack of time to learn inclusive design practice, inclusive design is expensive, the process is complex.	Lack of guidance, interest, motivation.
Dong, et al. (2005)		Not feasible for commercial projects.	Lack of user involvement in the design process.		Time and budget constraints.	Appropriate users are difficult to identify.
Dong, et al. (2015)			Marketing data lacks inspiration and understanding of the user; lack of tools to support effective use of user data.			

Paper	Education	Perception Barriers	Inappropriate Methods	Client Barriers	Time and Cost	Designer
Goodman, et al. (2006)	Lack of awareness; confusion over terminology.	Inclusive design not perceived as a need of the end user; compromises aesthetics.	Negative response to existing standards and tools.		Lack of time, money and appropriate tools and knowledge.	
Goodman-Deane, et al. (2010)	Designers lack knowledge, tools and experience; resistance to change.	User research is not considered part of the designer's role.	Data delivered in a definitive way – not suitable for the way designers work; limited levels of user involvement and too late in the process.	Client sets constraints and is the primary source of information – data not always accurate; clients provide feedback on concepts.	Lack of time and budget constraints; budget is set by the client.	Designers rely on self-experience and self-modelling; acceptance of vague target user specifications; high reliance placed on data from clients.
Lim & Nickpour (2015)	Limited understanding of inclusive design principles among stakeholders.					
Mival (2004)			Designers rarely receive first-hand information; summary information lacks contextual elements.			Junior designers are more concerned with aesthetics and engineering than final user experience.

Paper	Education	Perception Barriers	Inappropriate Methods	Client Barriers	Time and Cost	Designer
Sims (2003)	Lack of awareness of potential market.			Lack of client backing.	Lack of time and money.	Designers have to accommodate those they have never had to consider before; 34% of designers don't involve the end user if not requested by the client.
Vanderheiden & Tobias (2000)	Lack of awareness of increasing ageing population.	Inclusive design is too specialised.	Inclusive design training is critical but not available; no expert assistance within the company	Disabled market is not a big motivator.	Increased time to market; increased design and manufacturing costs.	

Table 2.6 - Barriers to inclusive design uptake

Lack of inclusive design education

A study by Sims (2003) found that in a survey of 29 design professionals, many were aware of and understood design for all, but very few practiced it – reasons for this included a lack of awareness of the potential market. Dong, et al. (2004) found a lack of awareness and motivation to be key perception barriers to inclusive design uptake. In a survey (Goodman, et al., 2006), it was found that only a third of the London FTSE100 companies were aware of universal design and reported confusion regarding what the term universal design actually meant. A more recent biomechanical study by Carse, *et al.* (2010) found although 90% of packaging designers interviewed could define inclusive design, few knew how to implement the approach in practice, as many had never designed inclusively before. This statement was backed up by Lim and Nickpour (2015), who state that the limited understanding and knowledge of inclusive design principles among stakeholders is an issue in the uptake of inclusive design.

The studies cited above indicate that there is a lack of knowledge regarding how to implement inclusive design in industry. However, the time progression of the studies indicates that awareness of the principle inclusive design is perhaps increasing. While awareness of inclusive design must be increased, awareness alone will not see the desired rise in inclusive design uptake in industry. Dong (2004) states that there is a current lack of organization policy on inclusive design, emphasising that it is not only the designers themselves who must take on a more inclusive approach to design but organisations as a whole need to adopt a more inclusive culture. There is therefore a need to increase the education of both the designer and the client: designers must have an increased understanding of user involvement methods and how to implement them. In addition, the client must be educated on the value of adopting an inclusive design approach, both in what inclusive design means and the value the approach has from a business perspective.

Perception barriers

Inclusive design is often perceived as design for disabled people only, rather than designing for all people (Keates, et al., 2000b). Goodman, et al. (2003) found that companies viewed inclusive design as compromising product aesthetics – they felt there was a stigma associated with inclusive design, which would have a negative effect on their branding.

However, other companies that took part in the same survey saw inclusive design as having the potential of enhancing the brand. This is in agreement with a study by Dong (2004), who notes that one of the most significant barriers from manufacturers is a "perceived sacrifice of aesthetics". If inclusive design is applied properly, the final product should not be identifiable as a product designed for a specific target group. There is therefore the need for good, effective implementation of inclusive design that will enhance product branding.

An earlier study (Bruseberg & McDonagh-Philp, 2000) reports that clients often assumed that by interacting with users, the designer will only produce what the customer visualises rather than something new and innovative. Another study from the same year (Vanderheiden & Tobias, 2000) found perception barriers within the designer population where many thought that inclusive design was too specialised, with many unaware of the increasing age of the population and the effect this would have on the market. Goodman, et al. (2006) found that inclusive design was not perceived as a need of the end user.

The perception that time and cost would be significantly affected by adopting an inclusive design approach is common throughout the literature. Vanderheiden and Tobias (2000) investigate current practices and perceptions of designers, interviewing 26 companies and found that many considered inclusive design as being too specialised, increasing time to market and design and manufacturing costs. Sims (2003) and Dong (2004) also found that a main reason for companies failing to implement inclusive design was a lack of time and budget. A more recent study (Goodman, et al., 2006) conducted a survey of 101 companies, which found that the most frequently identified barriers to inclusive design were a lack of time and money. Goodman-Deane, et al. (2010) also found that the main reasons for company's not practising inclusive design were a lack of budget and time constraints. It is apparent that in the last 15 years, there is an ongoing perception that inclusive design practice will significantly increase the time and budget of a design project.

There is a general perception among retailers that inclusive design is more expensive and the process is complex (Dong, 2004). Although user involvement can be a useful and inspiring approach, it is not always feasible in everyday practice – user trials can be time consuming and expensive, which clients may find difficult to finance (Cardoso & Clarkson, 2012). Dong, et al. (2004) found that, in addition to a perceived increase in the time of the development process, the inclusive design approach would also take time to learn with a lack of resources/guidance on inclusive design practice. However, Keates, *et al.* (2000b) found that most industrial participants stated they would be willing to implement inclusive design providing it was easy to do and did not increase the cost of the product, indicating that companies would be open to adopting an inclusive design approach provided it was feasible.

Inappropriate methods

Goodman-Deane, et al. (2010) found that many designers did not have the knowledge, tools or experience to implement inclusive design. There is a need to tailor design methods to suit the needs of the project, which can be time consuming with designers less likely to adopt new approaches they are not familiar with. There is also a lack of awareness of available methods.

It has been identified that one of the key reasons for failing to implement inclusive design is a lack of user involvement in the design process (Dong, 2004). Designers observing the user themselves are more likely to lead to more creative thinking to address the issues faced by users rather than receiving information from an independent researcher. User observation is vital, particularly in the inclusive design process as users may (Waller, et al., 2013):

- Have poor awareness of their own behaviour.
- Struggle to articulate their needs.
- Find it difficult to imagine what is possible.
- Say what they think the interviewer wants to hear.

Despite the need for user involvement in the inclusive design process, it was found (Goodman-Deane, et al., 2010) that designers often refer to self-experience, talking to experts, imagining user scenarios and putting themselves in "someone else's shoes". The use of past experiences and self-modelling is often thought to be an adequate way of taking into account the needs of the final user. Self-observation approaches may fail to identify the less obvious problems people with capability loss may struggle with (Cardoso & Clarkson, 2012). As a result, the designer ends up designing for a user of similar capabilities to themselves, disregarding the needs of other, less-abled users. Designers have to be educated in other ways of gaining direct access to the end user and gaining a deeper understanding of user needs based on the user and not themselves. This will have a major impact on the success of inclusive design as products will start to address the needs of a wider range of users.

Designers tend to use informal, low-cost methods (Goodman-Deane, et al., 2010) to assess the end user and the products' environment of use. Emphatic design can be useful at simulating the effects of age or disability without the time involved in recruiting a user group. However, it does not give designers the understanding of what it is like to live with and compensate for the disability (Cardoso & Clarkson, 2012). Focus groups can also be used by designers to incorporate users into the design process. However, Bruseberg and McDonagh-Philp (2000) found that using focus groups could constrain ideas as the designer would end up designing what the user had in their imagination, and not pushing for further creativity.

> *"The literature suggest that raw data is used more productive than more abstracted data, with designers tending to reject abstracted models of user behaviour in favour of richer user stories"* (Goodman, et al., 2007, p.5).

There is variation in where the information used by designers comes from (Goodman-Deane, et al., 2010). Designers refer to the internet, books, experts, their own experiences and users. In cases where formal information is supplied to the designer, vital details can often be lost by summarising results (Bruseberg & McDonagh-Philp, 2000). It was reported (Dong, et al., 2015) that designers often complain that marketing data they are supplied with often comes from the project manager in a bullet-point list and lacks inspiration, understanding of the user and rich, contextual elements. It was found (Goodman-Deane, et al., 2010) that a main source of information is other people – this may be due to designers preferring easily available, flexible information sources that are visual and stimulating, open-ended, and relate clearly and concretely to design issues (Goodman, et al., 2007).

Client barriers

A study by Goodman-Deane, et al. (2010) interviewed two designers and found that client influence plays a major role in the uptake of inclusive design within industry – "you sometimes need a reasonably enlightened client to allow user research to happen". The client sets the constraints, time and resource allocation, the target user group and the design brief, which details the problem to be addressed, meaning that there is not time or funding allocated to further user research if inclusive design has not been addressed by the client. The client can also influence the design process through feedback on concepts and their own aesthetic preferences (Crilly & Clarkson, 2006). The study (Goodman-Deane, et al., 2010) concludes that there is a need for materials to educate the client in the value of inclusive design and user consideration.

The client is often the first point of reference for the designer and is relied on as the primary source of information rather than designers conducting their own user research (Goodman-Deane, et al., 2010). Similar findings are also reported by (Bruseberg & McDonagh-Philp, 2002), who add that the use of focus groups is almost impossible as the client is unlikely to fund further user research and often assume that the designer already has an understanding of the target user. However, the study reports that designers regretted the fact that they lacked more detailed user information. Sims (2003) found that only 34% of designers had ever involved the end user if it had not been requested by the client. This is in agreement with (Goodman, et al., 2007) who found that there was reluctance from designers to carry out additional information searches themselves. However, when too much information is provided the time and costs needed to search for information can be prohibitive.

Bruseberg and McDonagh-Philp (2002) found that designers rely too much on second hand user information from the client (which is not always accurate) and recommend that there should be emphasis placed on designers conducting their own user research on top of what has been provided by the client to fully understand how the user will interact with the product, problems encountered and the environment of use of the product. For larger design projects, it was found (Goodman-Deane, et al., 2010) that user information is often supplied by independent research companies, although this data is delivered in a definitive way and does not suit the way in which designers work.

The findings of these studies are supported by Dong (2004) where interviews conducted with design consultancies found that the client and the design brief were the most significant barriers to inclusive design. The study also reports that the design brief often lacked inclusivity due to the lack of user involvement in the design process.

Role of the designer

Designers are critical in promoting inclusive design (Dong, et al., 2015) and the information needs of the designer must be understood to ensure effective uptake of inclusive design. The approach to inclusive design can be challenging for designers who often rely on assumptions made regarding potential users based on their own experiences (Dong, et al., 2005). Designers are also reported to "design for themselves", which raises problems as designers cannot anticipate the variety of backgrounds, knowledge and capabilities of the wider population (Cardoso & Clarkson, 2012).

> *"Designers tend to focus on the individual user and are often happiest when solving clear-cut problems identified from interactions with small numbers of users whom they can engage emphatically. They do not readily engage with conventional data presentation formats, which they find hard to interpret"* (Clarkson & Coleman, 2015, p.7).

Many consultant designers are reliant on the client for user research information – this makes it difficult to build empathy with the user (Dong, et al., 2005) as they often have to consider problems and empathise with the needs of individuals that they have never had to consider before (Sims, 2003).

2.5.5. Discussion

This literature review has emphasised the importance of inclusive design, primarily due to the ageing population in many countries. In addition to the moral argument for inclusive design (that designers *should* include everyone) there are also legal and business incentives for the approach which have been discussed here.

There are many methods and tools intended to aid the implementation of an inclusive design approach, a selection of which are presented here. However, there is clearly a lack of inclusive design uptake in mainstream design practice. Many of the barriers to this have been discussed here. It is apparent that many of these barriers (time and cost constraints, availability and quality of user information within the design brief, the target user group, user involvement within the design process) often stem from the client, rather than the designer. It is vital that designers have an awareness of how to design inclusively, for the widest user group possible, and that they have the supporting tools and methods to do this, indicating that there is still a need to address designer education. However, there is also a need to address another source of many of these barriers – in many cases, the client. The tools and methods discussed here, which are some of the more common within inclusive design, often target the designer and aid them in implementing inclusive design. However, there appears to be a lack of tools to support the client in raising awareness for the importance of inclusive design and how to implement the approach.

As discussed in Sections 2.2 and 2.4, sports design is another highly user focused discipline, where the sports equipment must work together with the athlete to enhance sporting performance. This section has identified the need for inclusive design, highlighting that the approach is both iterative and user centred. For an inclusive product to be successful, it must be usable by the target user groups in the same way sports equipment must be usable by the athlete to improve sporting performance. There are therefore apparent similarities between both sports design and inclusive design. Based on the findings from earlier in this literature review, there is a need to define the sports design process, capturing what characterises the discipline. Many design industries have design processes that are specific to their requirements – e.g. the design spiral for ship design (Rawson & Tupper, 2001). These models can then be applied across other design disciplines – for example the design spiral, intended for ship design, has evolved and is now used in the design of aircraft and in mature product architecture (Clarkson & Hamilton, 2000). There is therefore scope for a design process model that represents sports design practice to be applicable across other design disciplines with similar characteristics. Given the user centred nature of both sports design and inclusive design, this proposes the third and final research question: **how is the sports design process applicable to inclusive design?**

Section summary:

- Ageing populations are a main driver for inclusive design.
- Inclusive design should be incorporated within the design process – it is not a standalone activity.
- There is limited published work that discusses the inclusive design process itself.
- There are many barriers to inclusive design, many of which stem from the client.
- Research question: how is the sports design process applicable to inclusive design?

2.6. Chapter Findings

This literature review has highlighted that sports design is a highly user focused design discipline, where the biomechanical system formed between the athlete and the equipment is vital to sporting success. While several studies have been identified that focus on specific areas of the sports design process, a systematic approach to reviewing the sports literature did not identify any published work that has investigated and defined the sports design process as a whole.

The research discussed in this chapter has highlighted that design processes are linked to business success. It is therefore in the interest of companies to follow a design process that is reflective of their design practice. As noted in the literature, sports design has characteristics that are specific to that discipline. This research therefore proposes that a design process that reflects these characteristics would be of value to the sports design community.

There are reports in the literature of design processes being transferred across disciplines. This research suggests that the sports design process, which reflects the highly user focused nature of sports design practice is discussed here and highlights the importance of user information and involvement throughout the design process to enable designers to understand and build empathy with the user. It is also critical that the designers themselves are involved directly with the user and does not rely solely on secondary user information.

There appears to be a link between what is recommended for the implementation of user centred product design and what characterises the sports design discipline. This thesis hypothesises that the user focused nature of sports design practice will be reflected in the sports design process. Based on the findings of what characterises the sports design process, this research will assess the potential for that process to aid other user centred areas of design – this research will focus specifically on inclusive design. While this thesis does not argue that user information is of a greater importance than other design needs, the case will be made for the importance of user understanding, the benefits it brings to design and why user centred design should be given more consideration throughout the design process as a whole.

There are a number of drivers that have been discussed in this chapter that promote the value in an inclusive design approach. As a result of changing population demographics and advancing technology, there is a need for products that are designed to cater for a wider diversity of user needs. Understanding the user is becoming more important to designers in an effort to gain a competitive advantage and to gain entry into more lucrative markets.

> *"Overall, everyone benefits from inclusive design and in an era of a rapidly ageing population it is imperative that we design for the whole life course, rather than for a full bodied minority"* (Clarkson & Coleman, 2015, p.2).

This literature review indicates that more has to be done to develop a method/tool that designers can work within that will lead them towards a more inclusive outcome. Inclusive design is not more challenging than following a normal design process – it simply adds additional constraints into the specification and requires a deeper understanding of the intended users by the designer. It is recommended (Goodman, et al., 2006) that there is a need for better tools and methodologies that take into account the barriers to inclusive design and improve knowledge and implementation of the approach. However, barriers and drivers vary between companies, therefore it is important that the solution is flexible and can be implemented by all.

This research will be of value to the sports design discipline as it aims to capture the first model of the sports design process. However, as discussed here, there are possibilities to expand the reach of this research to the wider user centred design community. Inclusively designed products benefit not only the older and disabled population but able-bodied users as well.

Two knowledge gaps have been identified from this literature review that this research will address:

1. The first is the lack of a design process specific to the discipline of sports design. Chapters 4 and 5 of this thesis will identify what differentiates the sports design and product design processes in practice and will present a design process model that is descriptive of sports design practice in industry.
2. The second is the potential to improve inclusive design practice by transferring applicable lessons from the sports design discipline to inclusive design. While there are a number of tools and methods that currently aim to improve inclusive design practice and uptake, these are primarily focused on the designer and either do not take into account or do not represent the inclusive design process as a whole.

Chapter 6 will present the results from a study which investigates the potential of the sports design process model to aid inclusive design practice. Chapter 7 will detail the development of a framework based on the sports design process model and recommendations made by designers in Chapter 6. Chapter 8 will present the final framework and its validation.

This research will address both knowledge gaps by answering the following research questions that were identified from the literature review:

1. What differentiates the sports design process from the product design process in practice?
2. What is the sports design process?
3. How is the sports design process applicable to inclusive design?

It is noted that while research questions 1 and 2 were presented in reverse order within the literature review, there is a need to first establish what characterises and differentiates sports design practice before mapping the sports design process to ensure these characteristics are captured within the sports design process model.

Chapter 3: Research Approach

The literature analysis in the previous chapter identified the lack of a sports design process model that captured the sports design process as a whole. It was also recognised that there is a need for better tools and methods that take into account the barriers to inclusive design and improve knowledge and implementation of the approach in practice. The following chapters (Chapters 4-8) will present the four studies undertaken as part of this research to firstly identify and capture the sports design process and secondly to assess the potential of that design process model to aid inclusive design practice. This chapter will provide an overview of the research reported within this thesis and the structure of the research. The research philosophy is presented, in addition to the adopted research approach. This chapter will provide an overview of each of the four studies conducted within this research, with further detail of each study being provided within the relevant chapters.

3.1. Overview of this research

> *"The central aim of research is understanding"* (Robson, 2011, p.24).

Research design is defined by Kumar (2014) as, "the road map that you decide to follow during your research journey to find answers to your research questions as validly, objectively, accurately and economically as possible". During this journey a process is followed to complete the various tasks required by the research to gain understanding of the area of interest.

The research aim, as presented in Chapter 1 is:

> **To investigate how the sports design process can be used to improve inclusive design practice.**

To address this aim, the following research questions were proposed as a result of the literature review:

What differentiates the sports design process from the product design process in practice? (Addressed in Chapter 4)

What is the sports design process? (Addressed in Chapter 5)

How is the sports design process applicable to inclusive design? (Addressed in Chapters 6, 7 and 8)

Figure 3.1 illustrates the path of the research process followed in this thesis. The literature review was conducted to establish existing work into the fields of sports design and design processes in general and identified the link through user centred design to inclusive design practice and the barriers to the inclusive design approach. The outcome was the identification of the three research questions, which informed the conceptualisation of the research design and the methodology for collecting appropriate data. Pilot studies were conducted where appropriate (shown within Figure 3.1 as "field testing the research tool"). Data was then collected, analysed and conclusions were drawn. To answer the three research questions, four studies were conducted, as discussed in the next section. The research process was therefore repeated four times between points A and B, as illustrated in Figure 3.1. The result of the final stage ("write research report") is this thesis.

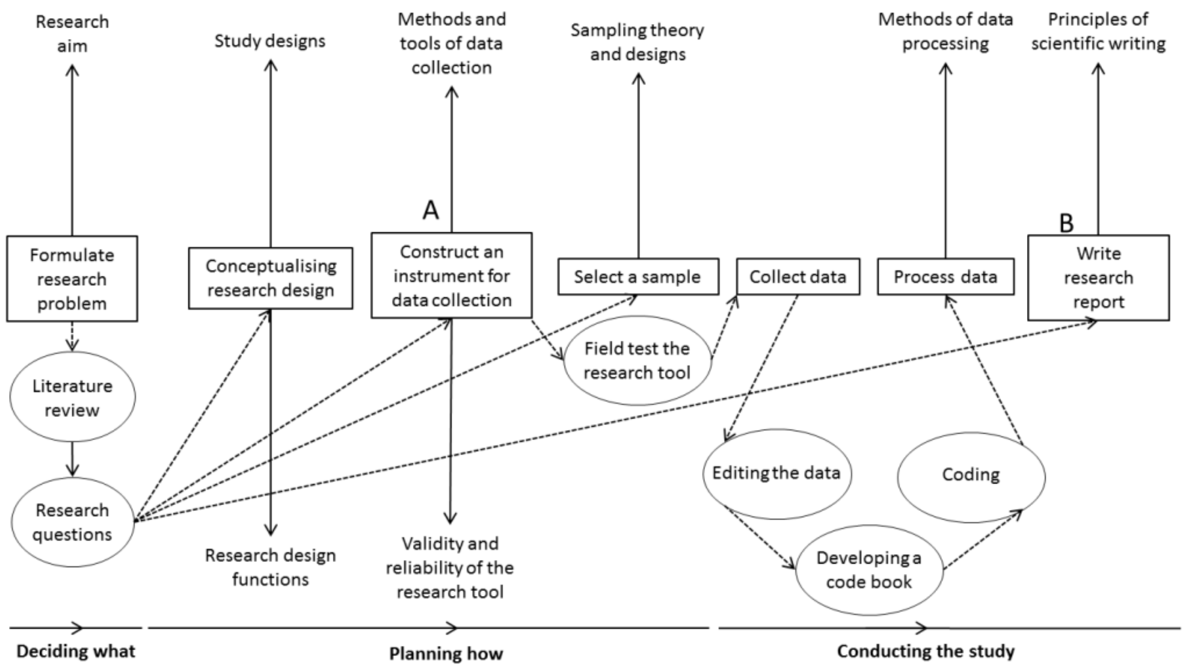


Figure 3.1 – Path of the research process – adapted from Kumar (2014), P36

3.2. Structure of the research

Figure 3.2 illustrates the structure of the research carried out in this thesis. The research aim addressed in this research is as stated in the introduction – **to investigate how the sports design process can be used to improve inclusive design practice.** As discussed, the literature review identified the three research questions that this research will address.

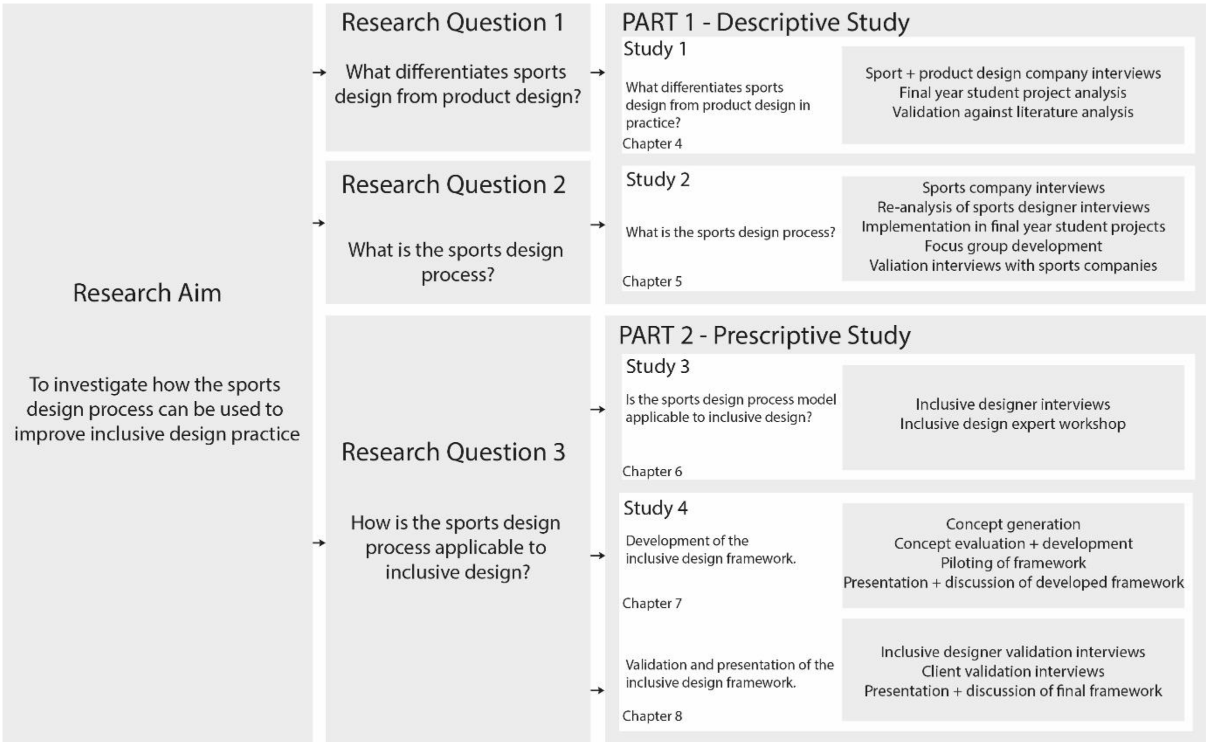


Figure 3.2 - Structure of the research

To address each of the research questions, this thesis is split into two distinct parts as is shown in Figure 3.2. Part 1 addresses the first two research questions, identifying what differentiates the sports design process from the traditional product design process in practice (Study 1) and what is the sports design process model (Study 2). The identification of the sports design process falls under basic research (Sim & Wright, 2000), which aims to shed new light on the theoretical processes within a particular body of knowledge. Part 1 of this research details two descriptive studies which assess the differences between the sport and product design processes practice and capture and describe the sports design process within a model. These studies are described in Chapters 4 and 5 respectively.

Part 2 addresses the third research question – how is the sports design process applicable to inclusive design? The application of the sports design process within an inclusive design setting is applied research (Sim & Wright, 2000), where particular issues are addressed and a solution is provided. Part 2 details two prescriptive studies that were undertaken to assess the potential of the sports design process model to aid inclusive design practice and the development of a framework to facilitate communication within the inclusive design process. Study 3 is described in Chapters 6, while Study 4 is presented over Chapters 7 and 8.

Four studies were carried out within this research to provide the necessary data to develop and validate both the sports design process model and the inclusive design framework. Where participant involvement was required, signed consent forms were gained with participants agreeing to participation in the study and (where relevant) recording of the interview/workshop. More detail on the exact nature of the studies conducted within this research is given within the relevant chapters of this thesis. A summary of each of the four studies is provided below, with more detail given in each of the appropriate chapters.

Study 1 – What differentiates the sports design process from the product design process in practice?

Study 1 addresses the first of the research questions through the comparison of sports design and product design processes in practice, and followed a triangulation approach using three methods. The first conducted interviews with sports and product design companies to identify differences between the design processes of each in practice. These results were validated through analysis of final year university sports engineering student projects and the findings from the sports design literature review (conducted and discussed in Section 2.2).

Study 2 – What is the sports design process?

Study 2 addresses the second research question with the sports design process investigated, identified and captured following an iterative process of detailing and evaluating the sports design process model. The study was made up of five steps –

interviews with sports design companies, re-analysis of those interviews, implementation of the sports design process model within final year sports engineering university student projects, focus group development and respondent validation through further interviews with sports design companies. The outcome is a design process model that is descriptive of sports design practice in industry.

Study 3 – Is the sports design process model applicable to inclusive design practice?

Study 3 is the first step in addressing the third research question by determining the applicability of the sports design process model to inclusive design practice. Within this study, interviews were conducted with product designers, with an additional workshop carried out with three inclusive design experts at the Helen Hamlyn Centre to gain a detailed understanding of "best practice" inclusive design and how the sports design process model could aid this within industry.

Study 4 – Development of the inclusive design framework.

Based on the recommendations of the designers interviewed as part of Study 3, a framework was developed to aid inclusive design uptake in practice. Study 4 documents the iterative process of concept generation and evaluation of the inclusive design framework, the piloting of that framework and presents the framework prototype that was developed.

Study 4 (continued) – Evaluation and presentation of the inclusive design framework.

Chapter 8 reports on the continuation of Study 4 and concludes the research by completing the response to research question three. Respondent validation was utilised within this study, with a final set of interviews carried out with the product designers that had been involved in Study 3. Further interviews were conducted with design clients to ensure the inclusive design framework was applicable to the intended user. Based on the results of those interviews, final developments were made to the framework, which is presented at the end of Chapter 8.

3.3. Research philosophy

The understanding of philosophical issues is important as it can help to clarify research designs, recognise which designs will work or not, and to create new designs that may be outside the researchers experience (Easterby-Smith, et al., 2012). The relationship between data and theory is critical to the quality of research (Easterby-Smith, et al., 2012). Each research approach adopts a particular philosophical perspective on reality and the way in which knowledge is gained, based on a specific epistemological perspective adopting a structure where inferences are drawn from the data (Sim & Wright, 2000). Any research that involves the collection of data from the surrounding physical world is empirical, with data being either qualitative or quantitative. The empiricism philosophical view understands that only knowledge that is observed first hand is valid (Sim & Wright, 2000). This view is therefore reflected in the practical approach followed throughout this research.

Ontology is the nature of reality and existence (Easterby-Smith, et al., 2012). There are four different ontologies, which are summarised in Table 3.1. This work will adopt a relativism position, which suggests that different people hold different views to which there may never be a definitive answer. As such, a variety of participant groups are involved in this research to ensure many of these viewpoints are captured.

Ontology	**Realism**	**Internal Realism**	**Relativism**	**Nominalism**
Truth	Single truth	Truth exists but is obscure	There are many 'truths'	There is no truth
Facts	Facts exist and can be revealed.	Facts are concrete but cannot be accessed directly	Facts depend on the viewpoint of the observer	Facts are all human creations

Table 3.1 – Four different ontologies (Easterby-Smith, et al., 2012).

Epistemology concerns the best ways of enquiring into the nature of the physical and social world (Easterby-Smith, et al., 2012). Within epistemology, the role of the researcher must be considered in terms of their degree of engagement with the subject of the research. The researcher can either maintain independence and objectivity or can fully engage with the subject (Easterby-Smith, et al., 2012). Due to the nature of qualitative research, the researcher themselves must collect and interpret the data, making them a part of the research process itself, to the same extent as the participants and their data (Corbin & Strauss, 2015). Within this research, the data collected is qualitative, with the researcher fully engaged in the collection and interpretation of the data.

There are two main views regarding how research should be conducted: positivism and constructionism. Table 3.2 summaries both these views. Based on the selection of a relativism position, the epistemological approach followed by this research will be that of constructionism. Constructionism is a view where social properties are constructed through interactions between people, rather than having a separate existence (Robson, 2011). The approach focuses on the way in which people make sense of the world around them through the sharing of their experiences. As such, the 'reality' is determined by people rather than by objective, external factors (Easterby-Smith, et al., 2012). Constructionist approaches are sometimes referred to as interpretivist, as they focus on how the world is interpreted by those involved in it (Robson, 2011).

The constructionist approach adopted within this research takes the assumption that there are many different realities, leading the researcher to gain multiple perspectives (Easterby-Smith, et al., 2012). It is the task of the researcher to understand the multiple constructions of meaning and knowledge – as such, interviews are often used as a research method to allow the researcher to understand multiple perspectives (Robson, 2011). The benefits to the approach include that it can incorporate multiple data sources – a triangulation approach is often used within constructionism and its adoption within this research will be discussed later in this chapter.

Ontologies	Realism	Internal realism	Relativism	Nominalism
Epistemology	**Strong positivism**	**Positivism**	**Constructionism**	**Strong Constructionism**
Aims	Discovery	Exposure	Convergence	Invention
Starting points	Hypothesis	Propositions	Questions	Critique
Designs	Experiment	Large surveys; multiple cases	Cases and surveys	Engagement and reflexivity
Data types	Numbers and facts	Numbers and words	Words and numbers	Discourse and experiences
Analysis/ interpretation	Verification/ falsification	Correlation and regression	Triangulation and comparison	Sense-making; understanding
Outcomes	Confirmation of theories	Theory testing and generation	Theory generation	New insights and actions

Table 3.2 – Methodological implication of different epistemologies (Easterby-Smith, et al., 2012).

3.4. Adopted research approach

The theoretical perspective adopted in this research is both an inductive and deductive approach, as shown in Figure 3.3. An inductive approach involves planning for data collection, which is then analysed to determine if patterns arise that indicate relationships between variables (Gray, 2014) and applies to Part 1 of this research, where the first and second research questions are addressed. Part 2 of this research will follow a deductive approach where a pre-existing idea or concept is tested (Robson, 2011) – in this case, whether the sports design process is applicable to inclusive design practice. Based on the philosophical perspectives detailed earlier, this research will conduct a number of practical studies within real world scenarios to ensure that findings are applicable to industry practice.

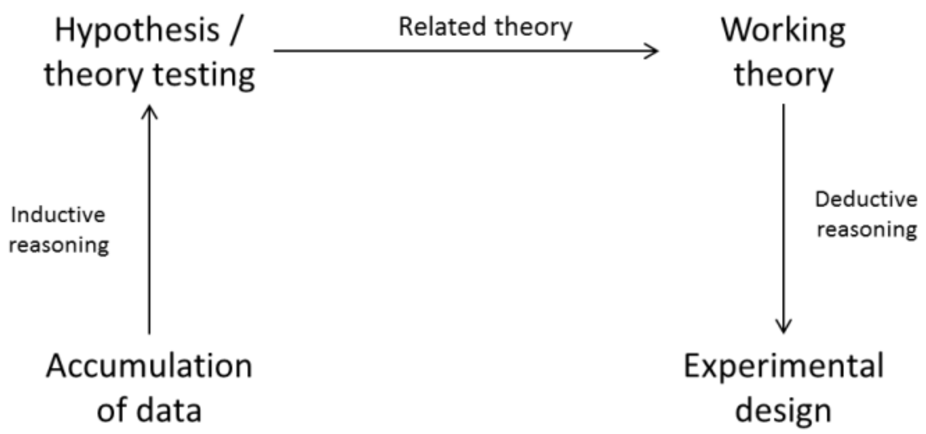


Figure 3.3 - Illustration of combined inductive and deductive methods. Adapted from Gray (2014)

3.4.1. Theoretical Positioning

Grounded theory comes from a constructionist approach (Easterby-Smith, et al., 2012) and is a means of generating theory from data that has been systematically gathered and analysed (Corbin & Strauss, 2015). Glaser and Strauss (1968) view the role of the researcher as that of developing theory using a comparative method – by assessing the same process in different ways. There are different ways to adopt a grounded theory approach. This research will adopt the view taken by Corbin and Strauss (2015) where the researcher takes the time to become familiar with prior research and takes a detailed and structured approach to analysing data, allowing the theory to emerge from the data.

The aim of grounded theory research is to construct theory rather than describe or apply existing theories. Based on the nature of this research, where there is a lack of evidence of the sports design process having been studied, in addition to the potential of the sports design process to aid inclusive design practice, it is concluded that grounded theory is applicable to, and will be adopted within this research. Grounded theory is an approach of qualitative analysis (Bryman, 2012) in which the researcher develops inductive theoretical analyses from the collected data, with more data then gathered to confirm these analyses – within grounded theory, there is a close relationship between the data collection, analysis and theory (Corbin & Strauss, 2015). The data is analysed using a process of coding and analysis, with the data collection stopping when a point of theoretical saturation has been reached – where no additional data is found (Glaser & Strauss, 1968). The phases of thematic coding analysis as outlined by Robson (2011) are summarised as follows:

1. Familiarisation with the data.
2. Generating initial codes.
3. Identifying themes.
4. Constructing thematic networks.
5. Integration and interpretation.

A general inductive approach (Thomas, 2006) is followed in this research as the method of data analysis as it allows the raw data to be condensed, establishes links between the research objectives and findings and reveals the underlying structure of the processes found in the raw data (Thomas, 2006). The analysis is an iterative process of identifying emerging themes in the raw data and refining those categories based on new observations, with a framework developed to illustrate the results. The process of analysis ends when theoretical saturation has been reached (Flick, 2011) – the point where further coding and analysis will not gain any new knowledge with no new categories emerging from the raw data. An inductive approach is associated with grounded theory, making it applicable to this research, where the outcome of the research is new theory (Bryman, 2012).

3.4.2. Research strategy

A research strategy is a plan of action designed to achieve a specific goal (Densombe, 2010). Qualitative research is associated with seeing things in context (Densombe, 2010). As a result, qualitative data allows a range of factors and relationships to be taken into consideration, making it a holistic approach that is suitable for use within this research project. A qualitative research approach is generally linked with constructionism, research strategies such as case studies, grounded theory and research methods such as interviews, documents and observation (Densombe, 2010). This approach places emphasis on the role of the researcher in the construction of the data (Densombe, 2010). In the case of this research project, the researcher will carry out the interviews and the analysis of the interview transcripts for each of the studies. Four essential features of qualitative research are identified as: “the correct choice of appropriate methods and theories, the recognition and analysis of different perspectives, the researchers’ reflections on their research as part of the process of knowledge production, and the variety of approaches and methods" (Flick, 2009). According to Flick (2011), qualitative research "selects participants purposively and integrates small numbers of cases according to their relevance". Qualitative data is appropriate for the research conducted here as it provides rich, detailed data with a tolerance for ambiguity and contradictions (Densombe, 2010).

Qualitative researchers tend to observe the reality (Silverman, 2013). The analysis of qualitative data is an iterative process (Densombe, 2010), which evolves as the data collection and analysis of that data happen at the same time. During this research, the transcribing and analysis of one interview often occurred before the next interview took place – it does not wait for all interviews to be conducted before the data is analysed. This is typical of qualitative data analysis. To ensure standardisation between the analyses of interview data, coding was used as a means of systematically analysing the qualitative data gained from this research, as discussed in Section 3.4.1.

Different researchers evaluating the data independently may produce differences in findings. However, the trustworthiness of the results can be assessed using other techniques. Reliability comes from the approach being based on straightforward scrutiny, data reduction and category refinement (Goodman-Deane, et al., 2010). Silverman (2013) identified the following weaknesses with the qualitative, in-depth approach to ethnographic studies:

1. Researchers rarely provide the criteria or basis that was used to include certain instances and not others. It is therefore difficult to determine the typicality or representativeness of instances and the findings they generate.
2. Research reports are often presented in a tabular form which does not preserve the original material from which the analysis was conducted. As a result, the original form of the data is lost as the researcher tries to summarise their findings, making it difficult to address whether alternative interpretations could have been taken from the data.

Within Studies 1, 2 and 3, a multi-method strategy was adopted to investigate current design practices, evaluate findings and explore the potential for a new approach to aid inclusive design practice. These methods included interviews, questionnaires, focus groups and workshops. Study 1 (presented in Chapter 4 of this thesis) utilised a triangulation approach where a range of methods are used, which are capable of producing independent results (Goodman-Deane, et al., 2010). The approach "produces knowledge on different levels, meaning they go beyond the knowledge made possible by one approach and thus contribute to promoting quality in research" (Flick, 2009). A triangulation approach can be used in the context of various research strategies, including grounded theory (Thomas, 2006). The use of multiple methods is common across many practical-based research projects (Grey & Malins, 2004) as it allows the researcher to understand more fully the complexity of issues by examining them from different perspectives, improving the quality of qualitative research and providing a more holistic view than a single method alone (Thomas, 2006). A triangulation approach was appropriate for answering the first research question (what differentiates the sports design process from the product design process in practice?) to ensure that correct conclusions were made regarding the sports design process, which shows variations between companies and projects. This would ensure the remaining three studies conducted within this research were based on strong foundations.

3.4.3. Validity and reliability

> *"Data are said to be valid when they represent what they purport to represent and meaningful inferences can therefore be drawn from them"* (Sim & Wright, 2000, p.123).

Validity is concerned with the integrity of the conclusions generated by the research (Bryman, 2012). Sliverman (2013) identified two ways in which the validity of qualitative data can be assessed:

1. A multi-method approach – triangulation of methods.
2. Respondent validation.

The use of multiple methods as a means of validation is based on the assumption that individual methods have different patterns of error associated with them (Sim & Wright, 2000). While every effort is made in this research to reduce methodological error, a triangulation approach incorporating various methods is used to ensure validity and overall reduce the error associated with individual methods. As illustrated in Figure 3.2, a triangulation approach utilising three methods was used to validate the results of Study 1. Studies 1, 2 and 3 also utilised a mixed-methods approach to ensure validity in results.

Within Studies 2 and 4, respondent validation was utilised. This process involved the return of conclusions based on the initial results to interviewees for validation of findings and to allow refinements to be made.

> *"Reliability refers to the degree of consistency with which instances are assigned to the same category by the same observer on different occasions"* (Silverman, 2013, p.302).

In order for data to be reliable, it must be repeatable and consistent (Sim & Wright, 2000) with the analysis procedure documented in a way that ensures future researchers can repeat the same study and gain the same results, interpretations and claims (Silverman, 2013). To ensure that data is reliable, Silverman (2013) states that it must meet the following criteria:

1. The researcher must ensure that the research process is transparent through a detailed description of the research strategy and the data analysis methods.
2. The researcher must make clear the theoretical stance from which any interpretations are made, including how particular interpretations were made and why others were excluded.

3.4. Summary

The research approach followed by this research is summarised in an adaptation of the research onion (Saunders, et al., 2016), shown in Figure 3.4. The research philosophy followed is that of relativism, with the epistemological view taken as constructionism. An inductive approach was followed in Part 1 of the research, with Part 2 following a deductive approach. In order to ensure reliability and validity in results, a multi-method approach for collecting qualitative data was used. This research adopts a grounded theory strategy, with the aim of constructing theory. Due to the time-scales of the research, the time horizon is that of a cross-sectional study. The methods of data collection and analysis within each of the studies carried out are described in detail within each of the respective chapters.

The development of the sports design process is a descriptive study, utilising designers from industry to capture the sports design process model. The outcome of Part 1 (Chapters 4 and 5) is the first representation of the sports design process model as a whole, which fills the first gap in the knowledge identified from the literature review – the lack of a design process model specific to the sports design discipline.

The development of the inclusive design framework is a prescriptive study, aiming to implement a user centred approach from sports design practice into everyday inclusive design practice. To ensure the framework is applicable to industry practice and meets the needs of those who are intended to use it (the designer and the client) both stakeholders are involved in this research to ensure their needs were met. The outcome of Part 2 (Chapters 6, 7 and 8) is a framework based on the sports design process model that is intended to improve the implementation of an inclusive design approach within product design in industry.

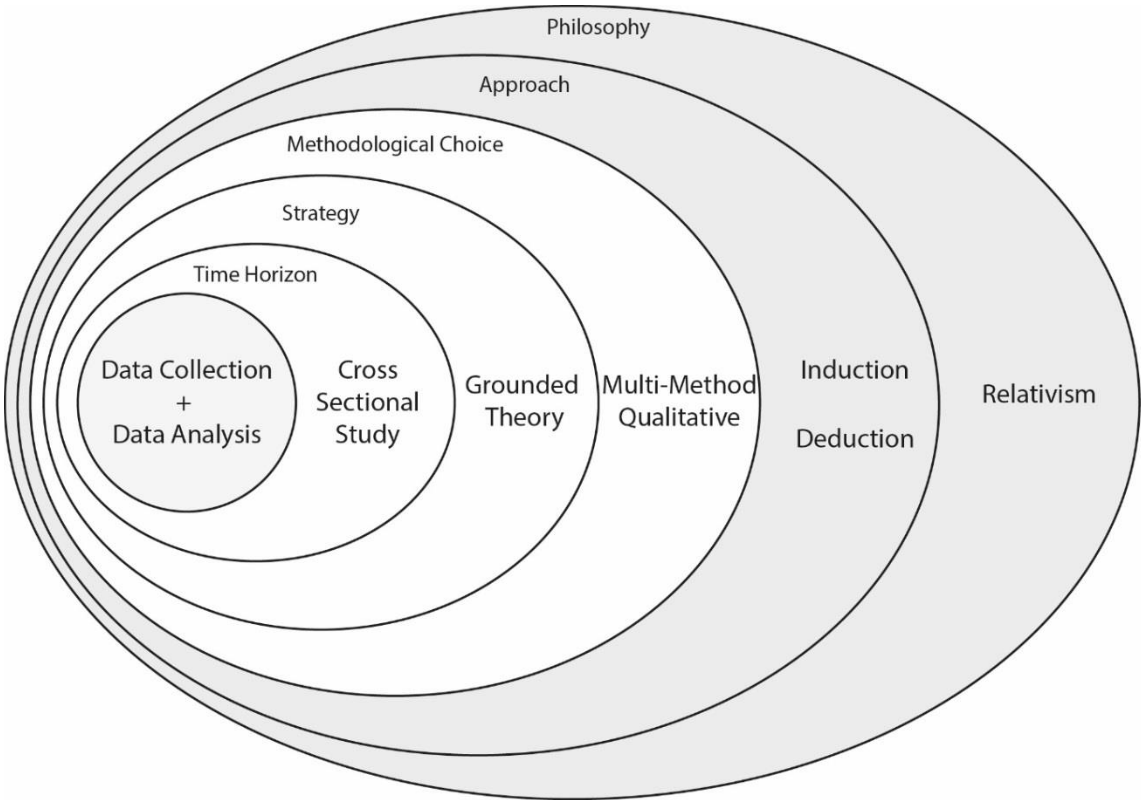


Figure 3.4 – Summary of the research approach followed. Adapted from the research onion (Saunders, et al., 2016)

Part 1

Part 1 of this thesis presents the descriptive studies undertaken to understand and capture the sports design process in industry. Part 1, Study 1 (Chapter 4) addresses the first research question – **what differentiates the sports design process from the product design process?** The triangulation study undertaken is presented along with overall findings to the research question. Study 2 (Chapter 5) addresses the second research question – **what is the sports design process?** The multi-method process of identifying, capturing and validating the sports design process is presented along with the first design process model to capture the sports design process as a whole.

Chapter 4 – Comparison of the sport design process and product design process

Following on from the overall research approach discussed in Chapter 3, this chapter presents the first of two descriptive studies to investigate and understand sports design practice in industry. This chapter presents Study 1 and will address the first research question taken from the literature review: **what differentiates the sports design process from the product design process in practice?** This chapter reports on a practical study that aims to identify the similarities and differences between the design processes followed by sports design and product design companies in practice, looking in particular at the stages of the design process and levels of user involvement within the design process. The outcome of the study is a discussion on what differentiates the sports design process from those of traditional product design companies, focusing on the design process itself in addition to the nature of user involvement within the design process.

The study follows a triangulation approach to ensure validity in the findings (Silverman, 2013). This approach was selected to eliminate respondent and researcher bias that could result from using a single method. Chapter 4 discusses the interviews conducted with designers from both sports design and product design companies to compare the sport and product design processes in practice. Past sports engineering university student projects are analysed to validate the findings of the interview results. The findings from the sports design literature review, conducted in Chapter 2 are used to provide a comparison between the work completed as part of this research and existing, published work to validate results and identify the contribution to knowledge.

Chapter 2 identified that sports design is a design discipline with its own characteristics that differentiate it from other design disciplines. However, it is also a discipline that has received little attention in terms of research into its design process. Having recognised that there is no design process model that captures these characteristics specific to sports design practice as a whole, this study aims to identify what characteristics differentiate sports design from product design practice.

This chapter is structured as illustrated in Figure 4.1. Each of the three methods used is discussed separately with their own detailed methodologies, results and discussion sections. The chapter concludes with an overall discussion of the chapter findings and conclusions from the chapter, including the contribution to knowledge that has been made. Scope for further work resulting from the findings of the chapter is also discussed.

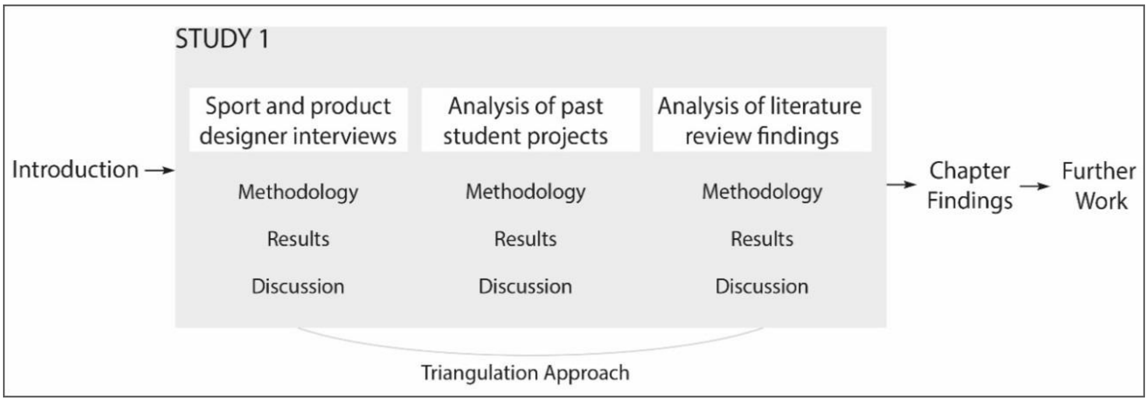


Figure 4.1 - Structure of Chapter 4

4.1. Sport and product designer interviews

This section reports the findings from a set of 12 semi-structured interviews with designers from both sport and product design companies to provide an understanding of design practice in industry and how this informs the design processes followed by each. Interviews were fully transcribed and analysed, as detailed in this section with results indicating similarities with existing work discussed in the literature review in addition to providing new insights, which will be discussed more fully at the end of this chapter.

4.1.1. Methodology

The first research objective is to understand what differentiates the sports design process from the traditional product design process in practice. From the literature review, it was found that Goodman-Deane, et al. (2010) reported on differences that exist between published design process models and the design processes that are followed in industry practice. Based on those findings, it was concluded that it would be invalid to compare sports design (as observed in practice) to existing published design processes models of the product design process. To ensure a valid comparison between the sport and product design processes, this study involved both sport and product design companies to allow conclusions to be drawn regarding the design processes followed by each discipline in practice.

It was unclear whether the design processes followed in practice would be influenced by company size, therefore both large and small companies were interviewed in this research. Company size was determined using The Companies Act (2006), which defines a small company as "meeting two of the following: annual turnover of £6.5 million or less, the balance sheet total must be £3.26 million or less, the average number of employees must be 50 or fewer". A large company is defined as being larger than the criteria listed for a medium-size company – "an annual turnover or £25.9 million or less and an average of 250 employees or fewer" (Clarkson, et al., 2003). All the large companies involved in the study were multi-national, while the small companies were all based within the UK.

The following criteria were used to select the companies involved in the study:

- Sports design companies: The literature review (Chapter 2) defined sports equipment as the artefact used by an athlete to undertake their sport. As such, sporting products such as rehabilitation devices and "traditional" sports equipment such as a high jump bar were considered out-with the boundaries of this research. Purely mechanical products such as race cars were also out-with the scope of this research. Sports companies involved in this research developed products that required direct interaction with the athlete, including football shoes, running shoes, tennis racquets and golf clubs.
- Product design companies: To ensure product companies were comparable to the sports companies involved in this research, criteria used to select product companies was kept similar (where possible) to that of the sports companies. Companies included in the research designed products that required direct user interaction with the product – this included consumer products such as home appliances, domestic sound systems and printers.

12 companies were interviewed as part of this study (see Table 4.1) – six sport and six product design companies, with three large and three small companies of each. The names

of the companies involved will remain confidential – the companies will be referred to throughout this section using the naming convention included in Table 4.1. E.g. LSA refers to Large Sports Company A.

Semi-structured interviews were conducted with designers from each company to gain a first-hand account of the design processes followed by each company in practice. The approach allowed the designers the freedom to develop their thoughts further on relevant topics without restriction, resulting in the exploration of topics not anticipated, therefore not included in the interview questions. A similar approach has been followed in several previous studies, which also conducted research into design methods and processes – (Bruseberg & McDonagh-Philp, 2000), (Goodman-Deane, et al., 2010). Each interview lasted around 40 minutes, providing sufficient time to ensure key points were covered and the clarification of relevant information. Nine questions were asked and covered topics including the design process followed by the company, the methods used and the levels of designer and user involvement within the design process. The complete set of interview questions is included in Appendix 1. Open ended questions were utilised to encourage a more detailed response from the designers.

Sports Design Companies		Product Design Companies	
Large Sports Company A	LSA	Large Product Company A	LPA
Large Sports Company B	LSB	Large Product Company B	LPB
Large Sports Company C	LSC	Large Product Company C	LPC
Small Sports Company A	SSA	Small Product Company A	SPA
Small Sports Company B	SSB	Small Product Company B	SPB
Small Sports Company C	SSC	Small Product Company C	SPC

Table 4.1 - Naming convention used for companies interviewed

Figure 4.2 illustrates the approach taken for the designer interviews. The literature review (discussed in Chapter 2) identified the lack of a model representing the sports design process as a whole and proposed the first research question this thesis will answer. This study addresses that research question by identifying what differentiates the sports design process from the traditional product design process in practice. To assess the suitability of the interview questions, an initial set of questions were piloted with three design researchers and five final year sports engineering university students. A final pilot was carried out with three small design companies (one sport and two product companies) that were not included in the final sample. Following the piloting, modifications were made to the questions to ensure they would be understood by the designers and the desired output would be gained to allow the design processes of sport and product design companies to be compared.

Interviews were conducted, where possible, in person with designers from each company. For two sports companies and one product company, Skype was used due to designer location. Designers that were interviewed had worked within their company for several years, therefore had an understanding of their company's design process and supporting methods. During the face to face interviews, designers sketched out the design process their company followed. For the interviews conducted via Skype, the researcher sketched the design process following instructions from the designer. The interviews were recorded and were completely transcribed, generating 12 transcripts, each of around 4000-5000 words. All interviews were completely transcribed and analysed using a general inductive approach (Thomas, 2006), where a framework was used to interpret and compare significant themes emerging from the interview data. More information on the analysis approach followed is provided in the research approach in Chapter 3. The analysis of the data was completed when a point of saturation was reached – where no new themes were identified within the data. Following the analysis of the interview transcripts, further information was added to the design process diagrams drawn out at the time of the interview. These updated design process diagrams were returned to each company via email for validation to ensure each company's design process had been accurately captured and the additional information added to the processes was correctly interpreted. In some cases additional information was asked for to ensure standardisation of content for all the design process diagrams.

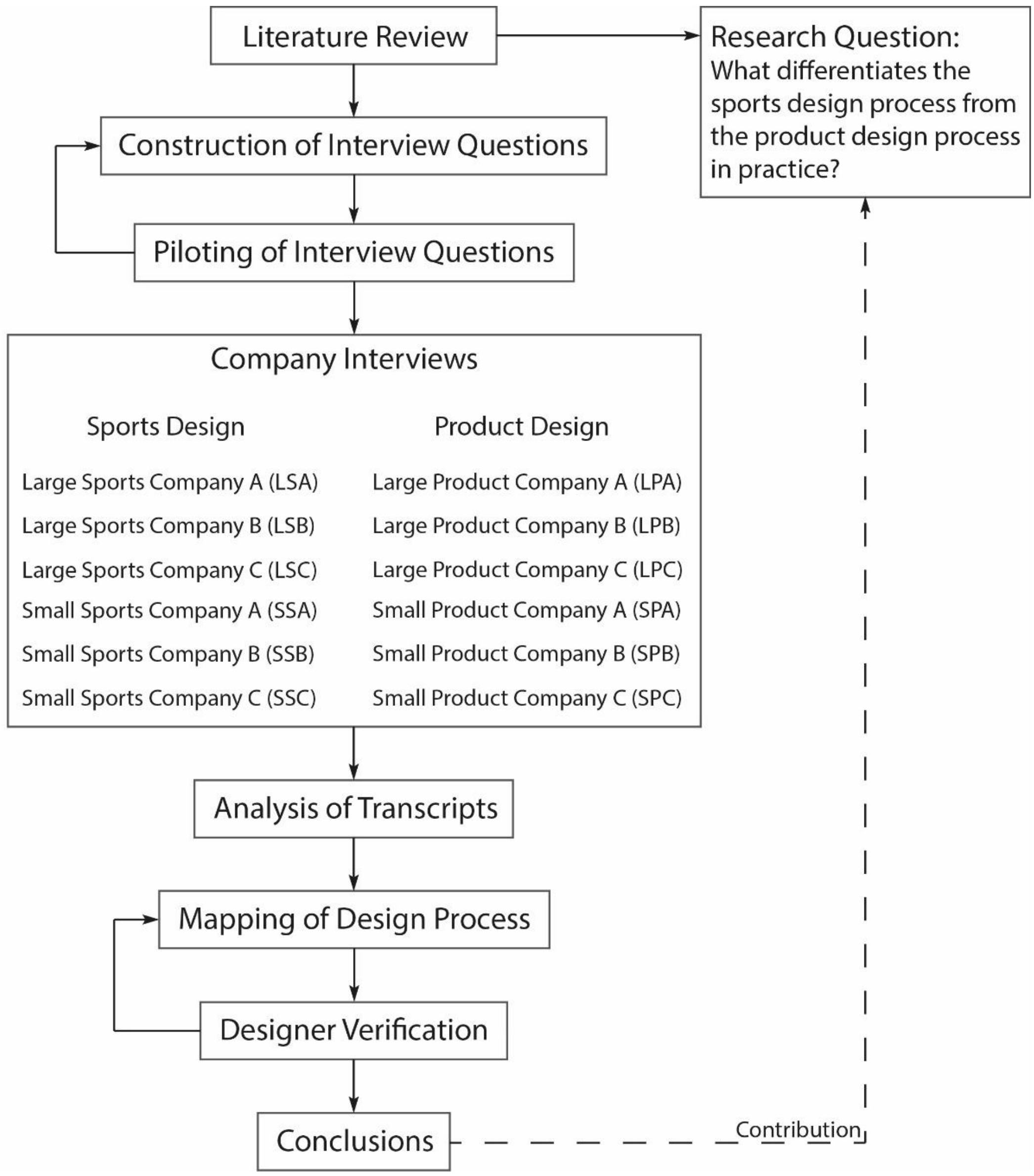


Figure 4.2 - Research approach to the designer interviews

4.1.2. Results

The results section is split according to the four key findings as follows: the design process stages, iterations in the design process, user involvement within the design process and levels of designer involvement throughout the design process.

Design process stages

All designers provided a linear representation of their design process despite no guidance for how to illustrate the process being given. The core stages of the design process for each of the companies interviewed are shown in Figure 4.3. The terminology used to refer to the core stages of the design process were standardised as a result of analysing the interview data, based on the key activities carried out at each stage. Each of the 12 companies interviewed is listed on the left of the table using the anonymous coding (shown in Figure 4.2), with shading illustrating the design process stages that were present within the design process for each company. Sports companies are shown in darker shading, with product companies shown with lighter shading.

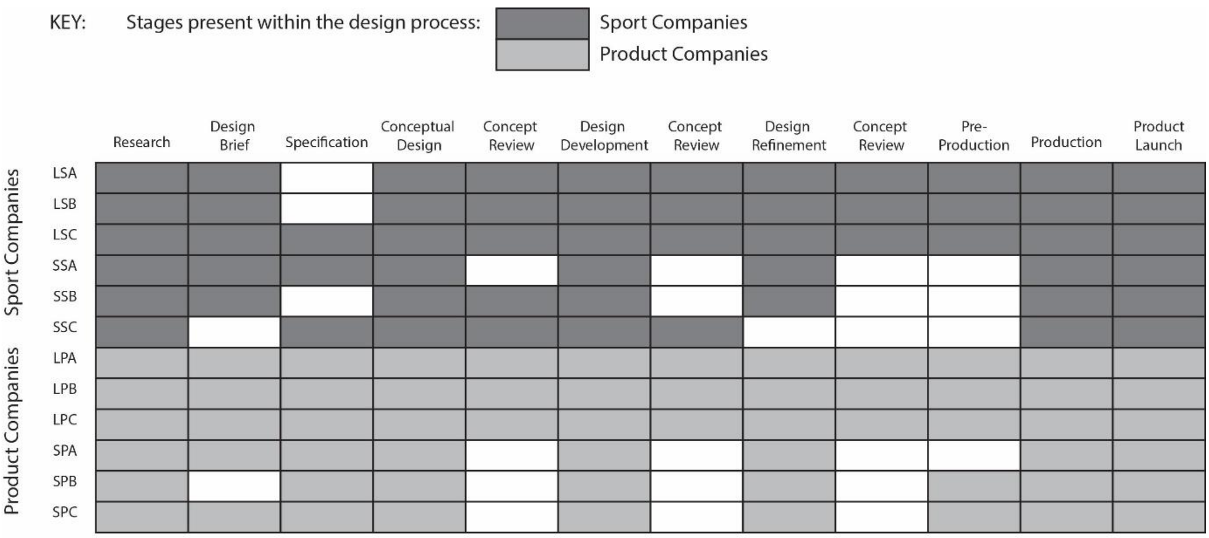


Figure 4.3 - Standardised design processes for companies

All large companies were able to provide a detailed explanation of their design process – LPC stated:

> *"In terms of an overall process, we do have quite a structured approach we follow".*

All large companies reported multi-disciplinary working with good communication between teams involved in the design process. LPB was the only large company not to have a formalised design process. However, the stages followed throughout the design process were clearly identified and did not vary between projects. Of the smaller companies, only SSA followed a structured, formalised design process and was the only company interviewed that reported following a published design process – the Lean 6 Sigma DMEDI methodology. The remaining small companies described their design process as "ad-hoc". Small sports companies showed more consistency and structure than small product companies – a designer from SSB reported:

> *"It's much more ad-hoc with us, but there is some structure to it (the process)."*

This was in comparison to the small product companies that reported greater variations within their design process between projects, although many of these variations are likely due to variations in the scale of the project.

Timescales for the design process were consistent for large sports companies, taking 1 ½ - 2 years from project initiation through to product launch, while large product companies and all small companies showed more variation between project timings, ranging from weeks in product update projects to 2 years or longer for new design projects – LPC stated:

> *"There's a fair degree of variation… things that affect the length of time are complexity of the product, type of product".*

All companies produced their own design briefs and/or specification with the exception of SPC which was a design consultancy, although some communication was reported between the designer and the client depending on the project. The designers themselves were only involved in the formation of the brief within the small sports companies, where data informing the brief was collected by the designers. All large companies produced a written design brief, with product companies providing an additional specification, although LPB reported lacking the detail in the specification that was reported by other large companies. None of the small companies reported producing a detailed brief, with communication being predominantly verbal. All small product companies added that their design briefs lacked detail:

> *"We get a Power Point with maybe 6 bullet points on it"* (SPA).

Data included in the design brief varied between companies but market need, competitors, technology and performance targets were often included.

All large companies carried out a pre-production stage to assess quality before mass production – an initial batch was produced to ensure quality was consistent when producing in high quantities. Although SPB and SPC showed a pre-production stage within their design process, this was for the purpose of building one complete working prototype rather than batch producing parts to test for quality.

Iterations in the design process

All companies reported iterations within design process stages – typically two to three iterations were common within each design process stage and were predominantly reported in the design development and design refinement stages. Figure 4.4 illustrates iterations within the design processes of each company. Shading represents the design process stages present within each company (as shown previously in Figure 4.3), with darker hatching illustrating reported iterations within design process stages. For sports companies, it was emphasised that iterations within the design development and design refinement stages were due to repetitive prototyping, user testing and evaluation to ensure that the product met the performance requirements of the athletes. Product companies also reported iterations within these stages of the design process where designs were refined and tested – in the case of product companies, testing was often mechanical rather than focusing on usability. Small product companies reported that the number of iterations within design process stages was often inconsistent between projects.

Sports companies reported that iterations between design process stages were extremely rare – no backwards iterations between design process stages were reported by any of the sports companies. In contrast, product companies reported that in some projects, problems could result in significant back-tracking through the design process. These backwards iterations within the design process are represented with arrows in Figure 4.4. Backwards iterations were found to be more common within small product companies compared to large (only LPB showed iteration between the first concept review stage and concept generation for large product companies).

All large companies included a fixed number of design review stages within their design process, where project progress was reviewed and stakeholders within the company (management, clients, designers, etc.) were involved in making major design decisions. These formalised review stages were uncommon in small companies. SPA and SPC reported occasional review meetings with management although these were not a formalised part of the design process and occurred infrequently and irregularly. As a result, last minute design changes were common due to a lack of communication with clients and were often problematic – SPB reported:

> *"You'll be quite far down the road when management say, what if we add this? Well we don't really have space any more".*

These changes were reported to result in projects running over-time with additional costs incurred, resulting in the backwards iterations within the design process for the product companies.

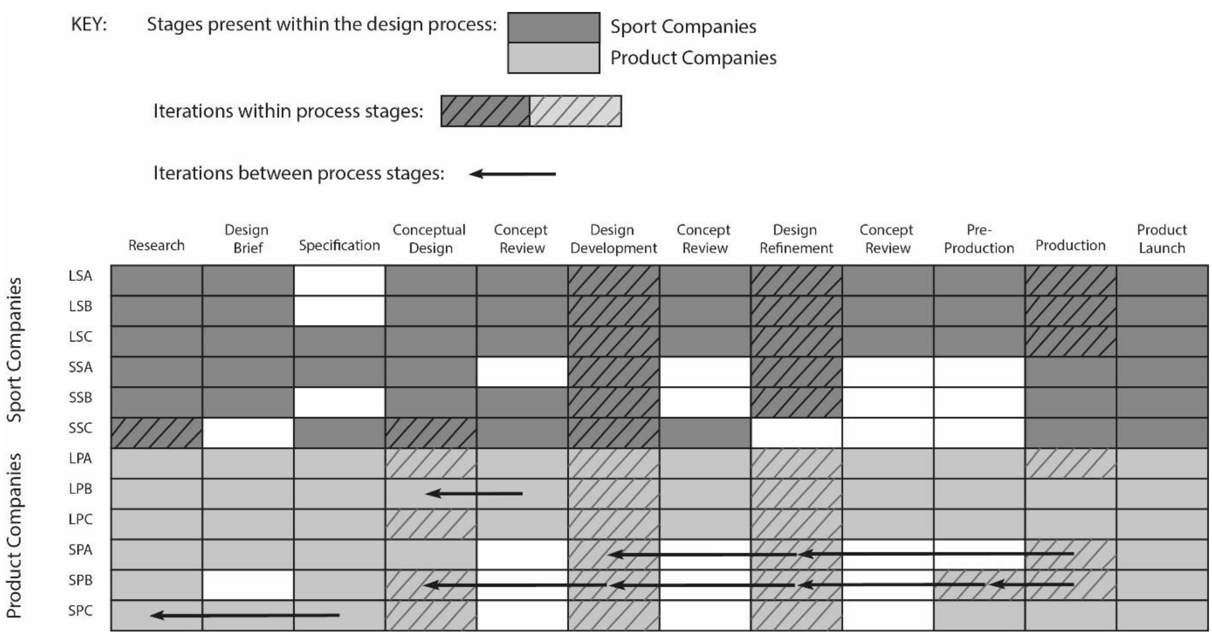


Figure 4.4- Iterations in the design processes for companies

User involvement

Figure 4.5 illustrates user involvement within the design process for each company, with shading highlighting areas of physical user involvement reported by the designer – darker shading represents the sports companies, while lighter shading represents the product companies. It should be noted that there were other areas within the design process where the results gained from user involvement were highly influential in design decisions made, particularly at the design review stages. These are not shown within Figure 4.5 as the users themselves were not physically involved.

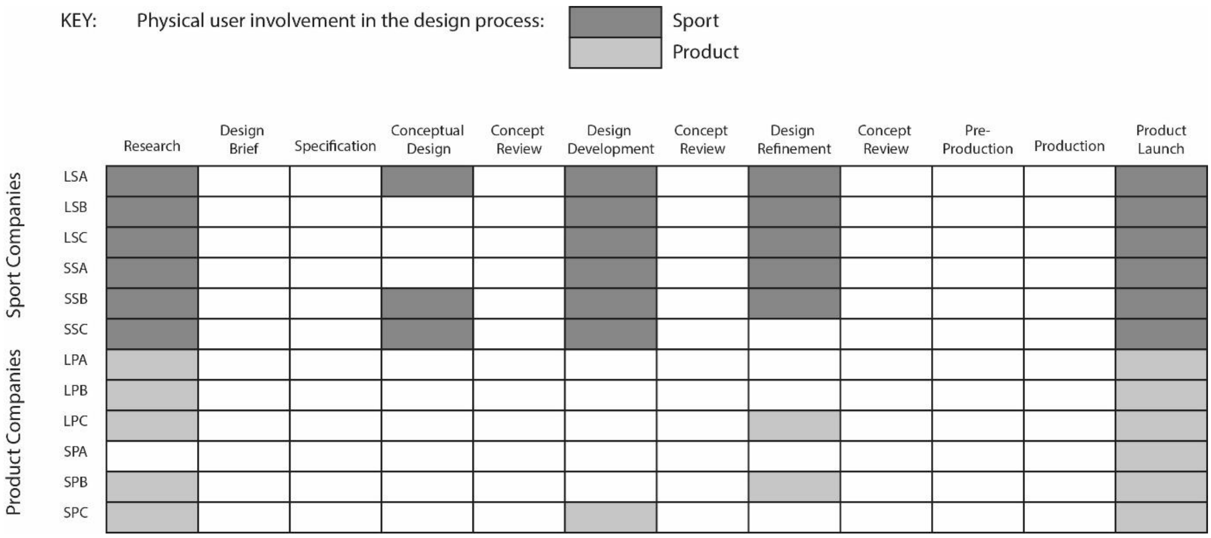


Figure 4.5 - User involvement in the design processes for companies

User needs played a key role throughout the design process for sports companies. User feedback, focus groups with athletes and coaches and observations were commonly adopted in the research and early conceptual design stages by all sports companies. More formal product/user testing was carried out extensively during the later design development and refinement stages to test products for durability, wear, comfort, fit and performance, with user testing key in determining the performance success of the product. Assessing the performance of the equipment when in use by the athlete was central to the sports design process, rather than testing the equipment alone in isolation. All sports designers regarded the equipment and the user as a system, emphasising that the user and equipment had to work together to ensure sporting success. One sports designer commented:

> *"You don't touch the equipment alone – you touch the system that you and the equipment build together".*

Consideration of competitor products was also essential for sports companies in the early stages of the design process to assess performance characteristics and customer preferences.

In contrast, user needs were not as dominant a consideration within the design process for the product companies. User information was often collected in the early research stage with most product companies not involving the user again until feedback was received on the finished product. User involvement methods reported by product companies included focus groups and feedback on the company's own previous products and competitor products, with this information often provided to the designer as secondary data, collected by marketing departments or external companies. Only LPB reported physical interaction between the designer and the user in the research stage to provide feedback to the designer on previous products. However, this was not carried out at the start of every project, with LPB stating that designer interaction with the user was typically carried out on an annual basis. Secondary user information was used for the remainder of the company's projects. LPA and LPC both reported involving the user at design refinement – however, this was reported to be at the end of the design refinement stage once a near-finalised prototype had been developed and did not occur in every project. Only SPC reported involving the user during design development, but this varied depending on the project. LPC stated that the user was at the heart of their design process although this was not reflected in the level of user involvement within their process – designers and technicians often simulated product use themselves rather than involving the user.

Figure 4.6 illustrates the levels of user involvement within the sport and product design processes with the sports companies reporting user involvement within process stages shown in red and product companies shown in blue. There is a significantly higher level of user involvement shown throughout the sports design process compared to that of the product design companies. The most significant difference in the levels of user involvement is within the design development stage, where sports companies reported early prototyping to allow user testing to occur earlier in the design process.

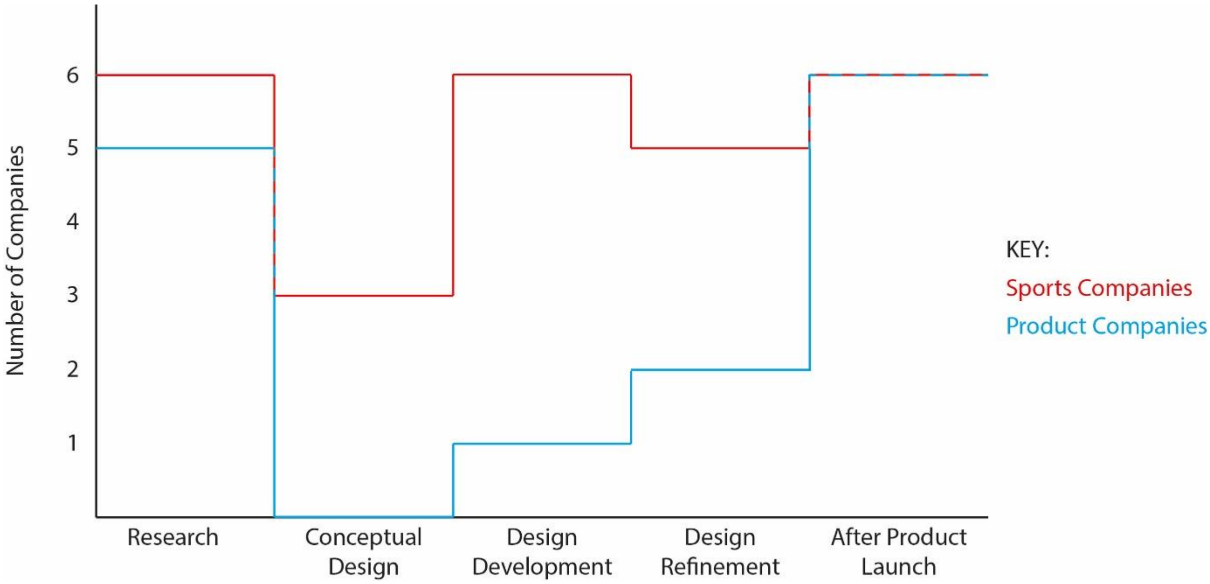


Figure 4.6 – Comparison of user involvement within the sport and product design company processes

Prototyping early was important in all sports companies to allow user testing to occur early, resulting in two to three iterations within design process stages. Many sports companies reported producing mock ups in the early conceptual design stage, with extensive user testing of these prototypes beginning in the early stages of design development. In contrast, the product companies focused mainly on early CAD work with physical prototyping carried out later in the design process, often during the design refinement stage. LPC was the only product company to report producing functional prototypes early at the conceptual design and design development stage, although this was reported to assess product functionality rather than usability. Other product companies prototyped individual mechanisms during design development to test functionality, with full product prototyping occurring towards the end of design refinement or into the pre-production stage.

Designer involvement

Designers within all sports companies had an extensive understanding of the sports they were designing for (many participated in their sport to a high recreational level) with all reporting that this aided their understanding of the performance requirements that their products should meet. Design decisions within all companies were mainly subjective, with designers often relying on their own experience and intuition to progress the project.

As discussed earlier in this section, user needs played a key role in the design processes for all sports companies with designers directly involved with users throughout the design process. Sports designers were regularly involved with athletes (both recreational and professional) as well as coaches. This primary data was reported to provide them with valuable insight into the requirements of sporting equipment. In contrast, the user data received by designers within the product design companies was often secondary. In reference to user data which was often collected by the marketing department, the designer from SPA reported:

> *"Nothing goes directly to me at all".*

Data received by product designers was often mechanical or functional, stating performance requirements, with little data regarding the user or product usability. LPB was an exception, where designers were involved in some informal discussions with customers during the research stage, although as previously reported, this occurred on an annual basis rather than on every project.

Designers within the small sports companies were involved in all stages of the design process and all aspects of the company due to company size. This involved creating and defining the design brief, interacting with athletes and coaches, and meetings with suppliers and manufacturers.

4.1.3. Discussion

This section discusses the results of the interviews conducted with designers from sports and product design companies in response to the research question – **what differentiates the sports design process from the product design process in practice?** This section firstly discusses the similarities observed between the sports and product design processes before discussing the differences that were observed. Sections 4.2 and 4.3 within this chapter present and discuss the results gained from the two other methods within the triangulation approach.

Similarities

Only SSA reported following a published design process – the Lean 6 Sigma DMEDI methodology. None of the other companies interviewed in this research reported following a published design process model, which is in agreement with Costa, et al. (2015), who reported on a lack of uptake of many published design models due to a lack of guidelines and support to implement them. The remaining companies interviewed in this research adopted many of the same common core stages of the design process, with the design process tailored to the needs of the company and the nature of the design project. This aligns with findings by Maffin (1998), who reported on many design practitioners developing their own processes that take into account company constraints and highlights that within industry there is a lack of a formalised design process specific to sports design being implemented.

Figure 4.3 illustrates the core stages of the design processes for each company, which show little variation between companies. This is in agreement with findings by Gericke and Blessing (2012) who concluded that design processes have similarities across disciplines in terms of their core stages. The standardised terminology of the core stages of the design process also aligns with many of the design process models discussed in Section 2.3.3 of Chapter 2. All companies included a concept generation stage, although the time allocated to this stage was dependent on whether the project was a new product design or existing product development – in many cases, companies reported their projects to be existing product development, which is in agreement with findings from Margolin (1997), who reported the majority of design work to be the redesign of existing products. It is therefore concluded that the sports design process follows the same generic high level design process as many other design disciplines.

Differences

As both large and small companies were involved in this study, differences between the two are briefly discussed here. The remainder of this section focuses on answering the research question, identifying the differences between the sport and product design processes.

Large v small companies

All large companies followed similar structured design processes where designers were aware of the design process and their role within it. It is anticipated that this is due to large companies being more established, with a need for structure due to company size. The literature also reports on the benefits of following a design process, with companies that do so often being more successful (Costa, et al., 2015). Although SSA also reported a formalised design process, it lacked the detail of the larger companies. The remaining smaller companies did not adopt a formalised design process, potentially due to the perceived time and resources required to do so.

Notable differences between the companies involved in this study include the use of formalised design review stages within large companies, which were not formalised within the design processes of small companies. Review stages were reported throughout the design process by large companies, occurring after conceptual design, design development and design refinement stages where stakeholders within the company were involved in making design decisions. It is expected that review stages were found in larger companies due to a greater number of people involved in the design process, therefore increasing the need to ensure communication throughout the design process between teams. Infrequent review meetings were discussed by some small companies when making design decisions, particularly when management and production were based out with the design department, although these meetings were rare. It is suggested that more frequent, structured review meetings would likely reduce the number of issues raised later in the project (as discussed in the previous section, suggestions raised by management late in the design process were difficult to accommodate), reducing costs and preventing projects running over-time as was observed in many of the small product companies.

It was reportedly common practice for designers within the same company (for small product companies) to follow different design approaches. This resulted in an increased number of unplanned iterations, duplication of work and poor communication. It is recommended that to improve efficiency within small design companies a more structured approach to the design process is needed and should be understood by stakeholders throughout the company. However, it can be argued that the design processes followed by large companies are not appropriate for use within small companies, due to limited resources, smaller teams and as observed in this study, a lack of structure. Maffin (1998) highlighted that many design processes do not consider variables such as quality and availability of resources, designers and managers. It is therefore suggested that there is a need for more research into the design processes of small companies to develop a greater understanding of their design processes and reasons for not following a more structured approach.

A pre-production phase was present in all large companies to determine moulds and refine the factory process. This was not observed within smaller companies, with the exception of SPC and SPB who reported one test manufacture run at the end of design refinement. However, all small companies reported communication with manufacturers prior to production, during the design refinement stage to select tooling, etc.

<u>Sport v product companies</u>

There were three distinct differences observed between the sport and product design processes – user involvement, iterations in the design process and designer involvement throughout the design process – which are discussed here.

User involvement

Figure 4.5 illustrated areas of physical user involvement within the design process highlighting a greater inclusion of the user within the design process by sports companies compared to product companies. It should be noted that these results illustrate user involvement as indicated by the designer, rather than formalised company practice. With the exception of SPA, all companies considered the user within the initial research stage, although with considerably less emphasis on user needs and abilities within product companies compared to sports companies. Considering the user in the early stages of the design process allows the greatest potential for user information to inform the project (McGinley, 2012). This lack of emphasis on understanding the user by the product companies therefore risks the needs of the user being left underexplored in the design process.

Within sports companies, the user was often heavily involved throughout the design process. User involvement methods varied within the early stages of the design process for sports companies but included athlete observation and feedback, game analysis, surveys and focus groups. Only SSB included the customer in the conceptual design stage to aid the selection of concepts, which were then developed further by the company with changes made to style, materials and aesthetics. User input played a key role during the design development and refinement stages for sports companies with methods including field testing, play testing, observations and biomechanical analysis. Physical prototyping was important for all sports companies, with the emphasis on producing prototypes early to allow user testing to be carried out early, resulting in two to three planned iterations within the design development and refinement stages. It is argued that without extensive user testing and prototyping occurring early and throughout the design process, it would become increasingly difficult for sports designers to ensure that products were meeting the performance requirements of the athlete. Sports companies viewed the user and the product as a system – both had to work together in order to be successful. All sports companies emphasised that a product producing good test results in isolation would not necessarily be a viewed as a "good product" when being used in context by the customer. This agrees with findings from the sports design literature review, where the interaction between the athlete and the equipment is discussed extensively. Sports companies interviewed as part of this research agree with these findings, in addition to adding detail on how and when this user testing occurs within the design process.

In contrast, product companies reported low levels of user involvement throughout the design process with the designer rarely collecting primary user data. User involvement methods within product companies included focus groups, feedback on the company's own previous products and feedback on competitor products, with this information often provided to the designer as secondary data – only LPB reported direct interaction between the designer and the user, on an annual basis rather than per project. The benefits of user involvement throughout the design process are discussed in the literature review of this thesis, as designers themselves are unlikely to have the skill set or experience to design for the wider population (Wilkinson & Angeli, 2014). User involvement at the start of the design process can inspire the designer but this requires the designer to be actively involved with the user – the product companies interviewed as part of this research reported a significant lack of designer engagement with the user. Instead, most product companies focused mainly on early CAD work with prototyping predominantly assessing mechanical functionality rather than usability. Although both LPC and SPB included the user at the design refinement stage to test developed prototypes, there was little scope for design changes at this late stage without impacting project costs and timescales. In contrast, sports companies placed emphasis on the user earlier in the design process and received continuous feedback, resulting in few issues raised in the later stages. While there are many factors that affect product success, it is likely that in some cases where backwards iterations were reported in the product company design processes, this may occur as a result of the product failing to meet user needs, with these problems only identified in the later stages of the design process.

Sports companies received additional input from professional athletes throughout the design process, particularly during early research and design development stages. This professional input was considered to be separate from that of the standard user as the professional athlete has a deeper understanding of the sport, the equipment and the performance requirements needed to improve their game. However, it should also be noted that the professional athlete is not a paying customer, therefore while their input was highly beneficial in terms of performance requirements, the recreational user should also be included to inform design decisions. In contrast, there was no “professional” involvement in the product development process to influence design decisions relating to user/product interaction. Although it can be argued that everyday consumer products do not have the same performance requirements as sports products, there is still the need to develop a product that is compatible with the user that will improve overall usability and product experience. It is suggested that many consumer products will have an equivalent of a “professional” user, who would use the product more often and with more experience than the standard user.

Although no sports company reported involving the user at the design reviews themselves, all sports companies stated that user requirements were central to these reviews, with results from user testing discussed extensively and informing decisions made. The results of user testing were also key to the small sports companies in terms of decision making throughout the design process although unlike the lager sports companies, the small sports companies did not formalise these review stages.

Iterations

The design process for large sports companies included a fixed number of review stages and typically two/three planned iterations within process stages with additional iterations reportedly rare for all sports companies. Additionally, sports companies also only reported iterations within design process stages, with backwards iterations rarely occurring between stages. While it can be argued that there are many factors which could influence this forwards only progression through the design process, this research suggests that the continual involvement of the user throughout the design process and the use of early prototyping and testing, may play a role in ensuring that a project progressed with minimal disruption. It is also suggested that the continual reviewing of project progress against user needs and performance demands ensured that sports projects iterated within process stages to ensure design requirements were met and would not progress onwards until all stakeholders were satisfied.

In contrast, the product companies reported iterations both within and between design process stages. There are extensive reports on the costs associated with making design changes later in the design process – as discussed by Sims (2003) design changes later in the design process can be expensive and time consuming. As previously discussed in this section, there is also an apparent lack of user involvement within the product design process compared to the sports design process, with user testing and feedback informing the decisions made at review stages and prototyping and testing occurring much earlier in sports companies compared to product companies. While there are many factors that could influence iterations within the design process which were not studied here, it is suggested that a lack of user involvement (and as a result a lack of user information on which to base design decisions) may result in some of the re-work between design process stages that was reported by the product companies.

Designer involvement

With the exception of the small sports companies, designers were not involved in the formation of the design brief. Within the small sports companies, designers were involved in all aspects of the business from formation of the brief to designing, marketing and sales. It is suggested that this was due to company size, resulting in designers playing a multi-functional role within their company. In contrast, designer involvement within large sport and all product companies was predominantly focused on designing.

Sports designers were far more involved with the user throughout the design process compared to product designers. While the users themselves were physically more involved throughout the sports design process than the product design process, when sport companies did report user involvement, the sports designers themselves were often involved. In contrast, where the user was involved within the product design process, the product designer was rarely in contact with the user. It is argued that this involvement with the user will give the designer a more informed view of the project, performance requirements of the product and user demands as designers receiving primary data can question, interpret and observe the user in context – Ielegems, et al. (2015) argues that direct user involvement with the designer helps to generate new data, with Dong, et al. (2013) adding that designers who receive a wide variety of user information sources are able to gain a more detailed understanding of those they design for. It is likely that continual designer involvement with the user will result in reduced design alterations later in the design process, explaining the lack of backwards iterations in the sport design processes. In contrast, the user information provided to product designers was often secondary making it harder for designers to understand the initial problem in its context of use and to fully test the usability of the product. While it can be argued that some product designers did complete rigorous product testing involving themselves and technicians, there is still value to be gained from receiving primary user feedback on a product in its intended environment of use.

Additionally, all sport designers played the sport they were involved in and had an in-depth knowledge of their sport. This experience was reported by all sports designers to play a major role in influencing design and decision making, in addition to information gained from the users themselves (both recreational and professional). However, one sports designer reported, “we are not consumers, we are not normal anymore,” emphasising the need for the designer to continue to take into account the paying customer who would need reason to spend money on the new product.

4.2. Analysis of student projects

This section details the analysis of final year sports engineering university student projects. While the findings of the interviews conducted in Section 4.1 reported some similarities with results discussed in the literature, there were deeper insights gained here into the sports design process which have not been discussed before in published work – the sports design process itself, iterations within that design process, the level of user involvement within the design process and the involvement of the designer with the user. This section provides a means of validating the findings of the interviews conducted with the sport and product design companies to ensure that appropriate questions were asked of the designers and the correct conclusions had been arrived at regarding the characteristics of the sports design process. As the students documented all aspects of their project work within reports and folios, this provided a platform to assess an entire sports design project and would complement the results of the sports design processes discussed by the sports designers in Section 4.1.

4.2.1. Methodology

The second stage of the triangulation approach involved the analysis of final year sports engineering university student individual projects. The projects reported the development of an innovative piece of sports equipment from the early research stages through to a finalised product (final prototypes and manufacturing drawings were produced for each project). A total of 17 projects were analysed in this research. Projects were included based on the selection criteria used to select the sports companies for the interviews conducted in Section 4.1 – projects must detail the design of a piece of sporting equipment that will be used directly by the athlete to undertake their sport. Projects that were included in the study covered a range of topics, ranging from the design of a shoe that simulated bare foot running, a training aid for rugby, a badminton training aid and an adaptive snowboard boot.

It is noted that this study intended to assess differences between sport and product design processes in practice – however, students were considered to be representative of the designer population as all were final year students with projects conducted over a 9 month period and contributing towards 25% of final year grades. Students involved in the research had experience working on industry projects (a core part of the course) and were encouraged to undertake industrial placements, therefore had an understanding of sports design practice in industry.

Fundamentally, the outcome of this method was used as a means of validating the observed differences between the sport and product design processes reported in Section 4.1 rather than to identify further characteristics of the sports design process. As this chapter reports on a study that is descriptive of industry practice, changes were not made to the key characteristics of sports design practice identified in the initial set of company interviews based on the analysis of the student projects. If differences had been observed between the results, the designer interview transcripts would have been re-analysed and more work potentially undertaken.

The analysis of the student projects involved a number of stages to analyse the results presented in the student reports and folios. This included developing descriptions of the design processes followed, identification of the justification provided by the students for using the selected design process, details of the activities undertaken at each stage of the design process and levels of user involvement throughout the project. The outputs of these activities were then grouped according to the core themes identified from the analysis of the transcripts from the initial company interviews discussed in Section 4.1 – iterations within design process stages, user involvement and designer involvement within the design process. No new relevant themes were identified – the exceptions (discussed in the next section) were purely project dependent.

4.2.2. Results

To allow a comparison between the student projects and company interviews conducted in Section 4.1, the results section will be structured in the same way as before, according to the main findings from the analysis – the design process stages, iterations in the process and user involvement within the process. Levels of designer involvement in the design process are not discussed here as all student projects were individual with activities carried out by the students themselves, therefore are not representative of the levels of designer involvement reported in industry (where designers work as part of a team) and will not be involved in the comparison.

Design process stages

It was found that 10 out of the 17 sports student projects adapted existing design process models to suit the needs of the project. Reasons given for this included: user involvement throughout the design process was not clear in existing models; a clear, structured approach was necessary; more emphasis on testing was required. One project reported:

> *"The (initial process model selected) did not consider the material testing and analysis protocol that would be essential to the success of the project".*

That project then adapted the initial design process model to include an iterative cycle of analysis, testing and prototyping. Another project, which combined two existing design process models stated:

> *"These methodologies (combined) allow continuous consideration of the user at each stage, which will be crucial in developing a user centred product".*

This was representative of many of the projects, where students felt the need to adapt existing design processes to incorporate a user centred focus into the design process itself to allow for user needs to be identified and met. Many of the students stated that they felt the need to increase the emphasis on user integration in the design process, with all projects stating that usability was a key design requirement and that the project itself should be user centred:

"A user centred design philosophy requires user centred research; lots of prototypes are necessary".

Continuous prototyping, testing and evaluation were prominent features for all the student projects.

All the student projects provided an illustration of the design process followed and all again adopted a linear representation. The core stages for each of the student projects are illustrated below in Figure 4.7, with shaded areas representing stages that were present within the design process for each project. It was noted that students were asked to provide a separate design brief document in addition to a product design specification that was included within the project reports. This was a project requirement and therefore not representative of design practice in industry.

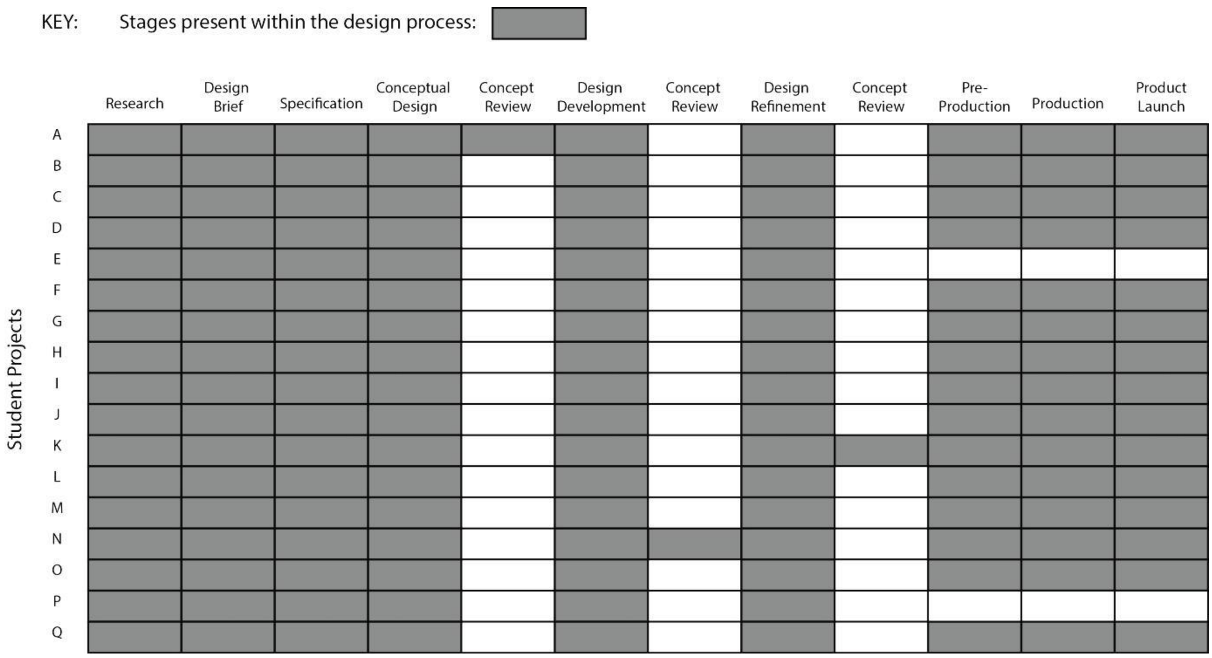


Figure 4.7 - Standardised design processes for student projects

Design review stages were rarely formalised within the design processes followed in the student projects. However, analysis of the reports and folios identified that areas of decision making did occur at the end of conceptual design, design development and design refinement – similar to that reported by the sports design companies. Similar activities occurred between the student projects and sports design companies – decision making was based on user and expert feedback and evaluation against the specification. There were also a number of formalised assessments reported by the students, which occurred at similar stages in the process to the design reviews reported by designers in industry. At these assessments, students were expected to present completed work, discuss future work and justify design decisions made.

Production and commercialisation phases were included in 15 out of the 17 design processes followed by the students. Although the projects themselves did not progress beyond the design refinement stage, students produced a set of manufacturing drawings and considered product production and manufacturing (including methods such as DFMA – Design for Manufacture and Assembly), which were included in many of the projects. Students also included details of business and marketing plans, detailing how the project would potentially be commercialised.

Iterations in the design process

Student reports documented the project activities followed within reports and folios, discussing the developments that were made at each stage of the project. Figure 4.8 illustrates the iterations reported within the design processes reported for each of the student projects. The grey shading represents the design process stages within each project (from Figure 4.7) with the darker hatching illustrating iterations within each stage. All projects progressed forwards through the core stages of the design process – none of the projects reported any major re-work.

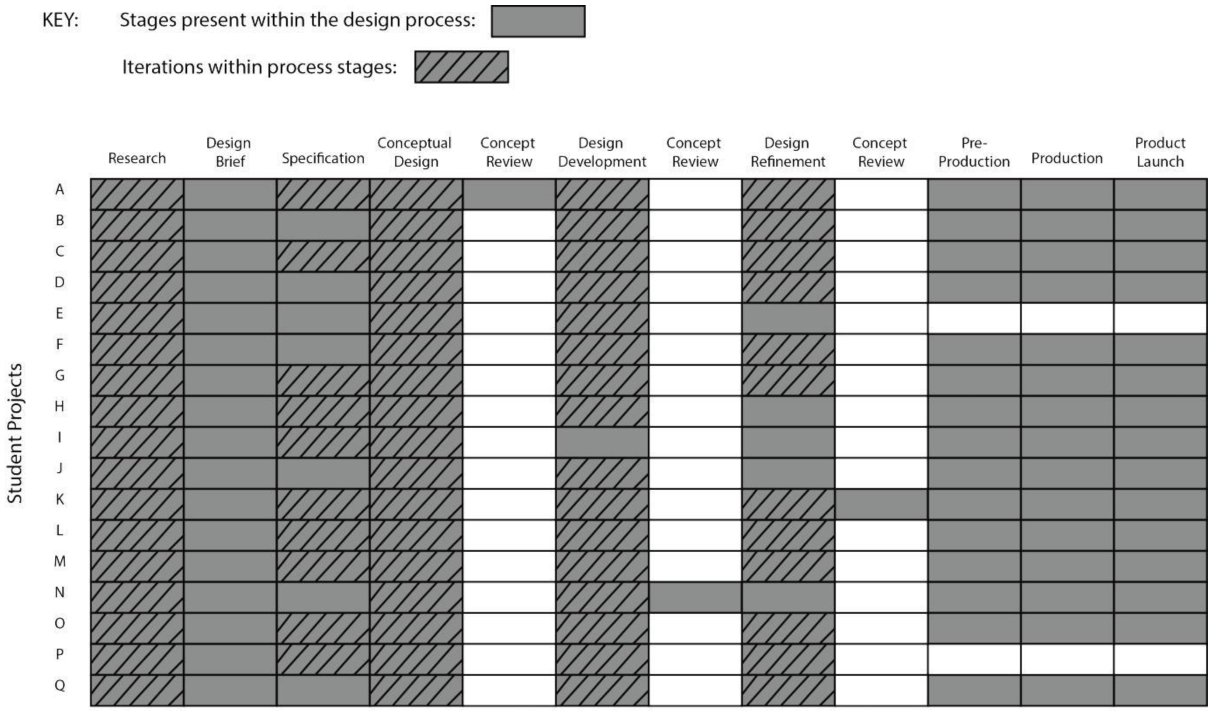


Figure 4.8 - Iterations in the design processes for student projects

Iterations were reported to occur extensively in the concept generation phase for all projects. Methods varied between projects but all reported several iterations of producing large quantities of rough sketches, which were evaluated, developed and reduced to a select number of detailed concepts.

16 out of the 17 projects reported iterations at the design development stage where the chosen concept was developed further, with early prototypes made, tested and evaluated in an iterative process. 12 of the 17 projects reported iterations within design refinement, where prototypes were again developed, tested and evaluated with the user themselves often involved. It is anticipated that the reduction in the number of projects reporting iterations in the later stages of the process is likely due to a lack of time to complete further work – students only had 9 months to complete the project. However, the majority of projects did report on some iteration within the design refinement stage to assess the final prototype.

User involvement

As with sports design companies, the student projects reported high levels of user involvement throughout the project, with design decisions and developments often based on user recommendations and testing results. Figure 4.9 illustrates areas of physical user involvement within each of the student projects, with darker shading representing areas of user involvement within the design process.

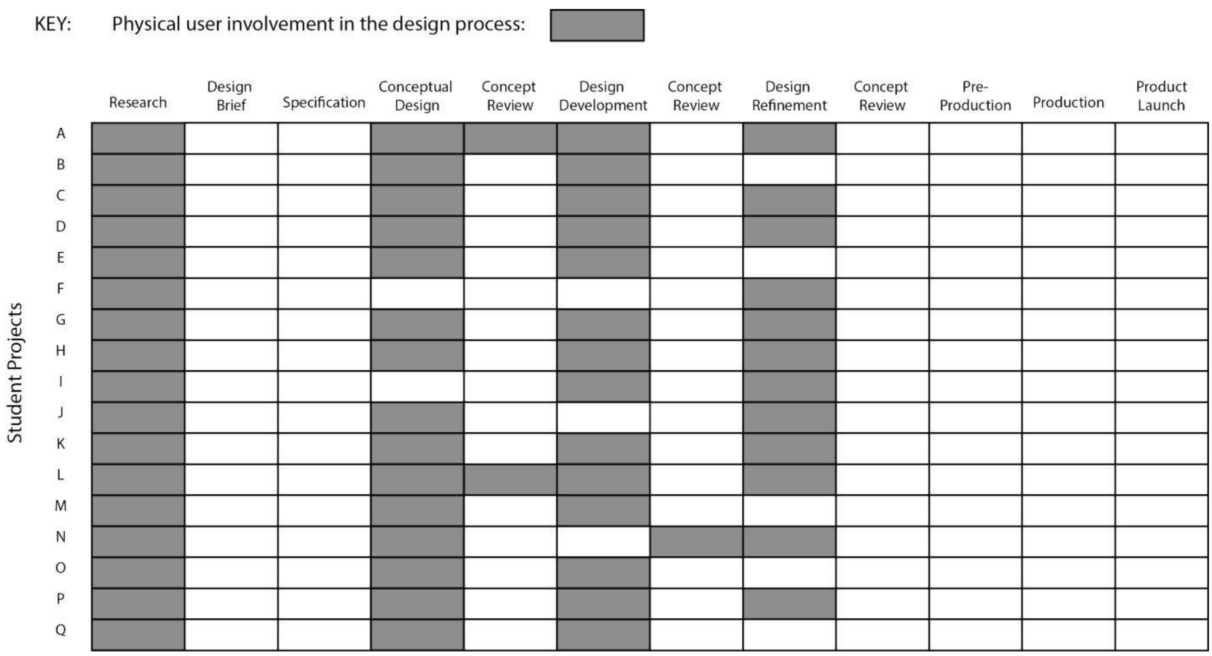


Figure 4.9 - User involvement in the design processes for student projects

All projects reported extensive user involvement in the early research phase, which was used to inform the design brief and specification. Methods varied between projects, but observations, surveys and interviews with elite athletes and coaches were common in many projects. Some early biomechanical analysis was also reported to improve designer understanding of the performance requirements of the athlete and equipment.

It was noted that the students often involved the user at the conceptual design stage – this was in contrast with the sports companies interviewed where conceptual design saw the lowest levels of user involvement. It is anticipated that this is partly due to the design methods taught to the undergraduate students in which some concept generation methods encourage group participation, rather than just the designer themselves. All student projects were new designs, therefore had greater emphasis on the concept generation stage compared to the sports companies. Three of the projects reported physical user involvement within the concept review stages, which was not reported by the sports companies. In the case of these projects, this involvement was in the form of one or two elite athletes/coaches who were involved in the decision making process of which concept should be progressed.

The majority of the student projects reported user involvement throughout the design development and/or refinement stages. No project reported zero user involvement during the design development and refinement stages. Methods of user involvement again varied between projects, but were more performance focused in these later stages – activities typically involved performance testing of the product and biomechanical or motion analysis. No user involvement was reported after the design refinement stage as the projects did not progress through the commercialisation and product launch phases.

4.2.3. Discussion

It is noted that none of the students followed a design process specific to sports design, highlighting again the lack of such a design process. As part of the project requirements, students were required to select a design process to follow – students were familiar with several existing published design process models prior to the project but were also free to choose an alternative design process. There were no stipulations regarding the design process to follow, allowing students' flexibility to find one that best suited their project needs or to develop their own. The adaptation of existing design process models by a number of students emphasises the need for a design process model that captures the characteristics of sports design. It is apparent that the sports design process is highly user focused, with students showing a need to illustrate this within the design process followed in their projects.

In addition to identifying the lack of a sports design process model, the analysis of the student projects also served as a means of validating characteristics that differentiated the sports design process, identified from the sports company interviews. Student projects involved the user throughout the design process, which was highlighted in the discussion of the user centred nature of the design processes the students followed. The design methods used varied between projects but showed similarities to those carried out by sports designers in industry – in the early stages of the projects, students utilised observations, focus groups and interviews, while in the later stages, testing was more focused on product safety and performance in use. Students made use of the resources available at the university, with the use of biomechanical analysis more prominent within the student projects as a result. Students were limited by the resources and timescales allowed to them and it is noted that while full working prototypes were often developed, these were not built to the same standards and quality possible in industry. Unlike the sports design companies, student projects did not involve the user at the end of the process for evaluation, as the projects did not progress into the commercialisation and product launch phases.

It is thought that the emphasis placed on assessing user needs early in the design process and continually referring back to the user for feedback and validation, enabled the projects to progress linearly through the core stages of the design process. It should be noted that given the timescales of the student projects there was not scope for students to carry out the same level of work and detail as reported by sports designers in practice.

It was concluded that levels of designer involvement are not comparable between student projects and industry practice, therefore this will not be discussed in detail. As students worked alone on their projects, all user involvement was carried out by the students themselves, therefore this was determined by the nature of the project and not necessarily reflective of the characteristics of sports design practice.

A number of similarities were observed between the student projects and the results of the designer interviews reported in Section 4.1:

- Similar core stages of the design process (research, conceptual design, design development and design refinement) represented in a linear manner within project reports.
- Like the sports companies, student projects showed iterations within design process stages rather than between.
- The user was vital to all student projects, with emphasis on user involvement throughout the design process – many of the student projects emphasised that the approach followed was user centred. User related activates included initial

interviews, questionnaires and focus groups with extensive prototype testing later in the process, which aligned with many of the methods reported by the sports design companies.

- Product testing was a core part of the student projects, validating the design solution in terms of improvement to performance. Students prototyped early to allow user feedback on design ideas. Sports companies also reported early prototyping and an iterative process of prototype development, testing and evaluation.

A number of differences were also observed:

- Student projects did not progress beyond the design refinement stage (although consideration was given to manufacturing processes and product promotion) due to the nature of university student projects.
- Design review stages were not formalised within the student design processes although key activities (reference back to the design specification and justification of design decisions) in addition to some formalised assessments were recorded at the end of conceptual design, design development and design refinement that were in line with the activities of the design reviews undertaken by sports companies at the same stages in the design process. It is also noted that student projects were individual and not completed as part of a design team.
- Greater emphasis was placed on the conceptual design stage in student projects, as all were new product development projects. In practice, very few projects are new product developments (Margolin, 1997), with many being developments of existing products, resulting in less emphasis on conceptual design.

The differences observed between the sports student projects and sports design companies are a result of the specific nature of the student projects rather than differences in the characteristics of sports design practice observed between the two methods. The core similarities between the projects and industry practice (the core stages of the design process, the iterations between stages, high levels of user involvement throughout, and emphasis on early prototyping) were observed within both studies conducted here, indicating that these characteristics are representative of sports design practice.

4.3. Analysis of the literature

This section documents the analysis of the sports design literature findings against the results from the studies conducted in Sections 4.1 and 4.2. This forms the third part of the triangulation approach followed within this chapter of the thesis, using the results of the three studies to validate the findings from each.

4.3.1. Methodology

Having validated the results of the company interviews with the findings from the analysis of the sports design university student projects to determine the similarities and differences between the sport and product design processes, these results were compared to the findings from the sports design literature (detailed in the literature review in Chapter 2) to allow further validation of the work undertaken within this research and to identify similarities with existing, published work in addition to the contribution to knowledge provided by this research.

Although no research was identified from the literature review that directly compared the sports and product design processes, there is work that indicates characteristics specific to the sports design discipline in addition to what differentiates the sports engineering degree from more traditional engineering subjects – for example: (Muller, et al., 2007) and (Medwell, et al., 2012). These findings from the literature were analysed against the findings from the previous methods conducted in this study to allow validation of the identified characteristics that differentiate the sports design process from the traditional product design process. It was vital that correct conclusions were drawn at this stage to ensure that any further work regarding the sports design process was based on solid foundations.

Results from the literature review were analysed and grouped according to identified categories. These included the aim of the studies, participants involved, key findings and conclusions. The results from the company interviews and student projects were added to these categories (where relevant) and additional categories were identified to accommodate the work carried out in this chapter. This process was repeated with new categories identified and duplicates combined up to a point of saturation. The process allowed identification of areas of overlap between this research and previous work – the identification of areas where the research agrees or disagrees with previous conclusions was a basis for validating the results. New categories that emerged from this research that were not identified from the existing literature indicated new knowledge that had been gained from this work.

4.3.2. Results

Following the sports design literature review detailed in Chapter 2, key themes identified from that literature were combined in a table format. The literature was organised according to paper and the themes identified from each of the papers, as shown in Table 4.2. The literature was organised according to the aim of the paper, the contribution, the sample group within the study (where applicable) and the key findings and conclusions that were gained from the papers.

The overall findings from the sports design literature review are detailed in Chapter 2. This section focuses on the literature relevant to characteristics of sports design and the sports design process, which are summarised as follows:

- The aim of the papers reviewed varies significantly between studies, including the incorporation of biomechanical analysis in the sports design process, the educational needs of the sports engineering degree and identification of criteria that impacts the sports design process.
- Contributions within the literature that are relevant to this research include the definition of various sports design related terminology, the identification of some of the characteristics of sports design and the proposal of several models that illustrate various aspects of, and interactions within, the sports design process.
- None of the papers reviewed within this literature propose a sports design process model, which captures the sports design process as a whole.
- A combination of both recreational and elite athletes was studied within the literature.
- Key findings that are relevant to this research and were consistent across the literature include:
    - The sports equipment and the athlete must work together to achieve sporting performance.

- The sports equipment (however well designed) can still fail if it does not interact properly with the athlete.
- The development of sports equipment is key to improving sporting performance.
- Sports engineers require a diverse skill set that is specific to sports design and not fully covered in more traditional engineering subjects.
- The sports design process is highly user centred.

Paper	Aim	Contribution	Sample Group	Key Findings	Conclusions
Krueger, et al. (2006)	To describe the aspects of the athlete-sports equipment-system and to model the interaction between athlete, equipment and environment.	1. A model of the athlete, equipment and environment interactions. 2. Definition of the term "sports equipment".	Performance athletes	1. For high quality sports equipment it is important to know the general characteristics, the interaction between athlete, sports equipment and environment and to take this into account at all phases of the design process. 2. The intended effect “improvement of the athlete's performance" is often desired in competitive sports to achieve an advantage. 3. Feedback effects are the functional relationship due to the action of the sports equipment on the athlete and used to evaluate the quality of a design proposal. 5. The precise requirements should be considered in all phases of the design process particularly concerning the product planning, conceptual and embodiment design.	1. All effects have to be considered during the design process of performance orientated equipment. 2. The model can be used to assist the designer of performance orientated sports equipment and support a systematic product design process in sports.
Muller, et al. (2007)	To find measurable criteria that have an impact on the design process.	1. Illustrates the impact of characteristics of sports equipment on the design process. 2. Definition for "sports engineering” and "sports technology".	Leisure sports	Characteristics regarding design and context of use distinguish sports equipment from other products, making them unique in terms of the design task.	Identification of characteristics specific to sports equipment.
Jenkins, et al. (2010)	Introducing the UCD Sports Engineering university program.	1. Sports engineering brings together skills from a range of disciplines. 2. Students have a chance to design research projects that require integration of fundamentals from several disciplines.	Sports engineering students	1. Sports engineering involves interacting with athletes, trainers, sports organisations and equipment manufacturers to develop new and better products. 2. Sports engineering is a link between classical engineering, sports science and medicine and sports equipment. 3. Sports engineers design and develop technology to solve the user's problems or to enhance the user's performance. 4. As athletes have searched for improved technology and equipment to better their performance, the need for sports engineering has grown.	1. Sports engineering brings together skills from a range of disciplines. 2. Students gain practical experience to address the design of sports materials, equipment and technology.
Medwell, et al. (2011)	The development of a GUI to interactively present the trajectory of a lawn bowl.	The skills that are introduced in this paper may readily be applied to a range of other sports engineering applications.	Sports engineering students	1. There are skills that are specifically required for sports engineers - sports engineers deal directly with athletes and coaches.	The paper aims to incorporate skills in GUI development in to undergraduate sports engineering programs.

Paper	Aim	Contribution	Sample Group	Key Findings	Conclusions
Muller (2011)	To enrich the technological approach of product design in the field of leisure sports with the potential to quantify selected aspects of human behaviour and motion tasks.	1. A model that identifies understands and describes the different instances of sport and their interrelations. 2. A prescriptive model that includes various aspects of the nature of sport in connection with the characteristics of sport technology. 3. Definition of "sports technology".	Leisure sports	1. Sports technology can be viewed as an extension of the athlete's body, enabling a fusion of human and object, allowing for the spontaneous generation of new movements. 2. Compared to the design of other technological products, the emphasis on the athlete's behavioural aspects is of unique importance in the context of sports technology. 3. Sports equipment should facilitate and/or increase performance - the fusion of the human body and sports technology is integral to these sports. 4. Despite the advances in sports technology, the sports activity is still performed by the athletes themselves and it is the athlete who utilised sports technology in the mastery of his sport.	1. Functionality is the most important characteristic of sports equipment. Usability of products is important in the athlete's point of view. 2. Little information has been published referring to the design process of sports technology manufacturers. 3. The main objective in the development of sports technology for competitive sports is to increase performance.
Wodehouse, et al. (2011)	Challenges of developing a cross-departmental curriculum for an integrated sports engineering degree.	1. Skills required by undergraduate sports engineers. 2. Example of Sports Engineering degree structure at University of Strathclyde.	Sports engineering students	1. Sports engineering is an emerging cross-disciplinary sector. 2. Sports engineers cover skills including physiology, anatomy, biomechanics, product development, mechanical, manufacturing, production operations and management techniques.	Sports engineering is increasing in popularity and courses should provide students with a balanced curriculum.
Medwell et al. (2012)	The suitability of sports literature for educational purposes is not clear - sports engineering requires a clearer definition and examples of suitable teaching material.	Examples of teaching material used in Australia's first Sports Engineering degree program.	Sports engineering students	1. Sports engineering programs typically incorporate aspects of existing courses in the broad fields of mechanical and electronic engineering, with other skills that are specifically required for sports engineers. 3. The specialised field of sports engineering requires a diverse range of skills to be developed, including some unique to this discipline. 5. Despite the recent growth of sports engineering as a field, there is a distinct lack of such reference texts.	Students will benefit from the development of computer graphical user interfaces, which are seldom taught in other subjects.

Table 4.2 - Summary of literature review findings

The results from the literature review were combined with the findings from the sports company interviews and sports engineering university student projects discussed earlier in this chapter to identify similarities and differences in the findings. The results were linked according to the core themes and categories identified from the sports design literature analysis, with additional themes added from the analysis of the results of the work undertaken within this chapter. The complete analysis of the results of this triangulation approach is shown in Table 4.3 – a visual breakdown of two selected areas outlined in red are shown in Tables 4.4 and 4.5.

There were a number of similarities observed between the sports design literature and the work carried out within this study, which are summarised as follows:

- There is no evidence of a sports design process published within the literature. In addition, none of the sports design student projects identified a specific sports design process, with many modifying existing design processes to suit the needs of their project. None of the companies interviewed reported following a specific sports design process – the design processes used had been developed over time to suit the needs of the company and individual projects.
- Findings were consistent that sports equipment should aim to improve sporting performance and/or reduce the risk of injury.
- There was agreement across all three methods that the athlete and the equipment must work together to improve sporting performance. The equipment must therefore be tested with the athlete to assess usability and performance – it cannot be tested alone in isolation.
- Findings from this chapter, in addition to the findings of the literature, agree that usability is a key requirement of sports equipment. Student projects reported iterative processes of prototyping, testing and evaluation, while the company's interviewed stated that they prototyped early to allow user testing to be carried out earlier in the design process.

Differences that were observed between the methods included:

- The findings reported in the sports design literature and the student projects focused on both the recreational and elite athlete (although the majority of the student projects focused on performance sports). In contrast, all the sports design companies that were interviewed focused on designing performance-orientated sports equipment.

- Only the published literature discussed the specific skill set of sports designers from an educational perspective and concluded that the range of skills possessed by sports designers differed from traditional engineering subjects. However, details of those skills that are identified and discussed in the literature are corroborated by the company interviews and documented within the student projects. For example: Medwell, et al. (2012) discusses the ability of sports designers to engage directly with coaches and athletes as a skill set possessed by sports designers. The designers from sports companies interviewed within this research spoke extensively of their direct involvement with athletes, while the student projects documented the student's observations and discussions with both coaches and athletes. However, this research focuses on the characteristics of sports designers in relation to the sports design process, rather than in an educational context.
- There are no specific details of the sports design process discussed in the literature – only the lack of it. However, there was agreement across the literature that the sports design process is highly user centred. In this research, both the student projects and sports companies reported a highly user centred design process but additional detail of that process was gained – all followed similar core stages of the design process, reporting iterations within process stages and user involvement throughout the design process.

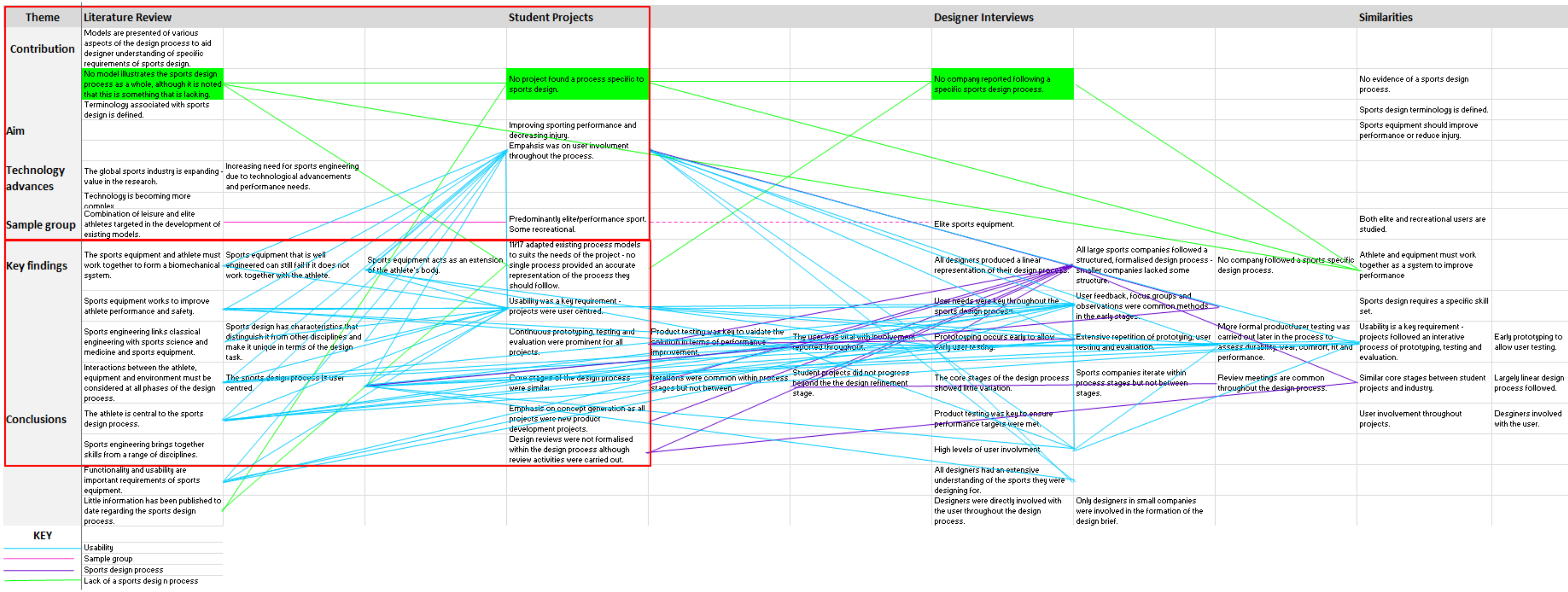


Table 4.3 - Results of the triangulation approach

Theme	Literature Review			Student Projects
Contribution	Models are presented of various aspects of the design process to aid designer understanding of specific requirements of sports design.			
	No model illustrates the sports design process as a whole, although it is noted that this is something that is lacking.			No project found a process specific to sports design.
	Terminology associated with sports design is defined.			
Aim				Improving sporting performance and decreasing injury.
				Empahsis was on user involvment throughout the process.
Technology advances	The global sports industry is expanding - value in the research.	Increasing need for sports engineering due to technological advancements and performance needs.		
	Technology is becoming more complex			
Sample group	Combination of leisure and elite athletes targeted in the development of existing models.			Predominantly elite/performance sport. Some recreational.

Table 4.4 - Results of the triangulation approach: enlargement 1

Key findings	The sports equipment and athlete must work together to form a biomechanical system.	Sports equipment that is well engineered can still fail if it does not work together with the athlete.	Sports equipment acts as an extension of the athlete's body.	11/17 adapted existing process models to suits the needs of the project - no single process provided an accurate representation of the process they should folllow.
	Sports equipment works to improve athlete performance and safety.			Usability was a key requirement - projects were user centred.
	Sports engineering links classical engineering with sports science and medicine and sports equipment.	Sports design has characteristics that distinguish it from other disciplines and make it unique in terms of the design task.		Continuous prototyping, testing and evaluation were prominent for all projects.
	Interactions between the athlete, equipment and environment must be considered at all phases of the design process.	The sports design process is user centred.		Core stages of the design process were similar.
Conclusions	The athlete is central to the sports design process.			Emphasis on concept generation as all projects were new product development projects.
	Sports engineering brings together skills from a range of disciplines.			Design reviews were not formalised within the design process although review activities were carried out.

Table 4.5 - Results of the triangulation approach: enlargement2

4.3.3. Discussion

The triangulation approach involving the comparison of the sports design literature findings against the results from the methods undertaken in Sections 4.1 and 4.2 provides a means of validation of the research findings and highlights the contribution to knowledge gained from the research undertaken in this chapter.

The literature review identified that sports equipment and the athlete must work together to achieve sporting performance. There were multiple reports of this in various papers: Jenkins, et al. (2010); Kreuger, et al. (2006); Muller (2011), which indicates that these findings are valid and a common theme throughout the sports design literature. The methods discussed in this chapter corroborate these findings further. The sports designers interviewed in Section 4.1 all discussed the importance of the athlete and equipment working together as a system:

> *"You don't touch the equipment alone – you touch the system that you and the equipment build together".*

All sports designers regard the success of the sports equipment as resting on how well it works with the user (athlete). The student projects provided further evidence of this as all tested the product in context with the athlete rather than the product in isolation. This research goes further than the existing studies discussed in the literature by identifying that in order to ensure the desired interaction between athlete and equipment is achieved, the athlete is involved throughout the sports design process in a series of iterative prototyping, testing and evaluation. While previous studies have hinted that the sports design process is user focused, Section 4.1 is the first to study the sports design process as a whole and highlight levels of user involvement throughout that design process.

Previous studies have highlighted the importance of the development of sports equipment to improving sporting performance. While this research did not focus on the performance outcome of sports equipment, designers interviewed in Section 4.1 all reported that improvements in performance and/or safety were the desired outcome of sports design projects. This was evidenced by the student projects, where the majority focused on improvements to sporting performance. Those that did not, focused on maintaining current performance levels, while improving safety.

The work conducted in this chapter highlights that the sports design process is highly user centred. This was a key finding observed in the sports design literature and is apparent from the findings of the sports company interviews. The sports design company's provided greater detail than the published literature on the nature of the sports design process, highlighting constant user involvement throughout the design process and the importance placed on meeting user needs at points of decision making in the design process. The student projects also noted the user centred nature of sports design, with the majority stating early on in the project reports that the project would be "user centred". Those that adapted existing design processes did so as they did not feel the level of user involvement and focus on performance were emphasized strongly enough in existing design process models.

A key finding of the triangulation approach discussed here is that none of the work carried out in this chapter identified a design process model specific to sports design practice. As discussed in the literature review (Chapter 2), a systematic literature review was conducted to identify if any such process model had previously been published. Although some papers had published models of aspects of the sports design process, there was no model found that illustrated the sports design process as a whole. None of the sports design companies interviewed in this research reported their company following a sports specific design process. In addition, none of the student projects identified a design process model specific to the design of sports equipment with many feeling the need to adapt existing design process models to represent the sports design process.

4.4. Chapter Findings

This chapter addresses the first research question – **what differentiates the sports design process from the product design process in practice?** The triangulation approach followed in this chapter allows a deeper understanding of the sports design process from a variety of sources and provides validation of results as the input from different perspectives offers a more holistic view than if a single method was used. The result of each method has been discussed separately within this chapter. This section discusses the findings from the three methods together in relation to answering the research question outlined above.

Section 4.1 reported on the interviews carried out with sports and product design companies to identify similarities and differences between the design processes of each in practice. Section 4.2 analysed sports engineering university student projects to validate the findings from those interviews. Section 4.3 collated the results from the previous two methods and compared the findings against published sports design literature. Similarities that were observed validated findings in addition to identifying areas where this research has gone further, specifically by offering new insights into what differentiates the sports design process to the traditional product design approach. The triangulation approach used here ensures validation of the results from the three sources.

There are a number of similarities between the work carried out here and past studies – predominantly the conclusion that sports design is a highly user centred discipline, with user testing and feedback central to evaluating the product. It is apparent that the athlete and the equipment must work together to form a biomechanical system in order to achieve sporting performance, which is a characteristic central to the design of sports equipment.

A number of areas were also observed where the findings from this study go further than the existing literature, highlighting that the work carried out in this research is a contribution to knowledge. This research has investigated what differentiates the sports design process from the product design process in practice – an area that has not been discussed before. This research has provided further evidence that the sports design process is highly user centred but also that the user themselves is physically involved throughout the design process and directly involved with the designer. User needs and the results from performance testing are also central to the design decisions made throughout the sports design process. It was found that the sports design process focuses on prototyping early to allow earlier user testing and feedback. It is suggested that this contributes to the lack of re-work and iteration between design process stages in the sports design process, as continuous user testing reduces design errors occurring later in the process.

This research has also highlights apparent differences in the structure of the sports design process, with sports design showing iterations occurring within process stages but rarely between processes stages. It was noted that there were two to three iterations occurring within stages of the sports design process, to ensure that user and performance needs were met before progressing to the next stage of the design process. In contrast, product companies showed iterations both within and between design process stages with re-work noted as standard practice. This is a further contribution of this research towards what characterises and differentiates the sports design process from the product design process in practice.

It is worth noting that this research highlights the direct involvement of the sports designer with the user throughout the sports design process, while product designers rarely come into contact with the end user in practice. This is in agreement with studies carried out by Bruseberg and McDonagh-Philp (2001) and Goodman-Deane, et al. (2010), where it was found to be common practice for product designer involvement in user research to be limited, with the designer often relying on the client for user information. The literature review (Chapter 2) discusses the benefits of the designer interacting with the user rather than relying on secondary user information, highlighting that it is important for designers to understand those they are designing for (Formasa, 2009) and that abstract, secondary user data does little to inspire the designer (Marshall, et al., 2010). It is interesting that sports companies are aware of the importance of understanding the user and are routinely implementing this in practice throughout their design process, while product designers continue to rely on secondary user data.

This chapter has highlighted the following key areas that answer the research question – the sports design process differs from the product design process by extensive user involvement throughout the design process, early prototyping and user testing, direct designer involvement with the user throughout the design process and a design process that only iterates within process stages rather than between. Based on these findings, the final section of this chapter highlights recommendations for further work.

4.5. Further Work

This chapter has provided the results and discussion to answer the first research question – **what differentiates the sports design process from the product design process in practice?** This has highlighted that there are key characteristics that differentiate the sports design process from traditional product design – user involvement throughout the design process, early prototyping to allow user testing, designer involvement with the user and iterations only within rather than between design process stages. However, despite these differences, there is a lack of a design process model that captures these characteristics.

The lack of a sports design process model was initially identified from the literature review in Chapter 2 – none of the published literature reviewed in this research has conducted extensive work into the sports design process as a whole or defined and captured that process. This is evidenced further by the lack of a sports design process model reported by sports designers across a range of sports design companies. Only one company reported following a published design process model (the lean 6 sigma DMEDI methodology) although not one specific to sports design. All others followed a design process that shared core stages with many existing design process models but had been adapted and developed over time to reflect the needs of the company and individual projects. The adaptation of existing design process models by sports design students reiterates the need for a design process model specific to the discipline of sports engineering as students were unable to find a design process model that captured the needs of a sports design project. It is therefore concluded that there is no existing published model of the sports design process as a whole, although there is a clear need for one that captures the characteristics of sports design practice.

Based on the findings presented in this chapter where the lack of a sports design process has been verified and the characteristics that differentiate the sports design process have been identified, the following chapter will build on these findings and address the second research question: **what is the sports design process?**

Chapter 5 – Development of the sports design process model

Chapter 4 answered the first research question: **what differentiates the sports design process from the product design process in practice?** The work undertaken within the chapter identified that none of the sports companies interviewed followed a specific sports design process, while none of the sports engineering student projects that were analysed had identified a design process specific to sports design – although many had adapted existing process models to meet the needs of the sports design project. The literature review (presented in Chapter 2 and discussed further in Chapter 4) highlighted a lack of published work regarding sports design and concluded that there was no published model of the sports design process as a whole. It is therefore concluded that there is no existing, formalised model of the sports design process as a whole although there is a need for one that addresses the characteristics specific to sports design practice. The benefits of following a design process have already been discussed in the literature review – companies that do tend to be more successful (Costa, et al., 2015) and (Haik, 2003). Chapter 4 concluded that the sports design process differs from the traditional product design process by showing extensive user involvement throughout the design process, early prototyping and user testing, direct designer involvement with the user throughout the process and a design process that iterates only within process stages rather than between.

This chapter will present the findings of Study 2, which will address the second research question: **what is the sports design process?** The study reports on the iterative approach that was taken to identify, capture, evaluate and validate a design process model that is descriptive of sports design practice in industry. The outcome of this chapter and contribution to knowledge is a descriptive sports design process model. It is noted that all developments made to the model throughout this chapter are based on findings of sports design practice and recommendations from sports designers to ensure the characteristics of sports design practice are clearly communicated within the design process model.

The chapter is structured as is illustrated in Figure 5.1 – following the introduction to the chapter and overview of the methodology followed in the study, each of the five steps conducted in the identification, evaluation and validation of the sports design process model are discussed separately, with their own relevant methodology, results and discussion sections. The chapter concludes with an overall discussion of the chapter findings and final conclusions in addition to the identification of further work.

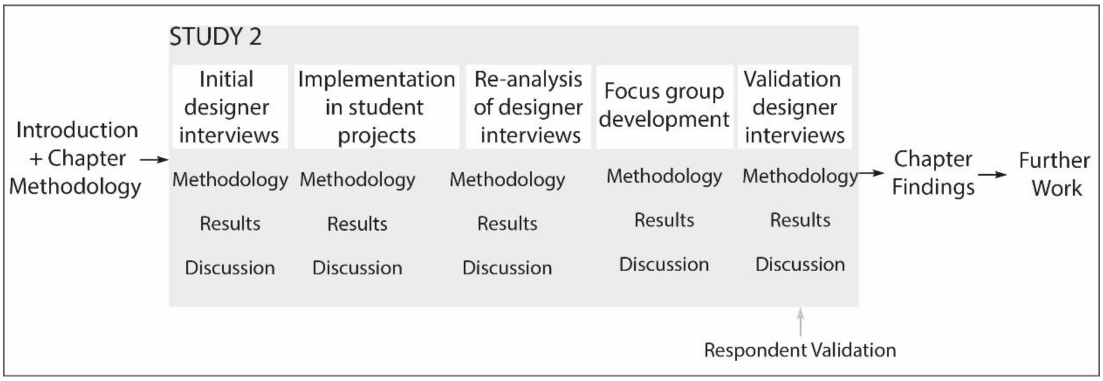


Figure 5.1 - Structure of Chapter 5

This study follows a five-step rigorous approach of identification, evaluation and validation, as illustrated in Figure 5.2. This approach ensures that the outcome is a descriptive design process model, representative of sports design practice and in a format that clearly communicates key characteristics of the sports design process, identified in Chapter 4. The study involves the participation of six different sports design companies (commercially practicing sports designers from each were interviewed) to ensure that the final model is descriptive of industry practice. Companies involved in the study specialise in the design of various sporting products including golf clubs, tennis racquets, running shoes and football boots, targeted at the elite/semi-professional athlete. The academic community were also engaged in the evaluation process to ensure the model was correctly communicated and interpreted. All developments of the model are based solely on feedback gained from sports designers at each stage. Studies involving sport engineering students are used to evaluate the model – developments were made based on interpretations of the visual representation of the process model rather than on student based design practice.

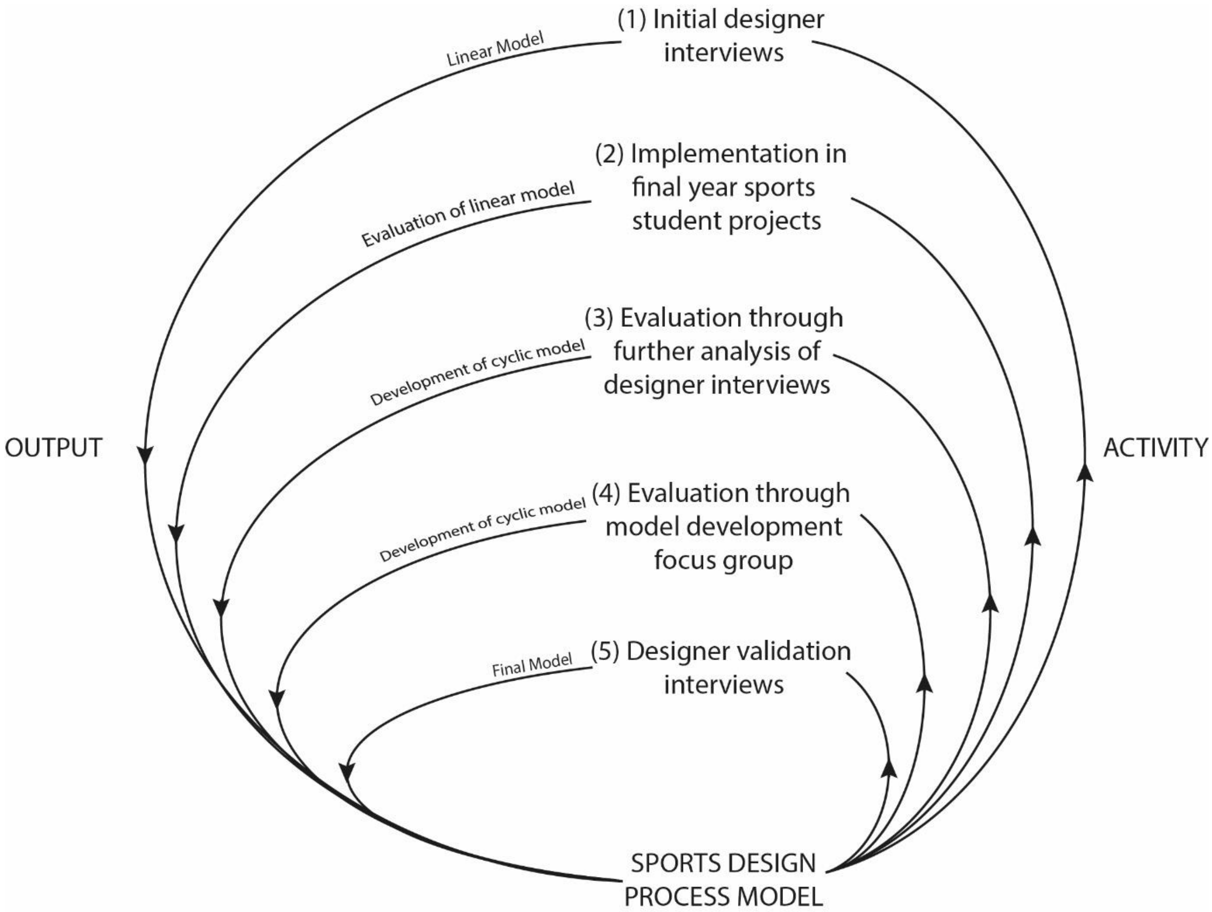


Figure 5.2 - Research methodology for Chapter 5

5.1. Initial designer interviews

The findings of the company interviews described in Chapter 4 that investigated the similarities and differences between sport and product design processes in practice is represented as step 1 in Figure 5.2. Chapter 4 compared the sports design and product design processes and identified characteristics that differentiate the sports design process, in addition to the mapping of the sports design process, produced by each sports designer at the time of the interview. The triangulation approach used in Chapter 4 validated the findings of those interviews (what characterises the sports design process in practice) and forms the basis for the development of the sports design process model, which is discussed in this chapter. Further details of the company interviews are discussed in Chapter 4 – in this chapter, the results of the sports design company interviews only will be discussed, in relation to the development of the sports design process model.

5.1.1. Methodology

Step one (of Figure 5.2) involved the completion of an initial set of semi-structured interviews with six sports design companies and six product design companies to understand the similarities and differences between the design processes of each. This comparison between the sport and product design processes has been discussed in Chapter 4. This section discusses what characterises and differentiates the sports design process specifically in the context of capturing the sports design process.

The interviews conducted with each of the sports design companies aimed to understand their design process, with questions covering topics such as the stages and activities within the design process, methods used and levels of user involvement. Designers were also asked to sketch out their design process, which was used as a discussion point throughout the interviews. Following the analysis of the interview transcripts using a general inductive approach (Thomas, 2006), additional detail was added to the design process models for each company. These processes were returned to the designers for validation to ensure the design process had been correctly captured and interpreted. In some cases, additional information was asked for to ensure the final design process models were consistent for each company in terms of data included. This ensured that key attributes of the sports design process discussed by the designers were captured within the graphical representation of the design process.

The design process models for each of the sports companies were standardised in terms of the terminology used. This formed part of the general inductive approach used to analyse the interview transcripts, discussed in more detail in Chapter 4. The output was a standardised design process model for each of the sports companies, using the same terminology to refer to core stages of the design process. For each company, additional activities and stages reported within that company were added with commonalities identified. This process was repeated until a design process model was produced that was representative of all the sports companies involved in the interviews.

5.1.2. Results

The results discussed here are for the sports design companies only – focusing on what characterises the sports design process. More details on the results from the company interviews (and the comparison between sport and product design companies) are provided in Chapter 4.

Following the coding and analysis of the interview transcripts, the key activities undertaken at each stage of the sports design process were identified. These were used to identify the core stages of the sports design process and allow standardisation of the terminology used to refer to those stages. Figure 5.3 illustrates the core stages of the design processes for each of the six sports companies interviewed. Shading is used to represent stages present in the design process of each company, while darker hatching is used to represent iterations within a stage.

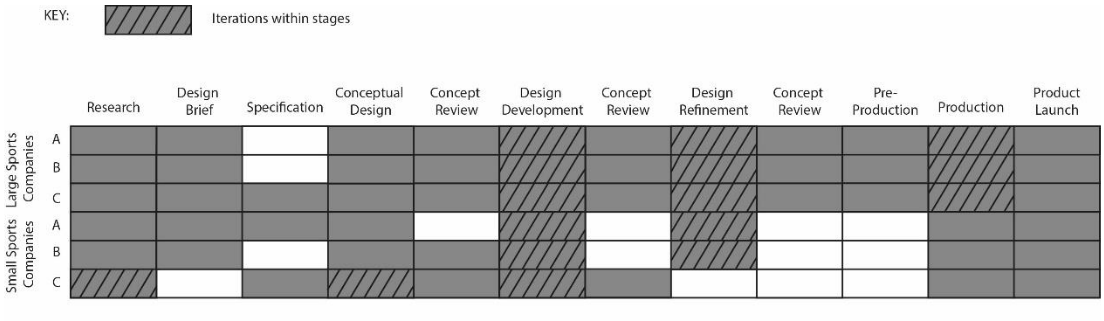


Figure 5.3 – Standardised design processes for six sports companies

None of the companies reported following a specific sports design process – all followed a generic product design process that had adapted over time to suit the needs of the company and the project. The three large sports companies followed almost identical design processes. All included the same core stages and worked to similar time scales of 1 ½ to 2 years. All included design review stages within the design process at points of key decision making. One small sports company showed an unusual process, (small sports company C in Figure 5.3) – it was concluded this was due to the nature of the product, which was assembled from existing component parts. The remaining small sports companies showed similar design processes to the large sports companies, with the exception of second and third design reviews and pre-production stages.

Following analysis of the interviews, it was concluded that the sports design process is highly user centred with the user involved throughout the design process. User involvement in the early stages (research and occasionally concept generation) was typically through interviews, focus groups and observations while in the later stages (design development and refinement), user testing involved more focused performance and wear testing. The users involved in the design process were often elite athletes, performing at the professional and semi-professional level of their sport, therefore they had a good understanding of the performance requirements of their sport. User involvement and feedback heavily influenced the design review process, where user requirements influenced design decisions made. One company quoted in reference to elite athlete input in the early stages of the design process:

> *"He's got specific requirements that he likes… we try and build that into the product".*

It is acknowledged by sports designers that the athlete has a high level of understanding of the performance requirements of their sport (more so than the designer) and it is in the interest of the designer to consult continuously with them throughout the design process to ensure that their needs are met. Sports designers focus on the performance aspect of the product, ensuring the product and the user work together to achieve optimal sporting performance. One company reported:

> *"Our target is to improve the perceived performance of the product".*

This highlights that the emphasis is not just on the technical output of testing but on the subjective feedback of the athlete. This results in high levels of user and product testing throughout the process, with prototyping occurring as early as possible.

The results of the interviews also show that sports companies did not report iterations between design process stages (no stages missed or back-tracking), although there were a number of iterations within the stages themselves (typically two or three). In contrast, the results reported in Chapter 4 found that product companies reported that it was standard practice for iterations and often re-work, resulting in backwards iterations within the design process.

5.1.3. Discussion

An initial linear model of the sports design process (Figure 5.4) was generated based on the standardised individual company processes shown in Figure 5.3. The model was generated based on the following rationale:

- All companies produced some form of design brief or specification. The information included in both showed little variation between companies, therefore both stages were combined.
- All large sports companies reported design review stages after conceptual design, design development and design refinement. Although smaller companies did not formalise this stage, a decision making point was reported towards the end of these core design stages.
- Iterations within design process stages were a feature of the sports design process. Designers reported multiple planned repetitions (typically two or three) of the conceptual design, design development and design refinement stages. However, iterations between design process stages were rare, resulting in a linear representation of the design process with iterations only within stages.
- A linear representation was adopted as a result of all the designers interviewed choosing to represent their design process in this manner, despite no direction being given by the researcher regarding how to represent the design process. It is assumed that this is due to the format that many traditional design processes are represented in, therefore is a format many designers are familiar with.

The linear model of the sports design process (shown in Figure 5.4) is based on the standardisation of the design process terminology and the conclusions drawn above. The square platforms represent the core stages of the process and highlights the iterations within these stages. A design brief and design review stages provide a link between the core stages of the design process.

Whilst there are some similarities between the linear process shown in Figure 5.4 and other conventional product design process models in terms of core stages and representation, there are key differences between the sports design process model shown here and other representations of the design process, including the emphasis placed on user involvement throughout the design process and the iterative nature within the design process stages.

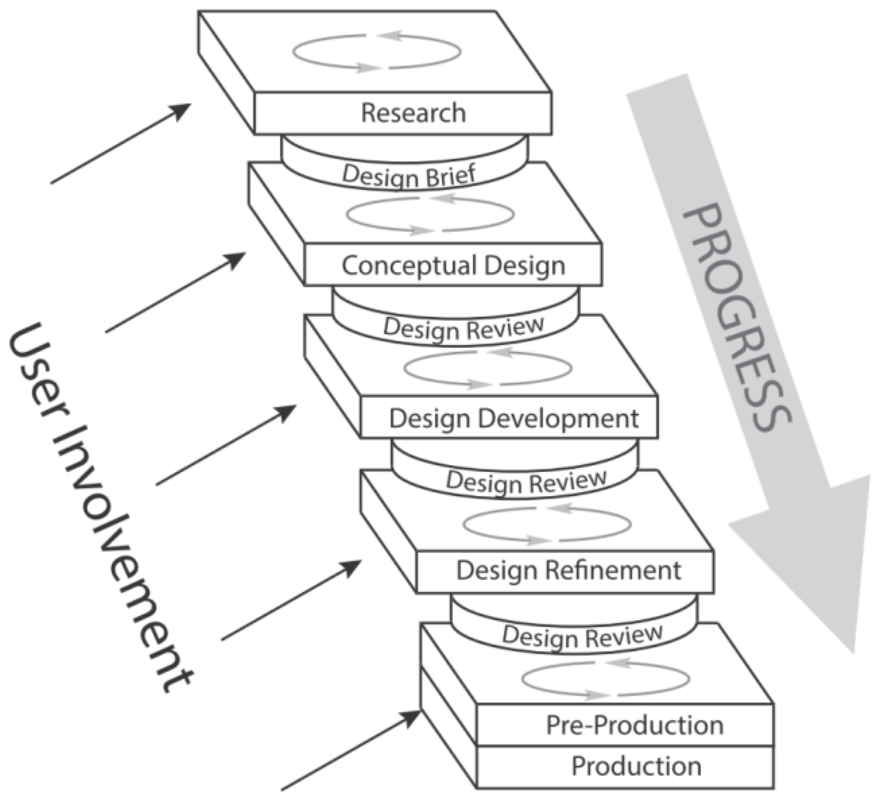


Figure 5.4 - Initial linear representation of the sports design process

5.2. Implementation within student projects

The initial linear model of the sports design process (Figure 5.4) was evaluated through implementation within five final year sports engineering university student design projects (step two of Figure 5.2), with the intention of receiving feedback from students within the context of a design project. The student projects differed from those utilised within Chapter 4 – Chapter 4 analysed the design processes used by past university students. This study focused on current students, implementing the linear sports design process model within their projects. This process intended to evaluate whether the characteristics illustrated within the linear sports design process model were representative of a sports design project and indicate potential areas where the model could be refined to ensure it was representative of, and communicated, sports design practice.

5.2.1. Methodology

The linear design process model, constructed as a result of the initial sports company interviews, was implemented within five final year sports engineering university student design projects (stage two of Figure 5.2). As the model is descriptive of industry practice, changes were not made to the model as a result – implementation of the model within the student projects intended to evaluate whether the characteristics communicated within the model were representative of a sports design project. Students were considered to be representative of the designer population as all were final year students with projects conducted over a 9 month period and contributing towards 25% of final year grades. Students also had experience working on group industry projects (a core part of the sports engineering course) and were encouraged to undertake industrial placements, therefore had an understanding of sports design practice in industry.

Students were introduced to the linear sports design process model in the first week of term – in the early project stages of research and formation of the design brief. At this stage, students were required to select a design process model to follow – they were familiar with a number of existing design process models but were free to choose one that best suited the needs of their project. All the students (five in total) selected to use the linear sports design process model shown in Figure 5.4. This design process model was then followed by each student for the duration of the project. An initial briefing was provided during which students were introduced to the model and the core characteristics of the sports design process. Following the briefing, no further guidance was provided regarding how to implement the model. Students were free to make their own interpretations and adapt the process model where needed to suit the project.

The student projects showed the development of an innovative piece of sports equipment from the early research stages through to a finalised product (final prototypes and manufacturing drawings were produced for each project). Projects covered a range of topics including: a golf training aid, badminton training aid, mountain bike handle bar adjustable mechanism, a means of reducing concussion in rugby and the re-design of a hard court tennis shoe.

Over the duration of the projects, the researcher observed progress meetings and made notes regarding the design processes being followed, activities being undertaken and rationale for decisions made. Students documented all aspects of their work through extensive reports and folios, detailing the methodology followed, justification for their choice, the activities undertaken throughout the project and a concluding reflection on the project as a whole. On completion of the projects, the final reports and folio were analysed using the same method used to analyse the past student projects (Chapter 4) to identify any additional information relating to the design process. Core themes and categories were identified from the analysis of the projects, focusing on rationale for selecting the linear sports design process model, a comparison between the process model and the activities carried out in the project, and on the students' reflection on the appropriateness of the model.

5.2.2. Results

Of the five sports engineering students that adopted the linear sports design process model within their final year design projects, none made any modifications to the model, which was recorded within the project reports and folios. All implemented the sports design process model throughout the project, with positive feedback received from all students. All five students commented that the sports design process model was selected due to the emphasis on the user throughout the design process, as this was vital to the projects:

> *"The key reason is it being employed, is the constant focus on the user needs and referral to the design brief".*

> *"This methodology has been selected due to the focus on the user's needs, which is highly important in my project".*

> *"This process is suited to sports engineering as the needs and requirements of users remain important throughout. Whilst the core aim of a new sports product is to enhance performance, it must also be designed with the end user in mind".*

During 'stage 1' of the student projects (the research and conceptual design stages of the design process model), user and expert involvement formed a significant part of the research stage, in helping students understand the problem and search for areas of improvement. User focus groups and expert feedback were also reported in the generation and evaluation of solutions during the conceptual design phase:

> *"Steps have been carried out concurrent with the sports design process model to keep user needs central to the project".*

'Stage 2' of the student projects reported on the design development and refinement stages of the sports design process model. User involvement was again central to the testing and evaluation of prototypes. One student reported:

> *"User feedback was the most useful mechanism in stage 1, providing analysis of various areas of research and should therefore continue to be used in stage 2 to aid in key decisions".*

Biomechanical analysis was used in three of the projects as a means of evaluating performance improvements brought about by the product designed by the students. Projects also relied heavily on evaluation from experts and professionals.

Students noted that the review process after each of the core stages of the process ensured that the project remained on track in terms of user needs and the original design brief and project aims:

> *"The process has the user as a major focus throughout, which is essential for this project and has constant reviews of the design so it meets the original aim".*

> *"The review stages allow for user needs to remain the focus of the development process".*

On completion of the projects, analysis of the project reports and folios showed that all students had involved the user extensively throughout the project, as was indicated in the sports design process model. It was apparent that the sports design process model had aided in the project planning phase, highlighting the need for continual user involvement and the time this would involve within the project:

> *"In constant relation to the sports design model, time is to be provisioned to obtain user feedback".*

5.2.3. Discussion

It was interesting to note that none of the students made any modifications to the sports design process model, suggesting that the linear model of the sports design process was more suited to the needs of a sports design project than other existing design process models. This is in contrast to the analysis of the past student projects (Chapter 4), in which 10 out of 17 students changed existing design process models to fit the needs of their project – the emphasis of the sports design projects was on user centred design and user requirements throughout the design process. While Chapters 2 and 4 identified and reported on the lack of a formalised sports design process, this chapter identified that there is also a need for that sports design process, with students selecting to use the linear sports design process model over other established design process models they were familiar with.

It was found that students implementing the linear sports design process model felt that the model indicated the appropriate level of user involvement throughout. All the student projects included high levels of user involvement within the conceptual design phase to generate and evaluate solutions. Although this falls in line with the sports design process model, it is not anticipated that this exceptionally high level of user and expert involvement at conceptual design would be practical in industry. The student projects were all new development projects, therefore showed significantly more emphasis on the conceptual design phase compared with most industry projects, which are typically product development projects (Margolin, 1997).

No changes were made to the linear sports design process model as a result of analysing the student projects as the model is intended to be descriptive of industry practice. However, implementation of the model within student projects helped to validate the conclusions reached following analysis of the sports design company interview transcripts. Students selected the sports design process model due to the high levels of user involvement illustrated within the model. The sports design process model also aided in the planning of the student projects as it identified where time was needed and should be set aside for user involvement and recruitment. Analysis of the student reports also highlighted that all projects showed iterations within design process stages, in line with reported sports design practice. None of the projects reported any rework resulting in back-tracking through the design process.

This section provided a means of evaluating the linear sports design process model, which was found to be more applicable to the sports design student projects than other existing models of the design process. The core characteristics of the sports design process gained from the sports design company interviews (user involvement and iterations within process stages) were applicable to the student projects with the integration of the user throughout the design process a key driver for students selecting to use the sports design process model.

5.3. Re-analysis of initial designer interviews

Following the construction of the linear sports design process model, it was concluded that the key findings from the sports design company interviews (shown as stage one of Figure 5.2) – the integration of the user throughout the design process, designer involvement with the user and the iterative nature within process stages – were not represented and visually communicated strongly enough through this linear model. As a result, the following section discusses the re-analysis of the sports design company interviews to ensure that all relevant information had been extracted in order to illustrate key findings within the sports design process model. The sports design process model was to be descriptive of sports design practice, but also had to communicate visually within the model what characterises sports design practice.

No new data was generated as a result of re-analysing the initial designer interviews (step three of Figure 5.2) as the initial analysis had been completed to a point of saturation. However, the output from step one (the linear model) did not appear to differ visually from many traditional product design process models. The results from the interviews with sport and product design companies indicated several characteristics that differentiated sports design from product design practice. Based on findings by Pugh (1996) and Maffin (1998) that designers lack more than a basic understanding of design process models and that many design process models are not self-descriptive (see the literature review in Chapter 2 for more details) it was concluded that the sports design process model must visually capture these characteristics. This section details the re-analysis of the designer interviews and presents the next development of the sports design process model.

5.3.1. Methodology

The initial interview transcripts were re-analysed (step three of Figure 5.2) using the same general inductive approach (Thomas, 2006) as used in Chapter 4, to validate the conclusions the linear model was based on and ensure that the key findings from the interviews were visually communicated within the sports design process model. No new themes or categories were identified – this was expected given the thorough approach taken within Chapter 4. However, the re-analysis helped to re-iterate the key characteristics that are central to the sports design process and that should therefore be illustrated within the sports design process model. As such, the sports design process model was re-illustrated to capture these findings – iterations within design process stages, user involvement throughout the process and designer interaction with the user – rather than based on the original linear representations of the sports design process provided by the designers themselves.

5.3.2. Results

Further analysis of the sports design company interview transcripts confirmed conclusions drawn previously that the sports design process is both highly user focused with the user involved extensively throughout the design process and the designer engaged with the user.

The core stages of the sports design process followed a linear route with a number of iterations occurring within each of these core stages. This suggested a cyclic route through the design process where stages were repeated before leading into the next iterative stage in the process. These characteristics therefore had to be emphasised and visually communicated within the sports design process model.

It is also noted that while designers had all included the pre-production and production stages within the design processes drawn out at the time of interview, the designers themselves were not extensively involved in these stages. The re-analysis of the interview transcripts identified that although the designers were able to give in-depth detail regarding their role and the activities carried out from the initial research stage through to the end of design refinement, the production stages were included as high level activities, lacking the detail of the other process stages.

5.3.3. Discussion

The initial linear representation of the sports design process model was adopted based on how the sports designers had illustrated their design process. However, it was felt that this did not visually communicate within the design process model what differentiates the sports design process from the traditional product design process. A cyclic representation of the sports design process model allowing for iterations within a stage and forwards movement between stages towards a central goal graphically illustrates these findings. This cyclic model was generated by the researcher to capture and describe the iterative nature of the sports design process reported by the sports designers – shown in Figure 5.5. The cyclic process allows the designer to repeat stages if the appropriate solution is not found or to move on to the next stage in sequence, but does not allow movement back to previous stages.

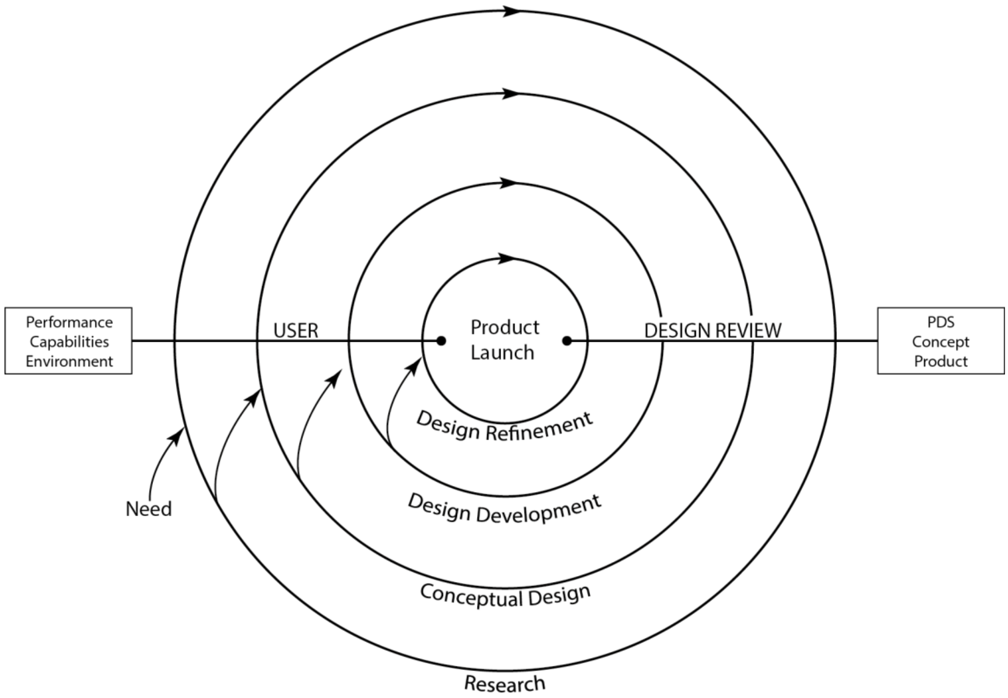


Figure 5.5 - Further development of the sports design process (initial cyclical model)

The re-analysis of the interview transcripts confirmed initial findings that user involvement throughout was central to the sports design process. Designers interviewed (at stage one of Figure 5.2) stated that "*the customer is king*" and "*you don't touch the product alone – you touch the system that you and the product build together*", emphasising the importance sports companies place on improving the overall performance of the product and user together. The horizontal line passing through each stage of the design process model in Figure 5.5 represent this user involvement, ensuring that the user is fully integrated throughout each stage of the process.

Sports companies reported that design reviews were completed at the end of each of the core stages of the design process. This was formalised within the design processes of the large sports companies but review-style activities were also undertaken by the small sports companies. These design reviews are included in the design process model in Figure 5.5 as a horizontal line that again must be passed through at each stage of the design process. It is at this point that the decision is made to progress to the next stage of the design process or re-iterate around the same stage again.

The central point of the process model was termed “product launch”, which follows on from the design refinement stage. This “product launch” incorporates the production and commercialisation phases of the design process. The output of this research is a design process model that represents the design and development process only. The sports company interview results indicated that the sports designers had little involvement beyond the design refinement stage and were unable to provide an accurate breakdown of what occurred during the production stages of the process. It was also apparent from some of the interviews that the production and commercialisation process was often viewed as a separate process. However, in-depth details of this process were out-with the scope of this research. It was therefore concluded that as the sports design process model would be targeted at the designers themselves, the production stages would not be included in the sports design process model.

5.4. Development focus group

A focus group was carried out with four final year sport engineering students (step four of Figure 5.2) to further refine the representation of the cyclic model to ensure it was descriptive of sports design practice. The aim of the focus group was to ensure the visual representation, descriptive of the sports design process, would be correctly interpreted by sports designers. Changes were not made to the characteristics that were represented within the model. The focus group evaluated the sports design process model from a designer perspective to ensure that the outcome was a truly representative description of how sports designers viewed their design process. The initial linear and cyclic models were based on the researcher's analysis and interpretation of the company interviews and student project results, therefore the focus group provided an opportunity to evaluate the model from another perspective and improve the model representation further, based on designer's own experiences.

5.4.1. Methodology

The focus group was carried out with four final year sports engineering students and lasted an hour, introducing participants to both the linear (Figure 5.4) and cyclic (Figure 5.5) versions of the sports design process model. The aim of the focus group was to ensure that the process model was a descriptive model of sports design practice and that the model would be correctly interpreted by designers. A group discussion followed a structured approach, with hard copies of the linear and cyclic design process models provided to all participants. A questionnaire was also given to all participants, who were asked to fill it in individually at the end of the session. Discussion questions that were asked included which aspects of the model did participants feel was reflective of sports design practice and ease of interpretation of the models. The focus group structure, including handouts, discussion questions and participant questionnaires, is included within Appendix 2.

The focus group was recorded and analysed following the same general inductive approach (Thomas, 2006) as used before in this research. Written comments made by the designers on the hard copies of the design process models provided to them were collected and analysed alongside the workshop transcripts, with notes categorised according to the core themes identified. The feedback questionnaires were completed by all participants and were analysed alongside the group discussion.

5.4.2. Results

The group discussion highlighted that while the linear model was simple to follow and would allow for good project structure, other characteristics including emphasis on iteration, user involvement and performance were lost. It was observed that several participants interpreted the arrows that represented user involvement within the linear model as illustrating a decreasing level of user involvement as the project progressed through the stages. This was not intended and was not representative of sports design practice.

Feedback indicated that the cyclic model was visually attractive and best illustrated the iterative nature of the sports design process. Whilst it was apparent that user consideration and design review lines were central to the design process, designers felt it was not clear from the lines that this was an activity to be undertaken – one designer commented:

> "*Doesn't use a line – an activity box would show something has to be done".*

It was concluded that with small developments, the importance of user involvement within the sports design process could be clearly represented within the cyclic design process model.

The simplistic, high level nature of the sports process was well received:

> "*Emphasise the stages but leave the activities flexible to the designer".*

It was noted that the cyclic model could be improved further by moving the design process stage names to the top of the model, to allow for a more natural flow when reading.

Results from the questionnaire showed that three out of the four designers felt that ease of interpretability (of the process model without prior knowledge from background reading) was the most important criteria. The fourth designer rated visual appeal as being the most important. When comparing the initial linear model to the cyclic model, all designers felt the cyclic model was the best representation of the sports design process and met those criteria.

The focus group concluded that the cyclic model was most descriptive of the design process followed by sports designers due to the visual representation of the iterative nature of the design process. The model could be easily improved further to place greater emphasis on user involvement throughout the design process. Feedback gained from the focus group emphasised that the model should be simple and flexible, illustrating a high level process. This could then be adapted by designers and organisations to reflect the specific needs and activities on a project to project basis. Illustrating too much information would result in the model becoming too restrictive, discouraging designers from using it.

5.4.3. Discussion

The findings of the focus group acknowledged that the linear model provided a structured approach that was easy to follow. However, there was confusion over the level of user involvement at each stage and the iterative nature of the sports design process was lost.

Participants indicated that visually, the cyclic model best represented the characteristics of the sports design process (user involvement throughout and iterations within process stages). However, in its current state, there were difficulties in interpreting the meaning of the horizontal lines. There were also aesthetic improvements that were recommended to improve the flow and visual appeal of the model, which were ranked as high priority requirements by the participants.

It was concluded that while the linear model provided a good structure as the basis for a project, there was limited scope to develop the model further to ensure it visually represented the characteristics of the sports design process. Therefore, the linear model will not be progressed further within this research. The cyclic model better represented the characteristics of sports design and could be improved further. Based on the feedback from the focus group, the following improvements were made to the cyclic model to ensure it was representative of industry practice.

- The horizontal lines in the model were confusing. As suggested, activity boxes were added to the model to highlight that a task should be undertaken.
- There was a lack of flow between stages of the design process, therefore process stage names were moved to the top of the model to allow for a more natural flow when reading– from top to bottom.
- It was unclear that the requirements listed next to the design review were outputs from each stage. These are now illustrated within the model as an output from the design review process. E.g. the output of the design review following the research

stage is an approved design brief. The output from the conceptual design stage is an approved concept that will be taken forward to design development and the output from design development is the near-completed product that proceeds to the final design refinement phase.

The model was refined based on the above responses to the focus group feedback and is illustrated in Figure 5.6. As a result of the initial designer interviews, implementation within student projects and focus group discussions, it was concluded that the cyclic model best captures and illustrates the characteristics of the sports design process. This model was progressed to the final stage of this study, where it was validated by sports designers from industry to ensure it was fully descriptive of sports design practice.

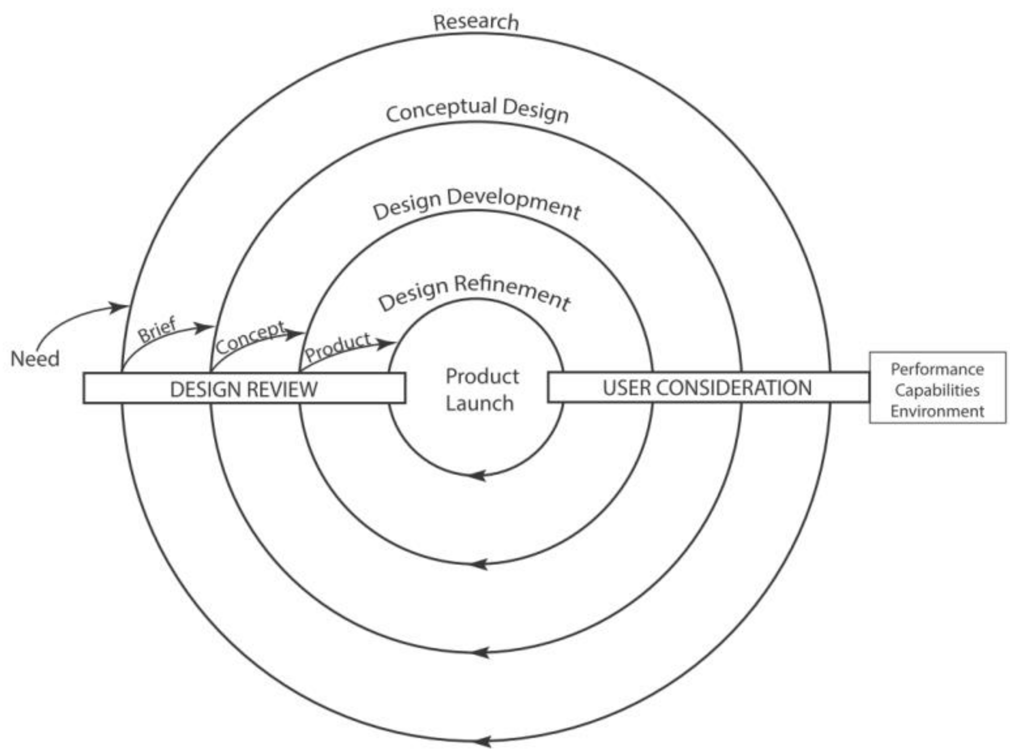


Figure 5.6 – Further development of the sports design process (developed cyclical model)

5.5. Final validation interviews

A final set of semi-structured interviews (step five of Figure 5.2) were conducted with designers from sports companies to validate the model and ensure it was truly representative of sport design practice in industry. This research utilised respondent validation to ensure validity in the results. Minor refinements were made to the model as a result of the designer responses and recommendations made. The final outcome is a validated, descriptive process model of sports design practice in industry.

5.5.1. Methodology

Designers from five sports companies were interviewed to validate the final sports design process model – from two large companies, two small and one medium. Of the five companies interviewed, two were involved in the initial interviews discussed earlier in this chapter (and in Chapter 4) and allowed for respondent validation based on their responses to the sports design process model, which was developed based on their initial descriptions of the sports design process that they followed in practice. Three of the companies were new to the research. The interviews followed a semi-structured approach, each lasting around one hour, which provided an in-depth analysis of the sports design process model and aimed to identify the following:

1. Did the designer understand the model?
2. Was the sports design process model representative of the company's own practice?
3. What modifications would be needed to ensure the model was an accurate visual representation of the sports design process in practice?

The sports design process model shown in Figure 5.6 was presented to the designers, who were asked for their initial impression of the model before any explanation of the model was given by the researcher. A description of the model and what it represented was then provided by the researcher before the designers were asked a series of questions (see Appendix 2 for interview questions, structure and overview provided of the sports design process model), to address the three core interview areas. As before, the interviews were recorded and fully transcribed, before being analysed using a general inductive approach (Thomas, 2006) to identify core themes and categories. The analysis process was repeated to a point of saturation, where no new themes or categories were identified. Themes that were identified from the transcripts included ease of interpretation, aesthetic appeal, terminology and implementation of the model.

Following the analysis of the transcripts and designer recommendations, final improvements were made to the sports design process model to ensure it was fully descriptive of sports design practice and that characteristics of sports design practice were evident within the process model itself.

5.5.2. Results

Designers were questioned on the following three areas:

1. Did the designer understand the model?
2. Was the sports design process model representative of the designer's (or company's) own practice?
3. What modifications would be needed to ensure the model was an accurate visual representation of the sports design process in practice?

In response to question one (before any explanation of the model was provided by the researcher), all designers were able to understand the model and identify the core characteristics of the process to the researcher. All commented on the visual appeal of the model:

> *"I think it's really attractive and easy to absorb".*

Ease of understanding was essential for the sports design process model, with positive feedback received from all designers – all could understand the model and were able to discuss the process with ease.

Following a description of the design process model by the researcher, designers did not feel they had missed any key areas represented within the design process when viewing it for the first time:

> *"I get it and instantly I was comfortable with it – I like how it just looks like it flows really well".*

In response to question two, all designers agreed that the sports design process model was representative of their own practice in industry. The cyclic nature of the model was considered by all designers to be representative of the nature of sports design:

> *"We're constantly going round in circles, constantly going round the same check points, but just at different points in the process".*

All designers thought the model had captured the sports design process, from the iterative nature of design, to the emphasis on the user and the decision making process at the review stages.

In response to question three regarding how the sports design process model could be improved further, all interviewees indicated that the terminology used for "product launch" implied the design process progressed from a fully developed product at the end of design refinement straight to the launch of the product – in reality there was a full commercialisation process that was not shown within the model. The sports design process model presented here is intended to represent the design and development cycle, therefore additional detail on the commercialisation phase it not shown. The term "product launch" was re-named "project sign-off" indicating that the product is not in a state to be 'launched' but design work is completed.

Designers felt that the representation of "user consideration" shown in Figure 5.6 could be interpreted as a "tick the box" activity and did not convey the high level of testing and user integration within the sports design process. One company was quoted saying:

> *"The reality is that we're constantly going round in circles… Testing dictates the design – we make design updates based on the testing feedback".*

This emphasised both the iterative nature of the sports design process and the high level of user involvement and testing throughout that was essential to sports design in practice. The sports design process model was further modified to reflect the feedback of sports designers regarding their everyday practice, as shown in Figure 5.7. This placed more emphasis on user involvement and extensive testing within the model, showing a breakdown of the nature of user centred design methods used from data gained from the original set of sports design company interviews.

Feedback from the designers indicated that additional levels of detail (such as the text next to user consideration – performance, capabilities, and environment shown in Figure 5.6) should not be shown within the model, as the more simplified version of the model was an accurate representation of industry practice. One small sports design company reported that it would be of benefit to allow designers to add to these considerations over time to ensure that all potential requirements were met within a project. However, these recommendations were not incorporated into the final model as feedback from all other companies was to keep the model simple without over complicating it. One designer reported:

> *"The more structured it would be, the less likely we would probably be to use it".*

This was due to the individual nature of design projects, resulting in designers preferring flexibility in the sports design process model. Additional comments relating to the aesthetic appeal of the model included that the arrows connecting the design process stages together should have a more subtle curve, which would also improve the cyclical appearance of the model.

Two of the companies interviewed as part of the validation process indicated an immediate intention to use the sports design process model as a training tool within their design and development team. It was stated that the model was representative of the design process currently followed and was applicable to each of the companies. Although the companies followed a similar series of activities within each project cycle, there was no formalised design process used within either company at the time of the interview. Both designers commented on the benefits of adopting the model within the company to provide an overview of the company's design process as a whole to enable designers to understand where everyday tasks fit "within the bigger picture" and to inform those within the company not from a sports design background of the sports design process.

5.5.3. Discussion

The final sports design process model is shown in Figure 5.7. The model illustrates a cyclic process, moving round the model from one stage in the design process to the next, conveying the iterative nature of the sports design process within stages. As it was noted that iterations between the process stages themselves were rare (for example, between conceptual design and design development) the model does not allow for backward iterations or the omission of stages.

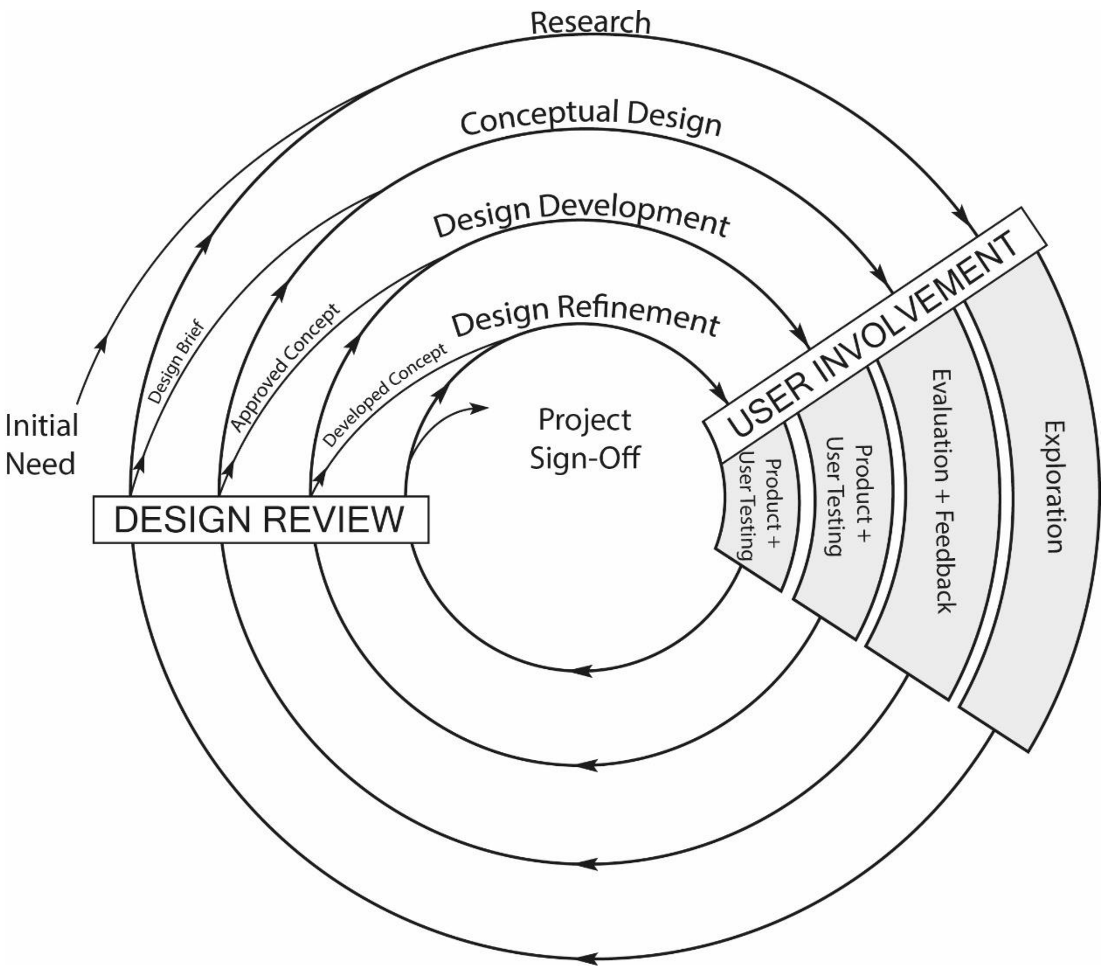


Figure 5.7 - The sports design process model

There are two activity boxes that must be passed through within each stage of the sports design process – user involvement and design review. User involvement ensures that the needs of the user are central to each stage of the design process. In sports design practice it was noted that the users themselves were involved at all stages, with the exception of conceptual design where there was less emphasis on user involvement. However, at the conceptual design stage, the needs of the user were emphasised and considered when generating and evaluating concepts, with users themselves at times involved in the evaluation of concepts. At all other stages of the sports design process, the user was directly involved through a range of methods, ranging from evaluation and feedback of existing products and competitors in the early stages of the design process, to user and product testing in the design development and refinement stages. The large proportion of the sports design process model given to user involvement emphasises the central role of the user within the sports design process. A design review is completed at the end of each design process stage to ensure that the project is on track to meet the design brief and should include input from a range of stakeholders within the company, in addition to the needs of the user.

The outcome of each stage of the design process is illustrated in the sports design process model after the design review process. After the research stage, a design brief (or specification) is produced. The outcome of the conceptual design stage is the approved concept that will be progressed through to design development, while the outcome of the design development stage is a developed concept. At the design reviews, the outputs are assessed in terms of how well they meet the design brief in terms of performance targets and user requirements and the decision is taken by the stakeholders to progress to the next stage of the design process or repeat the stage again.

5.6. Chapter findings

The literature review conducted in Chapter 2 identified the lack of a published design process model that captured the characteristics of the sports design process as a whole. Following the triangulation study conducted in Chapter 4, the key characteristics that differentiate the sports design process from the traditional product design process were identified. Based on these findings the study reported in this chapter addresses the second research question – **what is the sports design process?**

No company involved in the research reported having a formalised representation of their design process that is published or reportedly in use. The literature review (Chapter 2) produced no results in terms of an existing sports design process model as a whole and from analysis of sports engineering student projects (Chapter 4), it was apparent that none of the students found a design process model that was representative of the sports design process. During the final validation interviews reported in this chapter, designers commented that the sports design process model presented here was easier to understand

and more applicable to sports design practice than other published design process models. Following an iterative process of identification, evaluation and validation, the outcome of this study is the presentation of the first design process model to capture the sports design process as a whole.

The sports design process model differs from other design processes in that it is specific to the design of sports equipment. While some features of the model presented here show similarities with aspects of other design process models, the sports design process model is unique in that it provides a visual representation of the core stages of the sports design process, the iterative nature of that design process and the need for continual user involvement throughout the design process, which have been identified as characteristic of sports design practice. Other design disciplines have design process models specific to them, as discussed in the literature review. The work carried out in Chapter 4 of this thesis identified the need for a sports design process model as existing design processes do not convey the characteristics of the sports design process. It is therefore concluded that there is a need for the design process model presented here that illustrates the characteristics of sports design practice.

This study is in agreement with other literature cited in Chapter 2 that reported sports design as highly user focused, primarily due to the requirement of the athlete and equipment working together to improve sporting performance. Designer involvement with the coach and athlete is also cited as a core component of sports design practice. This user focused nature of sports design practice is reflected in the sports design process model, where user involvement is illustrated as a core requirement throughout the design process.

The sports design process model presented in this paper is a descriptive design process model and has been validated as an accurate representation of the sports design process followed in industry. As the first design process model to capture the sports design process as a whole, the contribution of this chapter is of direct value to the sports design community. As discussed in section 5.5.2, two of the sports companies involved in the final validation of the model indicated an immediate desire to use the model within their everyday design practice. It is expected that the model will be beneficial to sports designers themselves, allowing them to visualise the design process as a whole and for small companies to structure their process. There is also a clear need for the sports design process model in an educational context, as all five students involved in section 5.2 chose to implement an early version of the sports design process model over other established design process models they were familiar with. This re-iterates the need for a design process model that captures the characteristics of, and is descriptive of, sports design practice.

The study conducted in this chapter followed a thorough approach of continual evaluation, development and validation of the sports design process model, ensuring that the final design process model was both representative of sports design practice and presented in a way that was beneficial to sports designers themselves. This rigorous process of developing and validating the sports design process model will minimise any limitations due to sample size.

5.7. Further Work

This chapter presents the first design process model to capture the sports design process as a whole. It is apparent from the final representation of the sports design process model, in addition to the findings from Study 1 (Chapter 4) and the literature review (Chapter 2), that sports design is a highly user focused design discipline. The literature review also highlights parallels between the user focused nature of sports design and other design areas, such as user centred design and inclusive design.

Based on these similarities, it is anticipated that the sports design process model could benefit the wider design discipline as a whole. The model presented here is descriptive of sports industry practice and is therefore currently practiced within industry design constraints. There is therefore scope for the sports design process model to be followed within wider product design practice, where the sports design process may be able to address some of the barriers that have been cited within the literature review to user centred and inclusive design – primarily that the user is not engaged throughout the design process and the designer is not directly engaged with the user. Based on the findings from the literature review and the evident user focused nature of the sports design process, the following chapters will address the third research question – **how is the sports design process applicable to inclusive design?** Chapter 6 will determine the applicability of the sports design process model to inclusive design practice. Chapters 7 and 8 will present the solution to the third research question.

Part 2

Part 1 presents the descriptive studies undertaken within this research to identify what differentiates the sports design process from the product design process in practice and to capture the sports design process within a design process model.

Part 2 of this thesis presents the prescriptive studies undertaken to understand the applicability of the sports design process model to inclusive design practice. Within Part 2, the third research question of this research is addressed – **how is the sports design process applicable to inclusive design?** Study 3 (Chapter 6) reports on a two part approach to determining the applicability of the sports design process model to inclusive design practice. Study 4 presents the development of an interactive inclusive design framework based on the sports design process model (Chapter 7) and the validation of that framework with industry designers and clients (Chapter 8).

Chapter 6 – Application of the sports model in inclusive design practice

Chapter 5 reported on the development of, and presented, the first design process model to capture the sports design process as a whole. Based on evidence provided within Chapters 4 and 5 (Part 1 of this thesis), in addition to the findings from the literature review (Chapter 2), it is concluded that the sports design process is highly user centred, with the user involved directly with the designer throughout the design process. The literature review also highlights that a user centred design approach to product design requires user involvement throughout the design process and that this user involvement is critical – designers should not be left to rely on their own assumptions/experience. Based on this need for user involvement throughout the design process within a user centred design approach, it is anticipated that the sports design process could be applicable to other user centred areas of design, broadening the impact of this research.

This chapter presents Study 3, which goes some way to addressing the third research question: **how is the sports design process applicable to inclusive design?** The chapter discusses the study undertaken to establish whether the sports design process is relevant and applicable to inclusive design practice and how the user centred nature of the sports design process can encourage user involvement throughout traditional product design processes. While this study focuses specifically on the applicability of the sports design process model to inclusive design, it is anticipated that the results will be applicable to the wider product design discipline as inclusive design is widely regarded as being “good” design practice (Clarkson, et al., 2003).

This chapter will be structured as illustrated in Figure 6.1. Following the introduction to the chapter, the two stages of the study will be discussed – the interviews with product designers from industry and the workshop conducted with the Helen Hamlyn Centre, who specialise in inclusive design. Each stage of the study will be discussed separately with its own methodology, results and discussion sections. The chapter concludes with an overall discussion of the chapter findings and proposes how the sports design process model will be developed to aid inclusive design practice, as part of further work identified within this research.

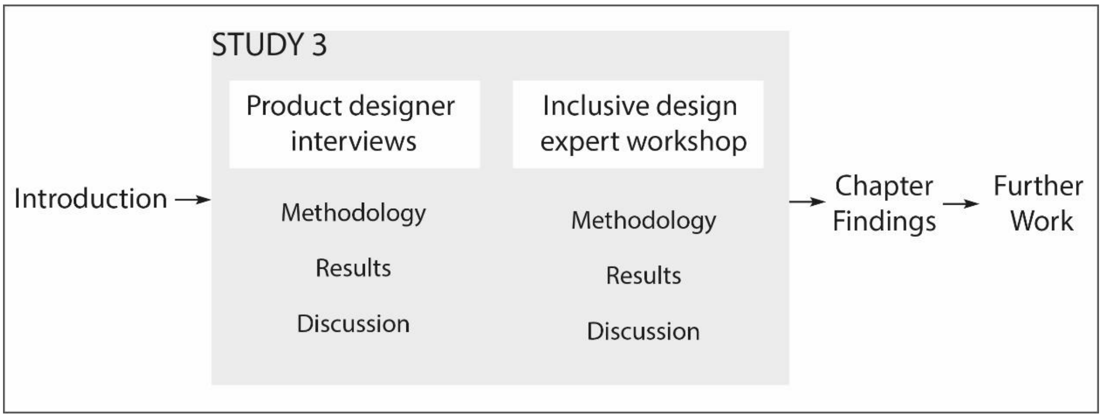


Figure 6.1 - Structure of Chapter 6

To ensure the outcome of this research is applicable to industry, two practical studies were undertaken. The first, conducting interviews with practicing product designers from industry and the second, a workshop completed with inclusive design experts from the Helen Hamlyn Centre. An overview of the research approach used in this study is illustrated in Figure 6.2. More detail on the methodology of each study is provided within the relevant sections of this chapter.

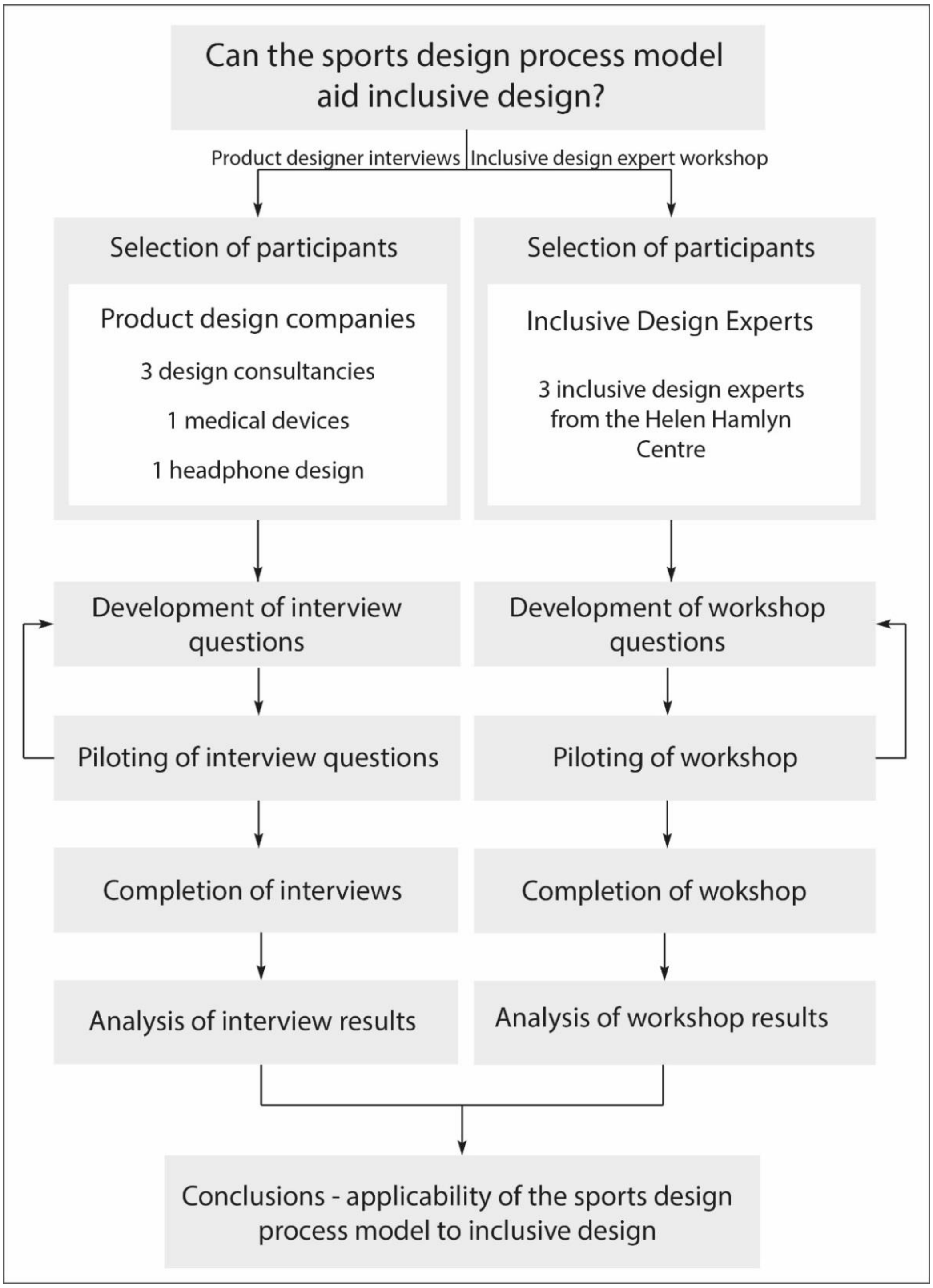


Figure 6.2 - Research methodology for Chapter 6

6.1. Product designer interviews

This section details the methodology, results and discussion from the interviews conducted with five product designers, each with experience in user centred and/or inclusive design. The interviews intended to identify characteristics of the inclusive design process currently implemented in industry practice and to determine whether the sports design process model was applicable within an inclusive design setting to facilitate the uptake of inclusive design practice.

6.1.1. Methodology

Five product designers from industry were involved in the interviews, each from a different design company and with experience in designing user centred and/or inclusive products. Designers that participated included one that designed medical devices, one designing headphones and three from design consultancies, which designed a range of products (as illustrated in Figure 6.2). None of the designers interviewed in this study had been involved in previous studies conducted within this research.

Individual semi-structured interviews were used to gain feedback on the applicability of the sports design process model within an inclusive product design context in industry, ensuring that in-depth data was collected. The interviews were initially piloted with two additional designers from design consultancies, which were not included in the final data that was analysed. Following the piloting, no changes were made to the sports design process model itself although some changes were made to the introduction and briefing given to the designers to ensure they understood what the sports design process model represented and the purpose of the interview. Some minor changes were also made to the interview questions.

The interviews lasted around an hour and interviewees were given freedom to develop their thoughts on key areas. The structure of the interviews is outlined below. Seven core questions were asked, which included a discussion of what characterised the inclusive design process followed by each designer, methods used within that process, user involvement within the inclusive design process, initial impressions of the sports design process model and developments that could be made to implement the sports design process model in inclusive design practice to promote inclusive design uptake. The full interview questions and additional prompts are included in Appendix 3. The interviews were structured as follows:

Interview Structure:

1. Designers questioned regarding their own design process and inclusive design practice.
2. Designers shown the sports design process model and asked for initial impressions with no explanation of the model provided.
3. Designers questioned on the sports design process model in more detail following a detailed explanation of the model by the researcher.

Designers were provided with a copy of the sports design process model, as illustrated in Figure 6.3. Designers were introduced to the sports design process model by the researcher – the transcript used is included within Appendix 3. An overview was given of the core stages, the nature of user involvement throughout the design process, the iterative nature of the sports design process and the design review process.

All interviews were completely transcribed and analysed using the general inductive approach (Thomas, 2006), as used in previous chapters when analysing interview data. Data was categorised into core themes, with the following section detailing the results drawn.

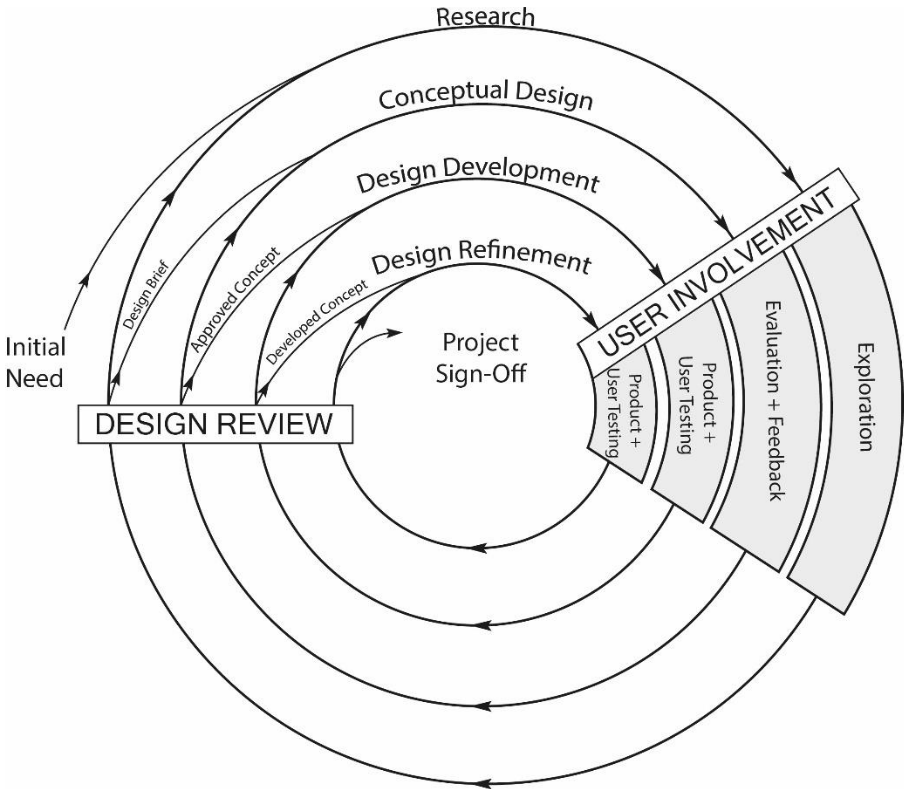


Figure 6.3 – The sports design process model

6.1.2. Results

The results of the interviews with the product designers are presented according to the three main topics used to structure the interviews – inclusive design within industry practice, feedback on the sports design process model and discussion of the potential development of the model to aid inclusive design uptake in industry.

Industry practice

Designers were questioned on their own companies design practice, focusing specifically on identifying the inclusion of diverse user groups within the design process. Feedback from the designers indicated that the term "inclusive design" was not commonly adopted within industry. It was noted that while designers themselves were aware of inclusive design and what the term meant, "inclusive design" was reported to be perceived negatively by the client. The involvement of a diverse group of users within the design process was reportedly rare for all the designers interviewed – diverse user capabilities were only taken into account if the project specifically required it (e.g. for products targeted specifically at those with reduced capabilities).

The design processes followed by the designers in their everyday practice noted an absence of user involvement generally, with diversity in those users even rarer. All designers interviewed had experience working directly with users but all commented that the level and diversity of user involvement within the design process was highly dependent on the demands and funding from the client. All designers found that the client was often the main barrier to user involvement within the design process as the client was responsible for allocating funding for the project and was often directly involved in influencing the level of user involvement:

> *"It depends on the project and it depends on the client and mainly their budget".*

One designer commented that projects which involved the user more often resulted in a better product, indicating the value of including users in the design process:

> *"Where we were able to do (user) research, you make the product better from the research".*

Designers often found it difficult to communicate to the client that user involvement was important in the early stages of a project to educate the designer on the needs of the user:

> *"There's a narrative to doing the first bit well and having user involvement – if you don't properly understand the need or the problem you're trying to address, there's no point in moving on to the next bit because you're more likely to fail".*

It was also found that when users were involved in the design process, clients were unaware of how to recruit appropriate user groups and how long this recruitment process would take – the greater the diversity in the user groups, the longer this process would take. The client was often cited as the main barrier to adopting an inclusive approach to a design project in practice:

> *"There are projects where the client has a really specific brief and we must design exactly what they say and there isn't any wiggle room to add an inclusive element".*

It was noted that the client themselves was rarely from a design background and therefore lacked knowledge of the design process:

> *"The client is quite often very ignorant to the design process".*

This created problems when designers were trying to communicate with the client – the client often assumed the design process was a linear route with one concept selected from the start and progressed through to the end. It was commented that clients often found the concept of an iterative approach to design to be a daunting one:

> *"The idea of going round and round can be quite scary for clients… they want to see value for money and tangible outcomes".*

> *"Clients often think it's going to be a much more linear route".*

Iterations were viewed by the client as a sign something had gone wrong rather than an essential part of the design process. The client focused on the value of design activities carried out in the design process and wanted to see the output from each activity – *"clients want to see tangible outcomes"* – rather than being concerned with the activities themselves carried out within the design process.

Feedback on the sports design process model

Designers were asked for feedback based on their initial impressions of the sports design process model, without any introduction from the researcher to the model itself. All designers liked the sports design process model:

> *"It's good because it shows you going round and round but also forwards visually".*

> *"I really do like this path though, there's something there about making it a path rather than a flow chart… It makes sense, it looks great".*

The designers were able to understand the model without an introduction by the researcher – designers were asked to guide the researcher through the model to understand their interpretation of it:

> *"When I look at it, it's very understandable".*

One designer commented on the size of the text, making some aspects of the model difficult to read. However, this interview took place over Skype, so it was unclear the size and quality of the image the designer was viewing. No other designers commented on the size of the text.

Development of the sports design process model for application in inclusive design

Following a briefing of the sports design process model from the researcher, designers were questioned on the applicability of the model to their everyday design practice, focusing specifically on inclusive design practice. The concept of the cyclic design process model was felt to be more representative of the iterative nature of inclusive design practice compared to the traditional linear design process representation:

> *"I like the track where getting on or going round the wheel until I get what I think is about right".*

Designers liked the simplicity of the model and felt that it should not become overly complex:

> *"I wouldn't complicate it more because it works well and if you complicate it, you take away from the core stages".*

The designers all commented that the sports design process model would be of limited use to product designers themselves in industry practice. It was apparent that the designers themselves did not "follow" a high level design process, commenting that all were well aware of the design process that they followed day-to-day:

> *"Once you've been in industry a while, you just kind of do it".*

However, several designers commented that the simple cyclic model could be a useful reference tool to aid communication between designers within a company and to track project progress. Based on designer feedback, there is a clear need for a tool that will facilitate communication between the designer and the client:

"I've had to sit down with clients and try and verbally and physically explain to them just how much goes into product development, so something really nice, one page, one image would be a beautiful thing to give people like that".

All those interviewed commented that the sports design process model would be highly useful as a communication tool to help the client understand the inclusive design process:

"I like to be able to show or illustrate to a client what goes into it (the design process), if you show someone who's never seen it, they start getting an appreciation of it".

Designers commented that aspects of the model, such as emphasis on iterations, effort involved at core stages and the value of user involvement were all important aspects of the inclusive design process and would be beneficial if included in a framework to accompany the sports design process model that provided more detail on each of these:

"If you can show that to them (the client) in a really clear way and that would just answer a lot of their questions immediately".

The following guidance was provided by the designers for developing the sports design process model into a communication tool for inclusive design:

- *"If you can find a clever way of visually illustrating the other stages or what would come at each stage".*
- *"You've got to make it simple enough that they can grasp it immediately but you've got to give them enough detail so they know there are tools to go along with that".*
- *"We would use these primarily to communicate to the client how we're going to do a project and potentially to quote for a project too".*
- *"Investing money in each stage is setting you up to succeed and not fail".*

It was vital the sports design process model did not become over-complicated with this additional detail. The designers suggested that a supporting framework could be used to illustrate the additional information that it would be needed to provide a client with a clear over-view of the inclusive design process and should be presented in a format that could be updated to reflect individual project needs.

6.1.3. Discussion

As with the results presented previously, the discussion section will follow a similar structure, discussing first current inclusive design practice in industry, followed by the feedback given on the sports design process model and its potential application within inclusive design practice.

Industry practice

The interviews conducted in this study focused on inclusive design practice and initially questioned the designers on their inclusive design process and involvement of diverse user groups within the design process. However, it was apparent that user involvement in general was severely lacking for all the designers interviewed. It was found that all designers felt that user involvement within the design process was highly beneficial and allowed clearer definition of the project early on. User involvement also helped designers to gain a thorough understanding of the design problem and the environment in which the problem originated. This is in agreement with many previous studies, where authors including Bruseberg and McDonagh-Philp (2000), McGinley (2012) and McGinley and Macredie (2011), all make the case for the value of user involvement early in the design process.

However, all designers interviewed here felt that the user was often not involved to the extent they would like within the design process and that user groups often lacked diversity in capabilities. Reasons given for this included a lack of time within the design process and insufficient funding allocated to user research by the client. This is again in agreement with the literature discussed in Chapter 2 (section 2.5.4.1.), where allocation of time and resources are frequently cited as barriers to inclusive design – (Dong, 2004), (Goodman-Deane, et al., 2010), (Sims, 2003), (Vanderheiden & Tobias, 2000). The term "inclusive design" was not commonly used within design practice as it was perceived negatively by clients. There is therefore a need to address the barrier of the client to inclusive design uptake and educate the client on the value and benefits of including a diversity of user groups within the design process to ensure appropriate allocation of funding and resources. However, this can be challenging as the client is often not from a design background, with designers reporting difficulty in communicating the design process to the client.

Designers commented that when users were involved in the design process, the recruitment of the desired user groups was highly time consuming, with recruiting diversity in those user groups even more challenging. The client, being responsible for allocation of funding, often did not see the value in allocating funds to the research phase and often provided the designer with secondary user information. Designers commented that the when a larger proportion of the budget was spent on the research phase, the project benefited as a result – this allowed the designer to gain a better understanding of the problem, carry out observation activities and assess user needs in the environment of product use. Although receiving secondary user information from the client was a quick and cheap method of understanding user needs, it was felt that a lack of direct physical user involvement and primary user data collection by the designers themselves often resulted in designers making assumptions regarding the end user, which could at times result in a poor final product. Sims (2003) argues that changes made later in the design process are often expensive and time consuming, therefore it is important the designer has a clear understanding of the user early in the design process to avoid mistakes in the later stages. Secondary user information and designer assumptions are also unlikely to be representative of the target population as a whole. This is in agreement with findings from the literature review, where Wilkinson and Angeli (2014) state that designers cannot rely on their own skills and experiences to design for the wider population and Marshall, et al. (2010) who notes that "abstract representations of people based information does not inspire designers". It is difficult for designers to gain an in-depth understanding of the user from secondary data, which lacks detail and context, emphasising the importance of physical user involvement within the design process. While user involvement in itself is a vital part of the design process, it is also critical that a diversity of users is included to ensure older and disabled users are not excluded from the end product. However, based on the findings of the interviews conducted here, there is perhaps a need to first increase user involvement itself within the design process as a whole, before inclusion of a diversity of user groups can be tackled.

Feedback on the sports design process model

Designers were not given any initial briefing of the sports design process model or told that the model represented sports design practice – they were told the model was simply a "design process" and questioned on their understanding and interpretation of it to ensure their responses would not be influenced by information provided by the researcher. It was apparent that the model was understandable to the designers and emphasised aspects of the inclusive design process that were important to the designers themselves – user involvement throughout the design process and the iterative nature of inclusive design. This is in agreement with findings from the literature that inclusive design practice should involve the user continuously in an iterative process of evaluation and development (Ielegems, et al., 2015). As the sports design process model communicates characteristics central to an inclusive design approach, it was concluded that no modifications to the foundations of the sports design process model itself were required.

All industry designers felt that the model of the sports design process would be of limited use to designers themselves as all were comfortable with the design process they followed day-to-day. This was expected as the core stages of the sports design process model do not vary significantly from other theoretical design process models and company specific processes that designers were already familiar with. As such, designers and their companies are unlikely to adopt a new design process as this would result in changing established design practice throughout the company.

It was noted that none of the designers reported following a specific inclusive design process on the occasion where diverse users were required in a project. However, an inclusive design approach has a clear impact on the design process with increased user recruitment time required and increased user testing. While designers were aware of inclusive design and the benefits of the approach, they felt the adoption of an inclusive design approach was out-with their control and lay with the client. The barrier of the client therefore has to be addressed to increase the uptake of inclusive design in industry.

Development of the sports design process model for application in inclusive design

It is apparent that the main barrier to user involvement within the design process (and ultimately to inclusive design) comes from the client. All designers commented that the sports design process model would be highly useful as a communication tool to educate the client of the inclusive design process. Many clients assume that the design process is linear and think that the project has gone wrong if iterations start to occur. Being able to communicate visually at the start of a project that the design process is highly iterative would be valuable to designers in informing clients of the nature of design and conveying to clients where time is spent throughout the inclusive design process.

It is apparent from the interviews that a lot of time can be taken up at the start of the design process educating the client of the process and what is expected to happen. There was agreement between designers that a framework that communicated the inclusive design process to the client would be beneficial to the designers themselves. This would aid designers in quoting for each stage of the design process and illustrate where funding would be allocated, areas of effort and what the value and output of each stage would be. Designers wanted to be able to show where effort was required within the design process, both in terms of time and resources required, using a visual aid.

Designers commented that the visual format of both the sports design process model and the framework would be highly important if being developed specifically for communication with the client. The design process model and framework should allow flexibility in the requirements of different projects. In terms of the client, the design process model should be simple enough to be understood by those from a non-design background, but with sufficient level of detail that the complex nature of inclusive design would be understood. The framework should communicate the designer's needs within the inclusive design process in a manner understood by clients without complicating the design process further. It should therefore be easily understandable to the client with minimal explanation required.

It is noted that the focus of all the interviews shifted from inclusive design to increasing general user involvement within the design process. To implement inclusive design, a good foundation of general user involvement is required, from which the inclusion of a greater diversity of users can be built. However, it was found that many design companies lacked consideration of not only the breadth of user capabilities, but also the involvement of any users themselves within the design process. While it is acknowledged that user involvement alone is not "inclusive design", it is apparent that increasing client awareness of the benefits of involving general users within the design process is needed.

Summary of product designer interviews

This section reports on the discussion of the findings from interviews with industry designers with experience in inclusive and/or user centred design. It is concluded that the characteristics of the sports design process model (the iterative nature of design, user involvement throughout the design process and direct interaction between the designer and the user) are representative of inclusive design practice. However, current industry practice shows a lack of general user involvement within the design process, in addition to a lack of diversity in the user groups recruited. It was found that an inclusive design process model alone would not benefit designers as it is the client that is often the barrier to inclusive design uptake. This is in agreement with findings from previous published work – (Bruseberg & McDonagh-Philp, 2002), (Dong, 2004), (Goodman-Deane, et al., 2010). It is apparent that the client lacks understanding of the design process in general. It is therefore critical that designers are able to communicate both the inclusive design process itself and the value of user involvement effectively to the client in order to build a user centred foundation on which a more inclusive approach to design can be built.

Based on designer recommendations, more detail is needed to illustrate user activities, user recruitment time and the value of user involvement to develop the sports design process model to aid inclusive design uptake in industry. Designers commented that this additional information could be better presented as a framework to allow a breakdown of relevant activities and avoid cluttering the sports design process model with too much information. Being able to visualise the inclusive design process to clients, illustrating the time involved and value added by user involvement and diversity in user capabilities throughout the design process would be highly beneficial to designers in communicating their own needs.

The recommendations from the designers interviewed here are included in a requirements list at the end of this chapter, where they are combined with the feedback gained from the workshop conducted at the Helen Hamlyn Centre for Design, discussed in the next section.

6.2. Inclusive design expert workshop

This section details the methodology, results and discussions from the workshop undertaken with three inclusive design experts from the Helen Hamlyn Centre for Design at the Royal College of Art. The Helen Hamlyn Centre is involved in design research and projects with industry that aim “to contribute to improving people’s lives”. As the longest running centre for design research at the Royal College of Art, the designers at the Centre have an expert knowledge of inclusive design practice and would provide valuable feedback on the potential application of the sports design process model within an inclusive design context.

6.2.1. Methodology

Three inclusive design experts from the Helen Hamlyn Centre specialising in inclusive design took part in a workshop to discuss their own approach to inclusive design and the potential development of the sports design process model in the context of inclusive design practice. The workshop was conducted at the Helen Hamlyn Centre and lasted approximately three hours. The aim of the workshop was:

1. To identify the design process and activities carried out by the Helen Hamlyn Centre, which would be indicative of “best practice” in inclusive design.
2. To gain feedback on the applicability of the sports design process model to inclusive design industry practice and to generate ideas on how the model could be developed further for industry use.

An overview of the activities carried out within the workshop is provided in Table 6.1. The workshop was recorded and analysed using the same general inductive approach as before (Thomas, 2006). In addition, sheets of paper and handouts on which participants had sketched ideas were collected and analysed alongside the interview transcripts. Within the workshop, participants were asked to complete two questionnaires, the first regarding designer feedback on the sports design process model and the second regarding the potential development of the inclusive design framework. The workshop plan, consent forms, interview questions, questionnaires and visual aids is included in Appendix 3.

Activity	Who	How	Outcome	Relevance	Tools
Mapping out Helen Hamlyn Centre inclusive design process	Group task	A3 paper. Map out key stages, additional steps, iterations, methods, user involvement.	Detailed design process of a specific inclusive design process.	Used to compare with company design processes to understand differences between each and the impact an inclusive approach has on the design process. Will be used to determine the applicability of the sports design process model to inclusive design practice.	A3 paper, pens, post-its, workshop questions.
Discussion of sports design process model	Group task	Presentation of sports design process model and group discussion.	Understanding of the sports design process model. Identification of applicability to inclusive design.	Is the sports design process model suited to inclusive design practice, communication with clients or as a learning tool?	Presentation slides, print-out of slides, A3 paper.
	Individual task	Feedback sheets rating the sports design process model.	Identification of the applicability of the sports design process model to inclusive design practice.	How can the sports design process model be adapted to aid communication with clients or as an inclusive design learning tool?	Feedback forms.
Development of inclusive design framework	Group task	Sketching on paper or sports design process model print-out.	Potential outline of inclusive design framework – what format is useful, what will it contain?	Initial identification of how to present the final inclusive design framework.	Sports design process model print-out, paper, post-its, pens, questionnaire.

Table 6.1 – Overview of activities conducted within Helen Hamlyn Centre workshop

6.2.2. Results

The results section is structured according to the two main categories discussed during the workshop – best practice in inclusive design (practiced at the Helen Hamlyn Centre for Design) and feedback received on the sports design process model development for application within inclusive design practice.

Best practice in inclusive design

The first part of the workshop focused on identifying the inclusive design process carried out at the Helen Hamlyn Centre for Design, which would indicate best practice in inclusive design. Unlike the industry designers interviewed within Section 6.1 who did not use the term “inclusive design” due to negative perceptions from clients, the Helen Hamlyn Centre did use the term “inclusive design”. The design process (shown in Figure 6.4) followed by the Centre originated from the double diamond design process model (Design Council, 2005), but has been developed by the Helen Hamlyn Centre to better represent their design process. The design process is split into a research phase and a solution phase, with the designers reporting that the Centre spent greater time on the research phase compared to typical design companies in industry. In the early stages of the design process, designers at the Centre gathered as much user information as possible with methods typically involving observations and interviews with users, with the aim of verifying the nature of the design problem:

> *“It’s more talking to the users and compressing that information into a single question or direct question”.*

User involvement was continuous throughout the design process followed at the Helen Hamlyn Centre for Design, with the solution phase consisting of prototyping, user testing and feedback iterations.

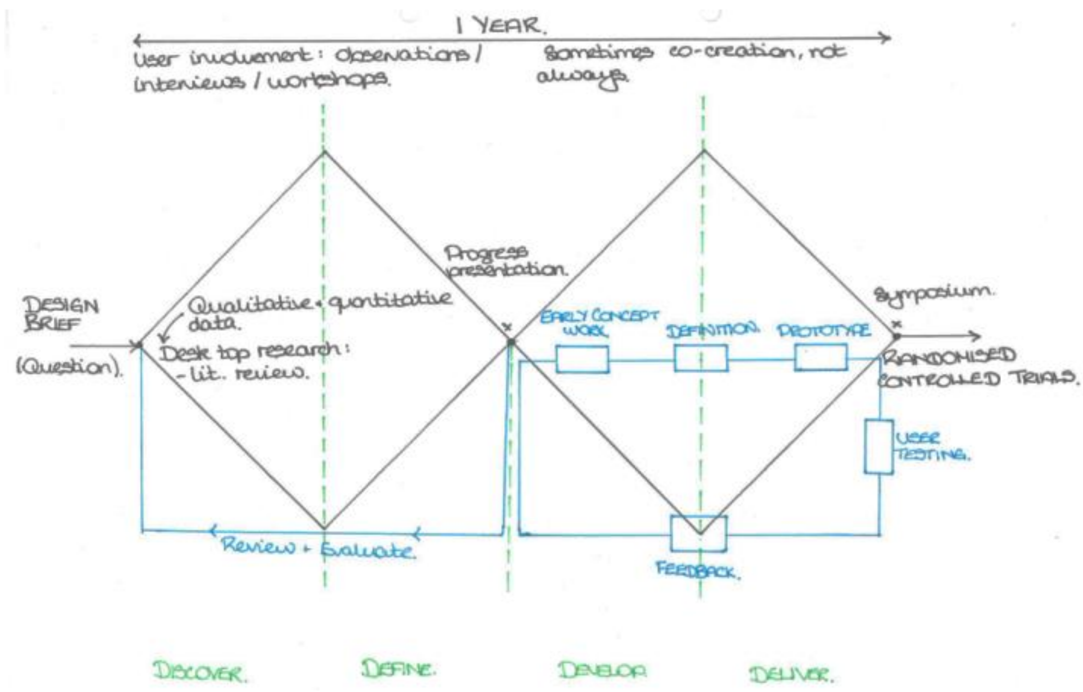


Figure 6.4 - Inclusive design process followed by the Helen Hamlyn Centre

User involvement occurred on a more regular basis throughout the design process followed by the Helen Hamlyn Centre compared to that observed for the product designers interviewed – where the product designers interviewed reported the level of user involvement being highly dependent on the client, designers at the Helen Hamlyn Centre reported involving users in every project. A range of diverse users were also included to ensure that the final design was as inclusively designed as possible:

> *"With users, we've tried to quite specifically be diverse with it – so people with arthritis, people with vision issues, parents with children, people using wheelchairs. And then anyone else we can get in that would be typical".*

User involvement was continuous throughout the design process, particularly in the early research stage:

> *"We involve them obviously throughout the research and observations and interviews, then we often do workshops to verify some of the insights that we observe and from the desk top research".*

During the research stage, designers were often involved in open interactions with users and talking to as many people as possible with a broad range of capabilities to help the designer understand the problem:

> *"I'd say every project involves users and it follows this pattern where at the beginning it's quite open – it's just generally talking about it, which probably involves more people as you try and understand. Then you start getting in key people around key issues and the key challenges".*

At the concept generation stage it was reported there were times when the user was involved:

> *"When you're sketching or developing the concepts, you have users involved. They can be quite creative".*

However, it was also reported there are times when the designers needed time to design by themselves:

> *"Sometimes it's appropriate to have users, but sometimes it's not and you need to just be a designer and design and then you go back to them and evaluate things".*

Users were involved extensively in the later stages of the design process once ideas were more developed. At this stage, the users involved were specific groups based on capability and diversity, to allow prototypes to be tested with the user group from where the idea originated. It was noted however, that the user recruitment process was often difficult and time consuming:

> *"Gathering users and gathering people is really time consuming and it often isn't given enough time or credit or resource".*

Sports model feedback and development

Feedback on the sports design process model itself was positive from all three designers involved in the workshop, with the visual presentation of the sports design process model well received:

> *"It's neat and you can grasp it in one visual".*

The iterative, cyclic representation of the sports design process model was considered to be more representative of the nature of inclusive design, in addition to the continual user involvement throughout the design process. Within the questionnaire, all three designers noted that while the importance of user involvement was illustrated within the sports design process model, additional material was needed to supplement this.

However, all three designers interviewed commented that the sports design process model would be of limited use to themselves as designers in inclusive projects or industry practice:

> *"Once you've gone through it, once you know it, you know it".*

This was in agreement with feedback gained from the industry designers.

The workshop participants agreed that with some development, the sports design process model would be highly useful as a communication framework to help the client understand the inclusive design process, which was again in agreement with comments made by the designers from industry:

> *"This is the most important role of something like this – to explain the role, to explain where you are, to explain what's going on and what's going to happen".*

> *"Designers know how to design, but for inclusive design, it's really important to have an educational role as well because you are designing with people who are not necessarily trained in design".*

Based on the feedback gained from the initial designer interviews, designers at the Helen Hamlyn Centre were asked the potential of the sports design process model to aid communication with the client within the inclusive design process. The designers at the Helen Hamlyn Centre reported that (like the designers interviewed from industry) the client often lacked knowledge of the design process in general:

> *"They maybe don't necessarily understand design at the beginning, then as we walk them through it's like a dialogue".*

> *"A lot of clients don't know the process we go through so in terms of that, the model could be used to educate them of your process".*

The educational potential of the sports design process model for inclusive design teaching to undergraduate students was also discussed by the designers due to the characteristics illustrated within the sports model:

> *"This would maybe be useful in education if I was talking to, lecturing or tutoring, I might use something like that. Because it's probably more accurate".*
>
> *"The graphic is avoiding that certain linear feel to it which is nice. It shows that things do go in circles and you do have to repeat stuff. It has a better representation or a closer representation of the realities of design".*

As this research focuses on inclusive design in industry, the potential educational benefits of this work are not explored further here. However, there is potential for future work to explore this area.

It was added that an indication of where the client should be involved in the design process would also be useful to ensure the client is aware of their role within the inclusive design process – potentially as a source of information or at key decision making points:

> *"It's almost like fading in from down here until the design review because when they come into a room cold they don't understand what's happened in the project… You can spend a lot of time with them asking the wrong questions".*

In terms of developing the sports design process model further into a framework to aid client communication within the inclusive design process, the following comments were made:

- *"I would say the biggest thing is communication, when is the design review, when does this break down into a space in time".*
- *"It's almost keeping it as a model and then somehow adding the layers to it but it's making sure that you're looking at the layers you want to see and not getting lost in heaps and heaps of data".*
- *"In terms of development with how users are integrated into the design spins – it's like probably rather than one section it's probably like small loops that sit all the way round".*
- *"I'm just imagining an interactive version of this where you can expand on things and what methods you are using and who is involved, etc."*

All designers indicated within the questionnaire that an interactive framework would be an appropriate format to develop the sports design process model further to facilitate designer-client communication within the inclusive design process and that they would use the framework if the discussed requirements were met. Figure 6.5 illustrates the requirements selected within the questionnaire by the designers that should be represented within the framework. User centred methods and user involvement were both vital to all designers, which is to be expected within an inclusive design process. Indication of client involvement was also selected by two designers, indicating that there is a need to make the client aware of their role within the inclusive design process. It was noted that the framework would have to be flexible depending on the nature of the project.

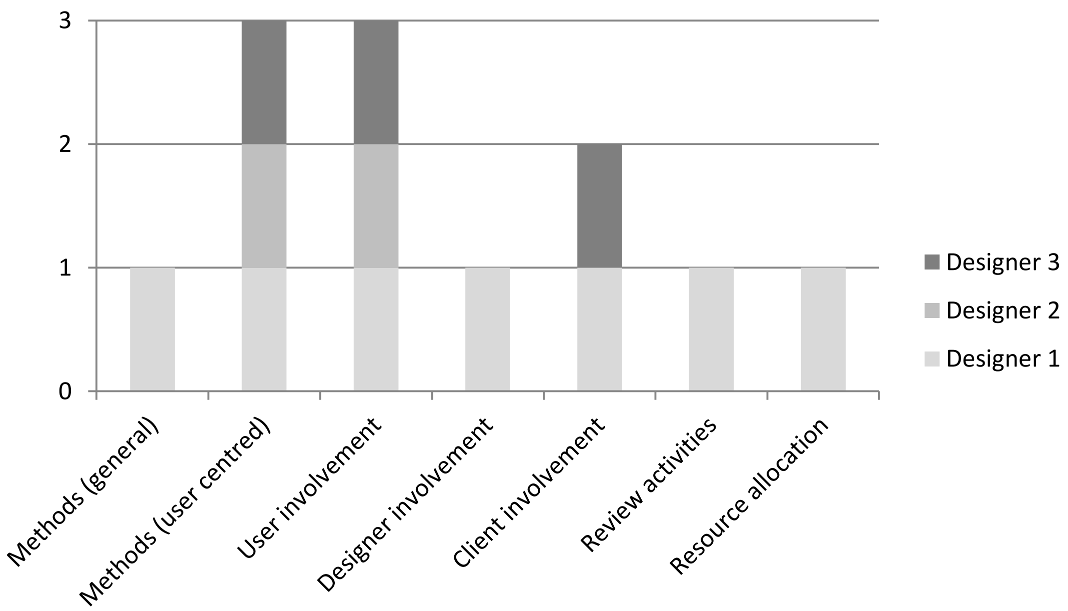


Figure 6.5 – Inclusive design framework requirements

6.2.3. Discussion

The discussion section follows a similar structure as before, discussing first inclusive design practice in relation to the Helen Hamlyn Centre for Design, followed by the feedback given on the sports design process model and its potential application within inclusive design practice.

User involvement in design practice

The reported levels of user involvement within the inclusive design process showed significant differences between standard design practice in industry and practice at the Helen Hamlyn Centre. While designers from industry (all with experience in inclusive and/or user centred design) reported low levels of user involvement and a lack of diversity of user capabilities, designers at the Helen Hamlyn Centre showed high levels of user involvement and wide diversity of user groups throughout their design process – it is expected this is due to designers at the Centre being more aware of how to implement inclusive design in addition to the emphasis the Centre places on the research aspect of a project. In contrast, user involvement in industry practice is determined by the client, who may not be aware of an inclusive design approach and its benefits. The user recruitment process is a core part of inclusive design to ensure that potential design solutions are tested and evaluated by appropriate user groups. The lengthy time process to locate appropriate user groups was also noted by Bruseberg and McDonagh-Philp (2002), who found that user groups were often not included in the design process due to recruitment difficulties.

Although this research did not assess the levels of success and inclusivity of the end products developed by the Helen Hamlyn Centre and the companies interviewed, the Centre has delivered a number of highly successful, inclusively designed products that have contributed to improving people's lives. It is therefore concluded that the design process followed by the Helen Hamlyn Centre for Design is successful in delivering inclusively designed products, in line with the needs of a range of diverse users.

No conclusions can be drawn regarding appropriate levels of user involvement throughout the design process as this study did not focus on the level of success of the final product. However, it is argued that the distinct lack of user involvement reported by the product design companies will severely impact the level of inclusivity and usability of the end product.

The design process followed by the Helen Hamlyn Centre for Design (which is considered a model representation of inclusive design practice) shows many parallels with the characteristics of the sports design process. These include the iterative nature of the design process, user involvement throughout the design process and physical interaction between the designer and the user, which are all core elements of both design approaches.

However, it was observed that while the Helen Hamlyn Centre involves a diversity of users throughout the design process, there is greater emphasis placed on the initial research stage of the design process, which may not be applicable to everyday product and inclusive design practice in industry.

Application of the process for designers

Findings from the workshop conducted with the Helen Hamlyn Centre indicate that the sports design process model would be of use to designers themselves only as a reference tool. Designers from the Centre commented that although they themselves followed an established design process that they were unlikely to change, a visual representation of the sports design process model on the wall of a design office could be a useful tool to allow designers to evaluate their progress throughout a project and could be used as a communication tool between designers to discuss project progress. This was also commented on by some of the product designers interviewed in Section 6.1, who felt that the sports design process model as it stands would be of most use as a reference tool and to aid project discussions between designers. Designers have an in-depth knowledge of the core stages of the design process, therefore do not need to rely on a high level representation of the design process in their daily practice.

It was concluded by all three designers involved in the workshop that the sports design process model could be extremely useful if developed further into a framework that would facilitate designer and client communication within the inclusive design process. The findings from the workshop are in agreement with the earlier designer interviews (see Section 6.1) that clients often do not understand the design process in general and findings from the literature review (Chapter 2) that clients to not understand the value of user involvement throughout the design process. It is therefore necessary to provide a means of enabling designers to educate the client on relevant aspects of the inclusive design process. Based on the feedback provided within the questionnaire, it is apparent that more detail is required to supplement the sports design process model in terms of illustrating the requirements of user involvement within the inclusive design process. While additional information would clutter the existing model, it was indicated that the developed framework should contain this detail.

To develop the sports design process model into a framework that would facilitate designer-client communication within the inclusive design process, the framework should indicate levels of client involvement to ensure they understand their role within the design process from the start. A core requirement of the framework that was identified as a result of the workshop was ease of interpretation. Clients are often ignorant of the design process, therefore it is essential to provide designers with a means of educating them of that process. As such, the framework must be simple enough that a client from a non-design background can easily understand it. However, in order to meet the needs of the designers, sufficient information must be included to illustrate the level of effort involved in the inclusive design process and a breakdown of aspects of the inclusive design process that are important to the designer – within inclusive design this is noted as user involvement throughout the design process, a diversity in the user groups involved and the need to iterate within design process stages to ensure the appropriate design solution is found.

6.3. Chapter Findings

Designers from industry reported low levels of user involvement within the design process, similar to the results reported from product designers interviewed in Chapter 4. However, those interviewed in Chapter 4 were traditional product designers. Those involved in this study had experience in inclusive and user centred design. The study found that in addition to low levels of user involvement, diversity in those user groups was also lacking. Reasons for this stemmed from the client rather than the designer. In contrast, designers at the Helen Hamlyn Centre reported much higher levels of user involvement within their design projects, focusing particularly on early user involvement in the research stage of the design process to ensure that appropriate insights were gained early but also to ensure that potential design solutions were tested and evaluated throughout the design process. The sports design process model (descriptive of sports design practice in industry) illustrates user involvement as central to, and throughout, the design process. Figure 6.6 illustrates approximate levels of user involvement throughout the design process for the Helen Hamlyn Centre, the industry designers interviewed in this chapter and the approximated levels of user involvement within the sports design process.

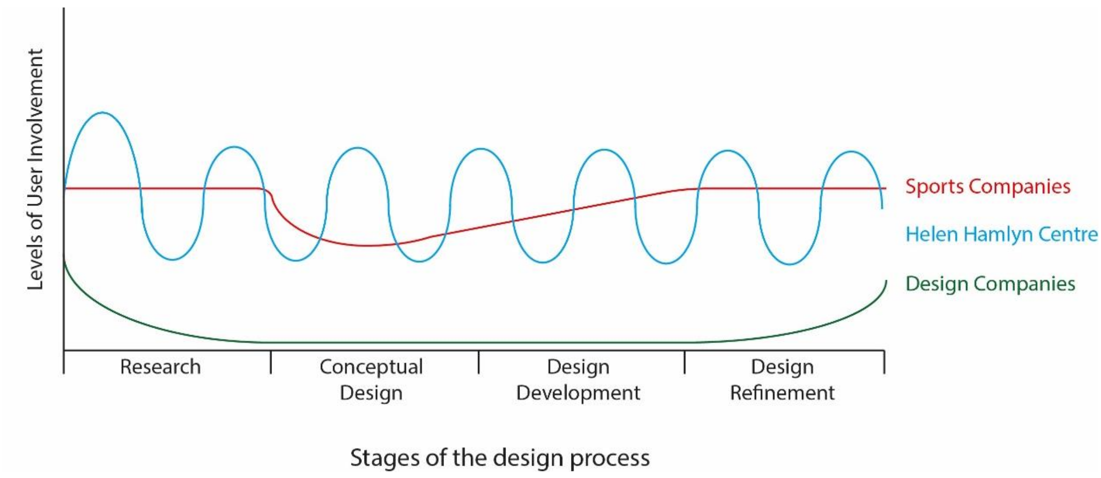


Figure 6.6 - Comparison of levels of user involvement within the design process

It is clear there are similarities between the inclusive design process followed at the Helen Hamlyn Centre for Design and the sports design process. Both are highly iterative and user centred – in the case of sports design, the user is involved continuously throughout the design project, while the Helen Hamlyn Centre places more emphasis on the early research phase while still involving the user throughout the design process. Like with sports designers, the designers at the Helen Hamlyn Centre also interact directly with the user.

The design process followed by the Centre is thought to be representative of "best practice" inclusive design. In contrast, the product designers from industry reported that their processes often lacked user involvement, although they aspired to follow a process similar to the one reported by the Helen Hamlyn Centre, with higher levels of user engagement throughout the design process. It is concluded that good inclusive design practice in industry should aim for a process similar to that of the sports design process model – while the design process followed by the Helen Hamlyn Centre indicates good inclusive design practice, the high level of emphasis placed on the research aspect may not be achievable within industry practice. The sports design process indicates a continual level of user involvement within an iterative design process, which is descriptive of sports design practice in industry and achievable within the constraints of industry practice.

It is acknowledged that in reality, an inclusive design approach is often made difficult by client barriers as discussed in the interviews with industry designers. This is in agreement with the findings of the literature review (Chapter 2), where the client was often cited as a barrier to inclusive design uptake. This study has identified that this is due in part to a lack of understanding of the inclusive design process by the client.

Feedback gained within this study from both designers within industry and inclusive design experts at the Helen Hamlyn Centre for Design indicate that there need for designers to be able communicate the inclusive design process to the client. It is recommended that an interactive framework could be used to develop the sports design process model further for the use of facilitating designer-client communication within the inclusive design process. This interactive framework would allow additional information to be added to the sports design process model to communicate the needs of the inclusive design process without "cluttering" the original sports design process model. Based on the recommendations provided by those involved in the study, a requirements list was prepared, identifying what the designers had requested the framework contain to ensure it would facilitate designer-client communication within the inclusive design process. Following analysis of the interview transcripts, the requirements list was refined with the final version listed here:

Inclusive Design Interactive Framework Requirements:

Visual Representation:

Iterations:

- Place emphasis on iterations at each stage of the process – prototyping and testing.
- Show iterations but also forwards progression – too many iterations can scare the client.
- Design development should be an iterative process of prototyping and testing.
- Illustrate sign-off points at each stage prevents backwards iterations.

Design outputs:

- Show outputs from each stage of the process.
- Illustrate how activities add value to the design process.
- Designers want to show the level of effort involved throughout the process.

Whole model representation:

- Whole process and additional activities all must be visually communicated.
- Visually illustrate activities/methods/etc. that come within each stage.
- Do not add additional information to the model.
- Process should be broken down into constituent parts.
- Illustrate the model on one page in one visual.
- Try to create a culture through visual tools.
- The process must be understandable to those not from a design background.
- The model must be understood immediately without explanation (by the designer).

Research:

- Show that a larger budget is often needed for research.
- Show that research runs all the way through a project.

Design brief:

- Illustrate that the design brief is used as a reference point throughout the design process.
- The brief should be shown as a dynamic document.

- Illustrate that research is an iterative process until designers and clients are happy with the brief.

Client involvement:

Design brief:

- Show that client agreement is needed over the content of the design brief.
- Show that the client should be involved throughout the design process to answer specific questions.

Design process:

- Illustrate it is iterative but progresses forwards – clients assume the design process is linear.
- The model must communicate the design process to someone from a non-design background.
- Must illustrate to the client where time and resources go.

Client funding:

- Clients allocate funding therefore emphasise where designers want funding to be allocated across the process and where it would be of most use.
- Clients want to see the value in each stage/activity.

User involvement:

- Show that user involvement should start as early as possible.
- Emphasise high level of user involvement throughout the process.
- Illustrate the value of user involvement.
- Show that users not involved in the design process are generally ignored.
- Show that design decisions are made based on user evaluation and testing.
- Show that user involvement must be with the right people to get the right insights.
- Show that user recruitment takes time.

6.4. Further Work

This chapter reports on feedback from product designers in industry and inclusive design experts at the Helen Hamlyn Centre for Design regarding the applicability of the sports design process model to inclusive design practice. Based on the findings of Chapters 4 and 5, the sports design process is highly iterative, with a focus on user involvement throughout the design process and designer interaction with the user. The literature review (Chapter 2) and the study reported within this chapter indicate that the inclusive design process is also highly iterative and should involve the user throughout the design process with the designer actively engaged with the user. These similarities between sport and inclusive design indicate that there is potential for the sports design process to aid inclusive design practice.

The findings from this chapter indicate that an interactive framework, developed from the sports design process model would facilitate inclusive design implementation in industry by aiding designers' communication with the client throughout the inclusive design process. Based on the sports design process model presented in Chapter 5, along with the designers requirements for the framework development constructed as a result of this study, there is a need to develop the sports design process model further to construct this framework. Chapter 7 will discuss the development of this interactive framework based on the requirements listed in this chapter. Chapter 8 will report on the validation of the interactive framework, which provides a solution to the third research question presented within this thesis – **how is the sports design process applicable to inclusive design?**

Chapter 7 – Development of the inclusive design framework

Chapter 6 identified that the sports design process model would, if developed further into an interactive framework, facilitate designer-client communication within the inclusive design process. The client is often cited as a barrier to inclusive design uptake (published work cited in Chapter 2 includes Bruseberg & McDonagh-Philp, 2002; Dong, 2004; Goodman-Deane, et al. 2010; which in agreement with the findings from Chapter 6 of this thesis) as they often set budget and time constraints, in addition to identifying the target user. However, the client is often unaware of the inclusive design process, particularly the effort involved and where the designer requires time and costs to be allocated. The output of Chapter 6 presents the requirements from designers that should be taken into consideration when developing the interactive framework to facilitate designer-client communication within the inclusive design process.

This chapter reports one part of Study 4, which goes some way to providing a solution to answer the third research question – **how is the sports design process applicable to inclusive design?** This chapter will report on the development of an interactive framework that is based on the sports design process model, which visually represents some of the core characteristics of the inclusive design process – an iterative design process with user involvement throughout and direct designer interaction with the user. The framework will facilitate designer-client communication of the inclusive design process by building on these characteristics to provide an interactive framework that will enable the designer to educate the client of the inclusive design process. Chapter 8 will report on the second part of Study 4, where the interactive framework is validated and the final framework is presented.

This chapter is structured as illustrated in Figure 7.1. Following the introduction to the chapter, the process of generating concepts for the framework based on the requirements list provided in Chapter 6 is discussed. These concepts are then progressed through an iterative process of evaluation against those requirements and further development. A prototype of the interactive framework is piloted with six researchers (three from design backgrounds and three with no prior experience of the design process) to assess ease of navigation through the framework. Further refinements are made to the framework based on feedback received. The refined prototype of the interactive framework is then presented.

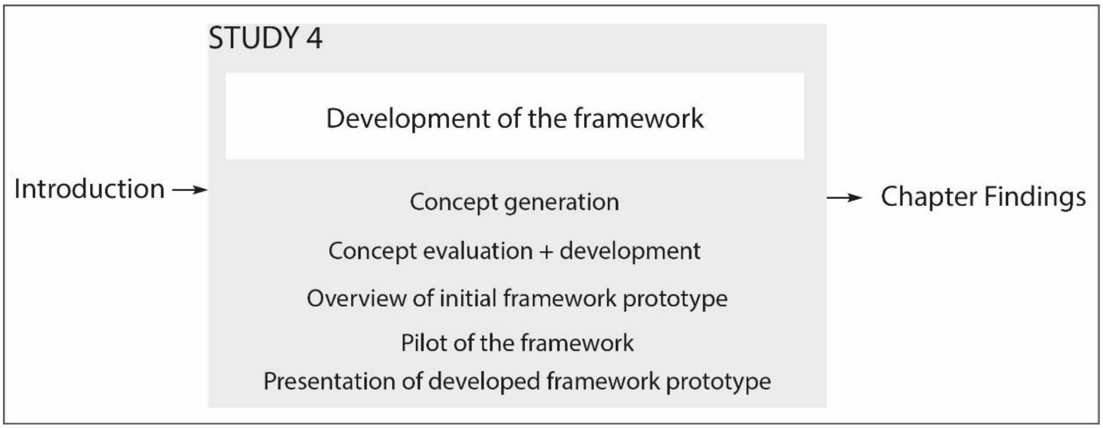


Figure 7.1 - Structure of Chapter 7

7.1. Development of the framework

The development of the interactive framework followed the core stages of a typical design process as illustrated in Figure 7.2. Study 3 (Chapter 6) formed the ‘research’ stage of this design process, where the needs of the designers (the users) were understood. The ‘specification’ was the output of Chapter 6, where the needs of the designers were translated into requirements. These requirements were then used as the basis for generating and evaluating concepts – this ‘conceptual design’ stage is reported within Section 7.2, where initial concepts for the content and structure of the interactive framework were sketched. The construction, piloting and development of a prototype of the interactive framework form the ‘design development’ stage of the process and are reported within this chapter. The ‘design refinement’ stage is reported within Chapter 8, where the prototype of framework is validated with designers and clients from industry before final refinements are made based on their feedback. The output is a validated interactive framework to facilitate designer-client communication within the inclusive design process.

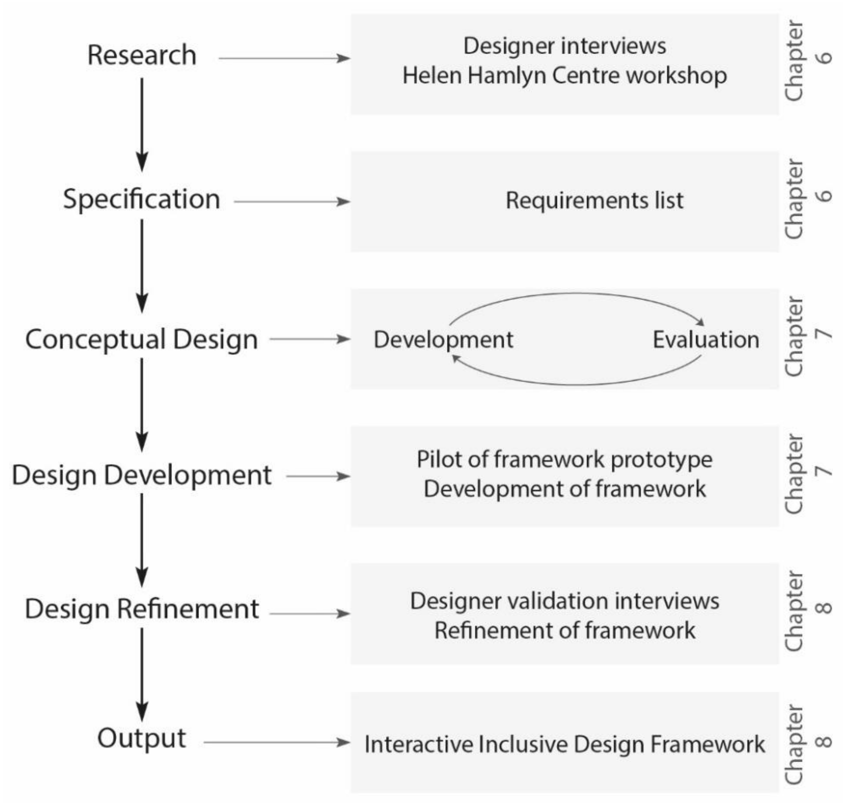


Figure 7.2 – Design process followed for the development of the interactive framework

7.2. Concept generation

Following the requirements of the designers reported in the requirements list (Chapter 6), a brainstorming exercise was undertaken by the researcher using the sports design process model as a template for generating ideas to address different categories within those requirements. A total of 18 concepts were generated as a result of the brainstorm exercise – an example of a selection of these concepts is illustrated in Figure 7.3. The complete results of the brainstorm exercise are shown in Appendix 4.

The results from the brainstorming exercise were assessed against the requirements list in terms of feasibility. An iterative process, consisting of pulling ideas generated from the brainstorm exercise and referring back to the requirements list to ensure each concept met the needs identified by the designers, was carried out. The output was four developed concepts of the framework – an example of one of these more developed concepts is shown in Figure 7.4. All four developed concepts are included in Appendix 4.

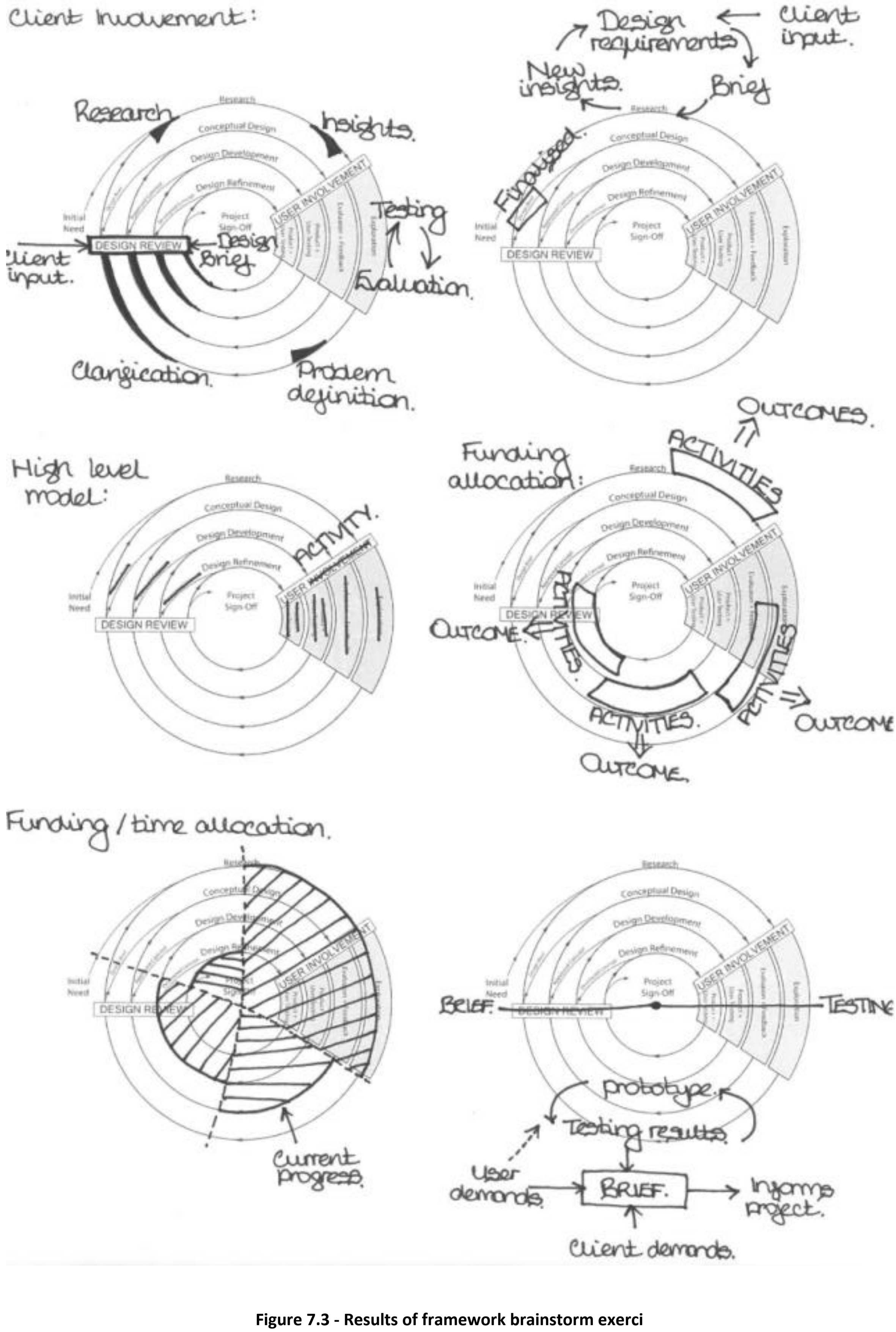


Figure 7.3 - Results of framework brainstorm exerci

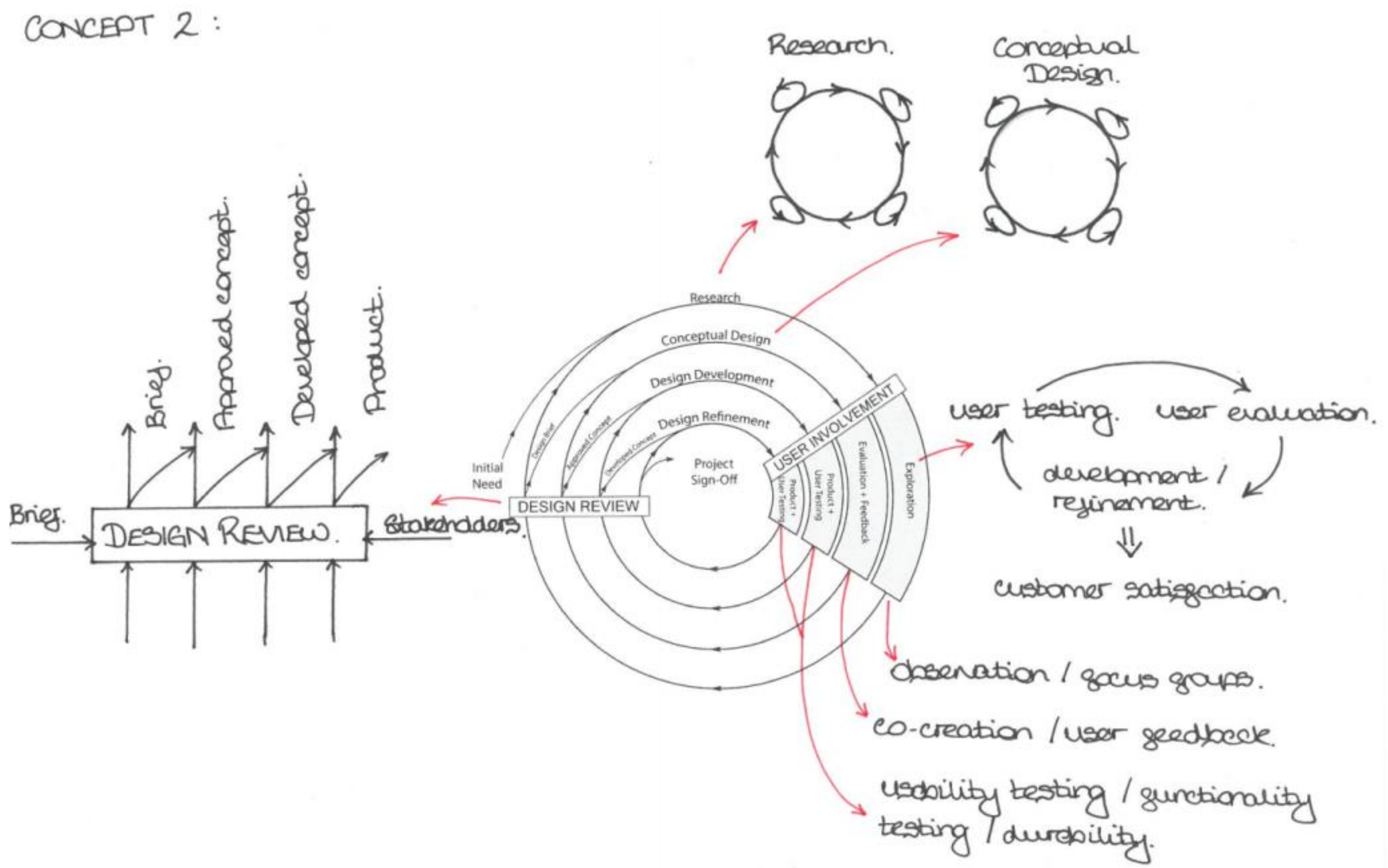


Figure 7.4 - Development of brainstorm concepts

The four developed concepts were evaluated by the researcher against the requirements specified by the designers within Chapter 6. Two concepts were eliminated as they did not adequately meet the requirements specified by the designers. The two remaining concepts were selected as potential solutions that would be progressed forwards. These concepts are illustrated in Figures 7.5 and 7.6.

Within both Figures 7.5 and 7.6, the sports design process model at the centre of the image illustrates the "home" screen for the interactive framework. The hatched pink boxes around the core stages of the process, user involvement, the iterative circles for each design cycle and the design review stage represent areas within the framework that can be "selected" by the user of the framework. A link is provided to new pages that contain further detail for each respective area. Green hatching allows the user to gain further detail on sub-sections of these areas.

Figure 7.5 (Concept 1.0) allows the user to select the area over the core stages of the process model and represents them in a high level, linear manner. The conceptual design phase can be selected to illustrate further detail for that phase. The area of user involvement within the design process can be selected and illustrates recruitment time that must be allocated to recruit potential user groups within the inclusive design process. The iterative nature of user involvement throughout the inclusive design process – user testing, evaluation and further development/refinement – is also illustrated. The lower section of the image can be selected to illustrate the iterations within the inclusive design process that occur throughout each process stage. The design review stage can be selected and illustrates the outputs of each stage of the process, in addition to the need to evaluate those outputs against the design brief. The design review is a decision making point within the inclusive design process, where stakeholders are involved in deciding whether the project can progress to the next stage of the process or whether a stage should be repeated.

Figure 7.6 (Concept 2.0) allows each of the four core design process stages to be selected individually and illustrates the iterations within that stage. The green hatching for each stage name can then be selected to provide more detail on the nature of the iterations at each stage. The section of the process model that illustrates user involvement within the inclusive design process can be selected, and illustrates the nature of user involvement within each stage of the process, detailing how the user is involved and how this impacts on the inclusive design process. For example: user involvement within the research phase of the inclusive design process is typically exploratory. It is anticipated that the designer can input specific methods at this point, customised to each project. This exploratory research helps the designer to identify user requirements, which in turn influence the design brief, which is referred back to throughout the design process. This is an iterative process until the design brief captures enough detail and the project progresses to the next stage. The design review stage within the "home screen" can be selected and illustrates the output from each stage of the inclusive design process, with the design brief referred to and informing design decisions made at the review. Stakeholders are again involved within the decision making process. The stakeholders themselves can be selected and the next level of the framework illustrates anticipated client involvement throughout the inclusive design process. Designers encourage the client to remain up-to-date throughout the process so they can make informed decisions at the review stage. Finally, the iterative nature of the inclusive design process can be selected, with a high level representation of the activities that should iterate within each design phase shown.

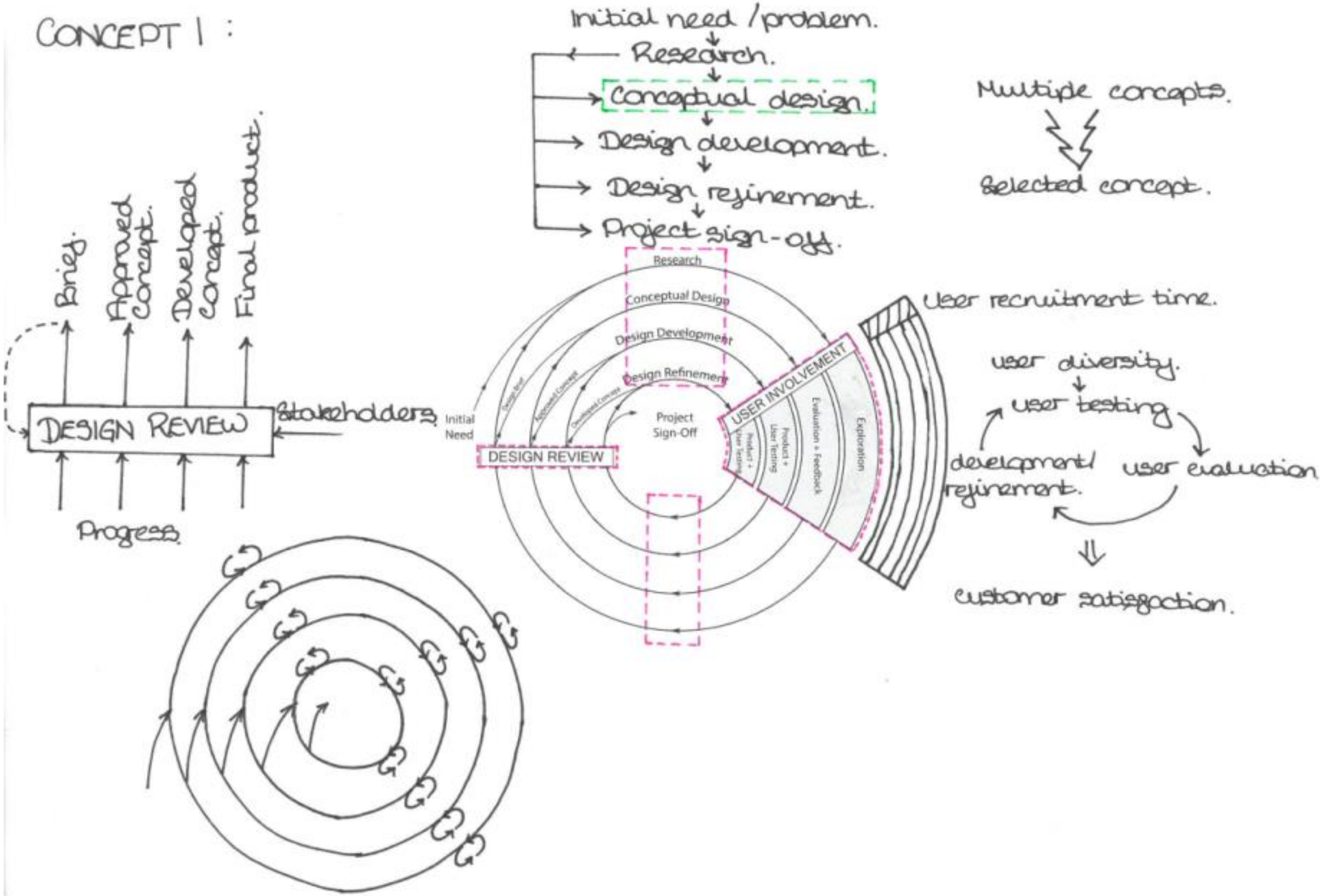


Figure 7.5 - Developed framework concept 1.0

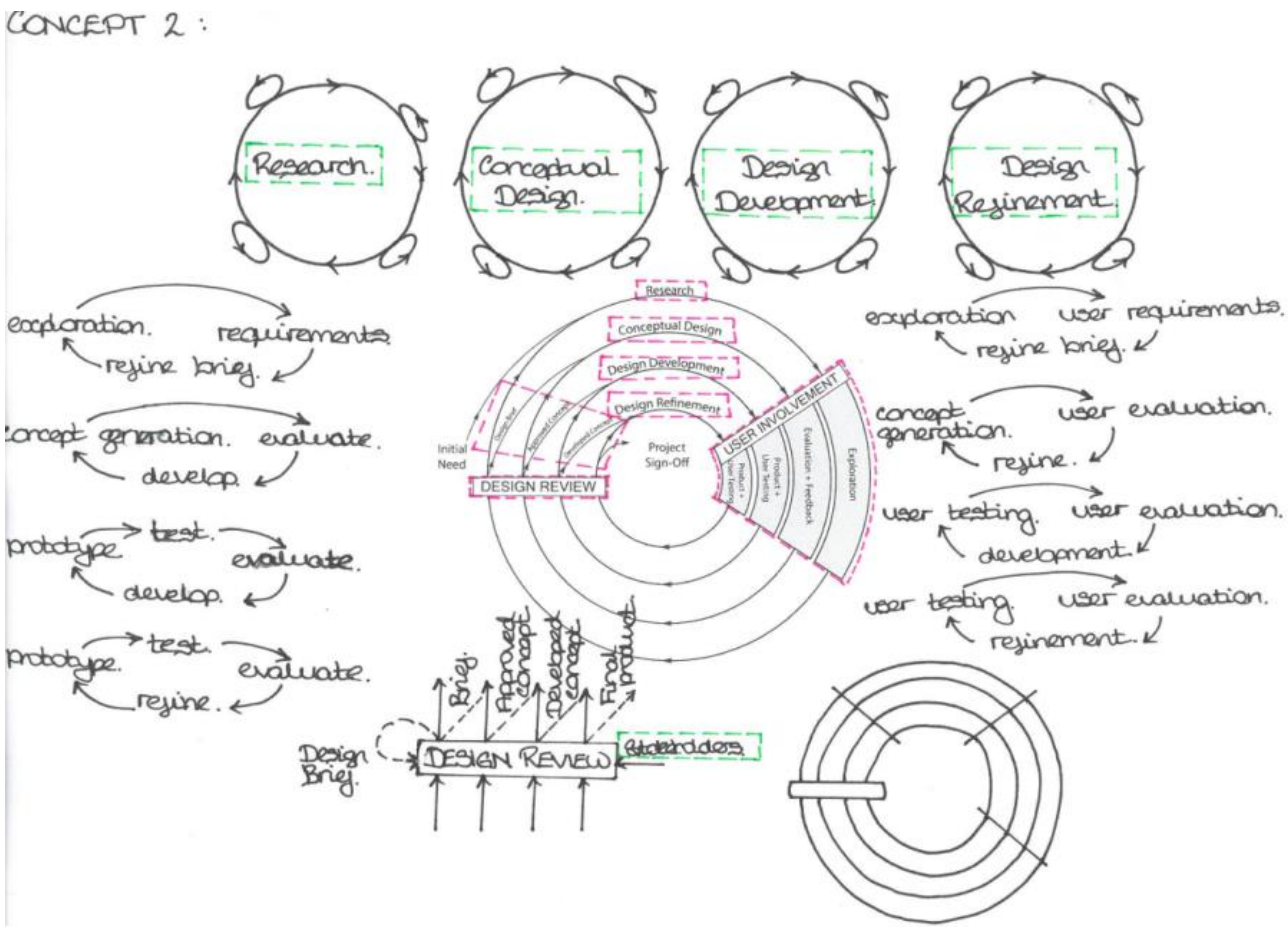


Figure 7.6 - Developed framework concept 2.0

7.3. Concept evaluation and development

Both the concepts 1.0 and 2.0 (shown in Figures 7.5 and 7.6 respectively) were evaluated in a matrix against the requirements list presented in Chapter 6. Concepts were rated according to the following criteria:

- **Y**: The concept met the requirement.
- N: The concept did not meet the requirement.
- **S**: The concept met the requirement to some extent but was not immediately clear.
- **NA**: It was not possible for the researcher to assess this. For example: for the requirement "must communicate the design process to someone from a non-design background" would require further investigation once the framework was in a more developed state.

Table 7.1 shows the summary of the results from matrix evaluation of the two concepts against the designer's requirements (as reported in Chapter 6). For the 34 requirements, it was concluded that five of the criteria could not be assessed by the researcher alone – further interviews with both clients and designers would have to be carried out. Concept 1.0 met 12 of the requirements and a further 7 to some extent. 10 requirements were not met by the concept. Concept 2.0 met 18 requirements and a further 5 to some extent. 6 requirements were not met. Table 7.2 illustrates the full matrix, showing the results for two concepts against the requirements.

Concept 1.0	**Concept 2.0**
12 requirements were met	18 requirements were met
7 requirements were partially met	5 requirements were partially met
10 requirements were not met	6 requirements were not met

Table 7.1 – Summary of results for evaluation of concepts 1.0 and 2.0

Requirements	Concept 1.0	Concept 2.0
Iterative process of prototyping and testing	S	Y
Show iterations but also a forwards progression	Y	Y
Design development is an iterative process of prototyping and testing	N	Y
Sign-off points at each stage prevents backwards iterations	N	Y
Show outputs from each stage of the process	Y	Y
Illustrate how activities add value to the design process	N	N
Designers want to show the level of effort involved throughout the process	S	Y
Whole process and additional activities all must be visually communicated	S	S
Visually illustrate activities/methods/etc. that come within each stage	N	N
Do not add additional information to the model	Y	Y
Process should be broken down into constituent parts	Y	Y
Illustrate the model on one page in one visual	-	-
Create a culture through visual tools	-	-
The process must be understandable to those not from a design background	-	-
Model must be understood without explanation	-	-
A larger budget is often needed for the research	N	N
Research runs all the way through a project	Y	S
Design brief is used as a reference point throughout the design process	Y	Y
The brief should be a dynamic document	N	S
Research is an iterative process until designers and clients are happy with the brief	S	Y
Client agreement is needed over the content of the design brief	Y	Y
The client should be involved throughout the process to answer specific questions	N	Y
Clients assume the design process is linear – illustrate it is iterative but progresses forwards	Y	Y
Must communicate the design process to someone from a non-design background	-	-
Illustrate to the client where time and resources go	S	S
Emphasise where designers want funding to be allocated	N	N
Clients want to see tangible outcomes and value for money	S	Y
User involvement should start as early as possible	Y	Y
Emphasise high level of user involvement throughout the process	Y	Y
Illustrate the value of user involvement	Y	S
Users not involved in the design process are generally ignored	N	N
Design decisions are made based on user involvement and the project progresses	S	Y
User involvement must be with the right people to get the right insights	N	N
User recruitment takes time	Y	Y
YES	**12**	**18**
NO	**10**	**6**
SOME	**7**	**5**
N/A	**5**	**5**
Total	**34**	**34**

Table 7.2 - Matrix evaluation of concepts 1.0 and 2.0

Following the evaluation of concepts 1.0 and 2.0, each concept was developed further to address more of the requirements specified by the designers. The strengths of each concept were kept (or improved on) while weaknesses were targeted in each for improvement. Figures 7.7 and 7.8 illustrate the developments made to each of the concepts.

Figure 7.7 shows concept 1.1 (the development of concept 1.0 shown in Figure 7.5). The concept was developed to better represent the iterative nature of inclusive design practice, the activities involved at each stage of the inclusive design process and the level of effort involved at each stage of that process. There was a need to illustrate that the design brief was a dynamic document, evolving throughout the design process. The concept now shows the outputs of user involvement influencing the development of the brief at all stages of the inclusive design process, with that design brief influencing the decision making process at the design review stage. Client input is also illustrated within the design review stage to ensure clients are aware of their role and involvement in the decision making process.

Figure 7.8 shows concept 2.1 (the development of concept 2.0 shown in Figure 7.6). Like concept 1.1, more detail has been added to illustrate that research should run throughout the inclusive design process, with new insights often gained as a result of evaluation. Changes were also made to the representation of user involvement within the design process, illustrating how the user influences the outcome of each stage of the inclusive design process.

Neither of the developed concepts illustrates the activities and methods within the inclusive design process – designers had previously stated this would deter them from using it. Individual methods were therefore not included in the framework, but it is proposed that there is scope for designers to add this detail on a project-by-project basis. The nature of the user groups involved in the inclusive design process is also not represented here as this will change depending on the nature of the project. Like the design methods, this is likely to be added by the designer for individual projects. However, as the interactive framework is representative of inclusive design practice, diversity in the user groups involved is acknowledged. Allocation of budget is not illustrated within either concept – this would require input data from designers and the study did not investigate how designers would want budget allocation represented. It was therefore concluded that allocation of budget was out-with the scope of the framework. However, the framework can be used to aid budget allocation discussions by breaking down the inclusive design process.

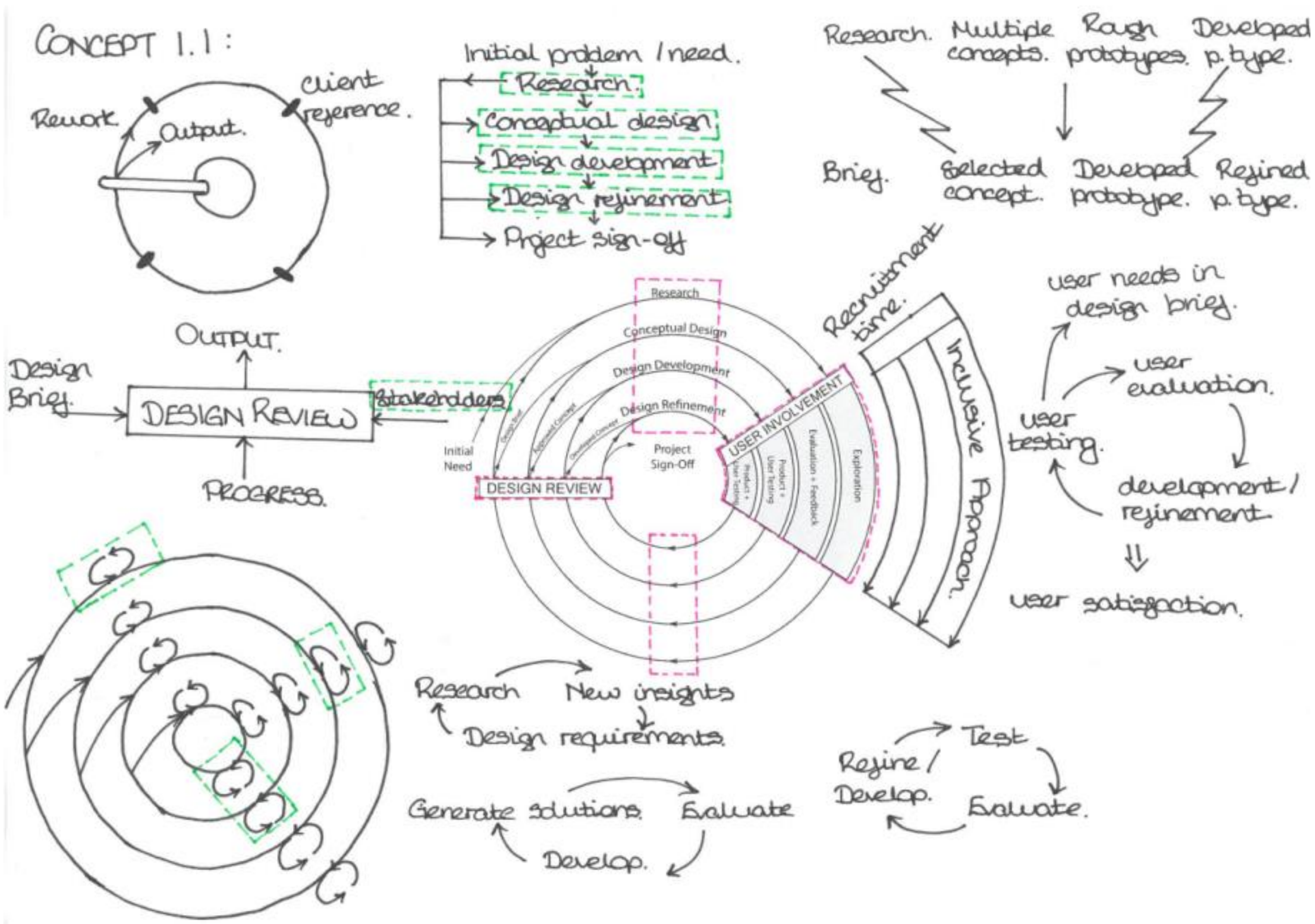


Figure 7.7 - Developed framework concept 1.1

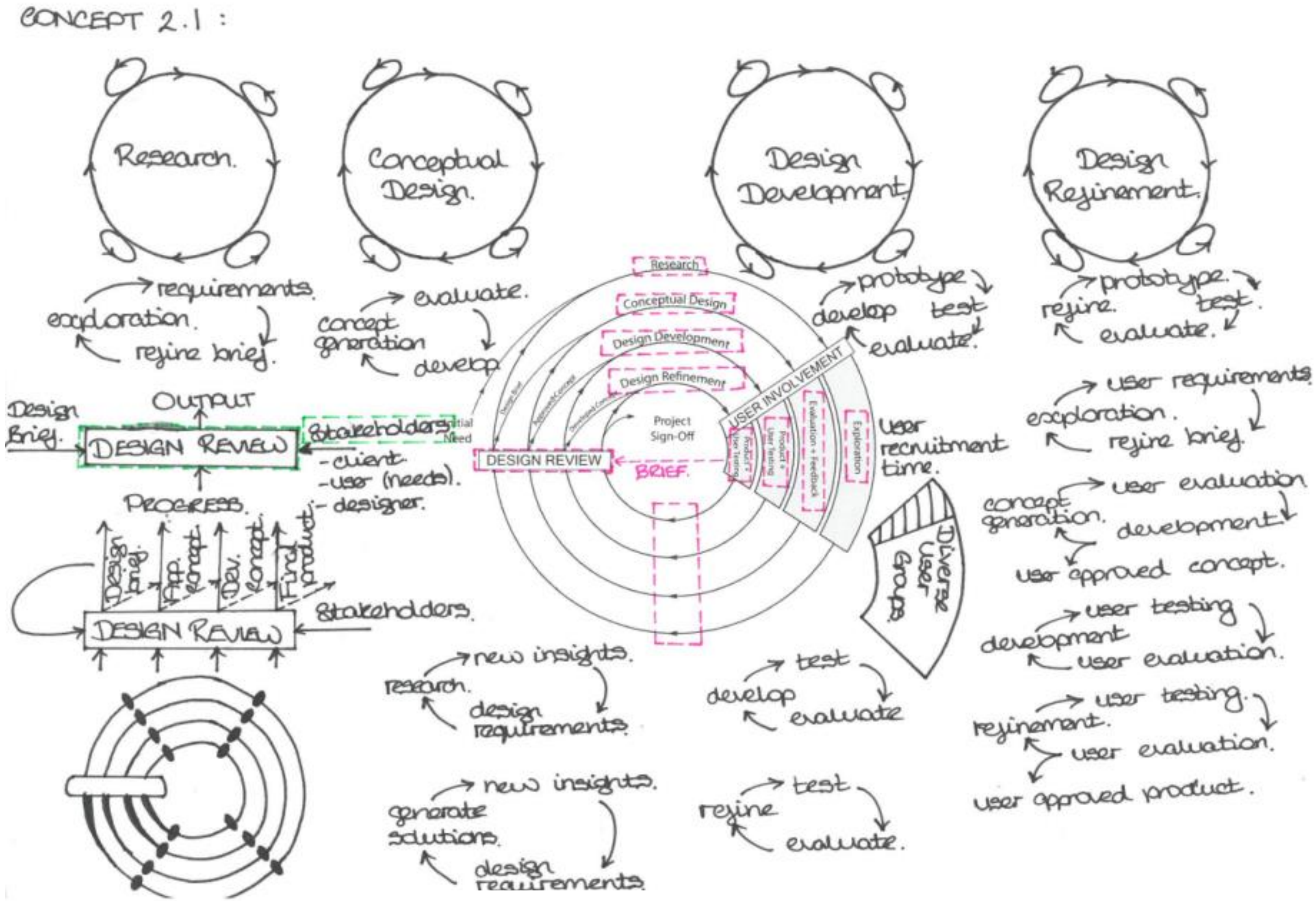


Figure 7.8 - Developed framework concept 2.1

The matrix was repeated using the same requirements as before, against which the concepts were evaluated. Table 7.3 summarises the results from the previous matrix (concepts 1.0 and 2.0), with the results of concepts 1.1 and 2.1 added. As before, of the 34 requirements, it was concluded that five of the criteria could not be assessed by the researcher alone. For the remaining 29 requirements that concepts were assessed against, the results for concepts 1.1 and 1.2 are shown in addition concepts 1.0 and 2.0 to show improvements between the concepts. Concept 1.1 was improved on to meet 19 requirements and a further 4 to some extent. 6 requirements were not met, compared to 10 for concept 1.0. Concept 2.1 was improved on to meet 22 requirements and a further 2 to some extent. 5 requirements were not met, compared to 6 for concept 2.0. The full matrix is shown in Table 7.4.

Concept 1.0	Concept 1.1	Concept 2.0	Concept 2.1
12 requirements were met	19 requirements were met	18 requirements were met	22 requirements were met
7 requirements were partially met	4 requirements were partially met	5 requirements were partially met	2 requirements were partially met
10 requirements were not met	6 requirements were not met	6 requirements were not met	5 requirements were not met

Table 7.3- Summary of results for evaluation of concepts 1.1 and 2.1

Requirements	Concept 1.0	Concept 1.1	Concept 2.0	Concept 2.1
Iterative process of prototyping and testing	S	Y	Y	Y
Show iterations but also a forwards progression	Y	Y	Y	Y
Design development is an iterative process of prototyping and testing	N	Y	Y	Y
Sign-off points at each stage prevents backwards iterations	N	S	Y	Y
Show outputs from each stage of the process	Y	Y	Y	Y
Illustrate how activities add value to the design process	N	N	N	S
Designers want to show the level of effort involved throughout the process	S	Y	Y	Y
Whole process and additional activities all must be visually communicated	S	S	S	Y
Visually illustrate activities/methods/etc. that come within each stage	N	N	N	N
Do not add additional information to the model	Y	Y	Y	Y
Process should be broken down into constituent parts	Y	Y	Y	Y
Illustrate the model on one page in one visual	-	-	-	-
Create a culture through visual tools	-	-	-	-
The process must be understandable to those not from a design background	-	-	-	-
Model must be understood without explanation	-	-	-	-
A larger budget is often needed for the research	N	N	N	N
Research runs all the way through a project	Y	Y	S	Y
Design brief is used as a reference point throughout the design process	Y	Y	Y	Y
The brief should be a dynamic document	N	Y	S	Y
Research is an iterative process until designers and clients are happy with the brief	S	Y	Y	Y
Client agreement is needed over the content of the design brief	Y	Y	Y	Y
The client should be involved throughout the process to answer specific questions	N	Y	Y	Y
Clients assume the design process is linear – illustrate it is iterative but progresses forwards	Y	Y	Y	Y
Must communicate the design process to someone from a non-design background	-	-	-	-
Illustrate to the client where time and resources go	S	S	S	S
Emphasise where designers want funding to be allocated	N	N	N	N
Clients want to see tangible outcomes and value for money	S	S	Y	Y
User involvement should start as early as possible	Y	Y	Y	Y
Emphasise high level of user involvement throughout the process	Y	Y	Y	Y
Illustrate the value of user involvement	Y	Y	S	Y
Users not involved in the design process are generally ignored	N	N	N	N
Design decisions are made based on user involvement and the project progresses	S	Y	Y	Y
User involvement must be with the right people to get the right insights	N	N	N	N
User recruitment takes time	Y	Y	Y	Y
YES	**12**	**19**	**18**	**22**
NO	**10**	**6**	**6**	**5**
SOME	**7**	**4**	**5**	**2**
N/A	**5**	**5**	**5**	**5**
Total	**34**	**34**	**34**	**34**

Table 7.4 - Matrix evaluation of concepts 1.0, 1.1, 2.0, 2.1

Based on the results of the matrix evaluation shown in Table 7.4, it was concluded that concept 2.1 was the stronger of the concepts and would be continued to form the basis of the interactive framework. Concept 2.1 successfully met 22 of the 29 requirements it could be evaluated against at this stage, in addition to meeting a further 2 to some extent. In contrast, Concept 1.1 met 19 of the requirements and a further 4 to some extent. The requirements that concept 2.1 did not meet were considered to be out-with the scope of the framework at this point, as discussed below:

- Visually illustrate the activities/methods/etc. that come within each stage of the process: while this was considered to be of benefit to designers, it was also commented on by designers in Chapter 6 that too much detail and structure would deter them from using the framework. As such, the framework will be developed to allow designers to input their own methods and activities on a project-by-project basis. However, the framework itself will not illustrate specific design activities.
- A larger budget is often needed for research: the framework does not illustrate budget as there was insufficient information collected from the interviews to determine the budget split over the design process. This is also project specific therefore cannot be accurately illustrated within a generic overview of the design process.
- Emphasis on where designers want funding to be allocated: as stated above, there was insufficient data collected regarding project budgets, in addition to budgets being project specific, therefore cannot be accurately illustrated within a generic overview of the design process.
- Users not involved in the design process are generally ignored: although this was not specifically illustrated within the framework concepts, there is emphasis placed on continual involvement of users and diversity in those user groups.
- User involvement must be with the right people to get the right insights: as above, the framework emphasises continual involvement of users throughout the inclusive design process and diversity in those user groups.

Concept 2.1 was progressed to form a mind map of how the interactive framework would potentially work, as illustrated in Figure 7.9. As in the previous sketches, the sports design process model illustrated at the centre of the mind map, would form the "home screen" image of the framework – referred to as level 0. The four areas highlighted in pink (core stages of the process, user involvement, iterations and design review) can be selected by hovering the cursor over the pink box outlining those stages to provide more detail on each – level 1. These four areas were identified within the designer interviews (Chapter 6) as being core characteristics of both the sports design process model and the inclusive design process. The pink lines show how each of these four areas on the sports design process model would link within the interactive framework to provide a breakdown of each of those parts. Within level 1, there are areas within each image, highlighted in green that can be selected to provide further detail on each area. The green lines in Figure 7.9 illustrate the links between the areas shown in level 1 and the breakdown of each of these areas (level 2) within the interactive framework. The lowest level of the framework (level 2) is shown within Figure 7.9 outlined in purple and provides additional detail for some of the areas shown in level 1.

An example of how the interactive framework allows the user to move through each of the levels is provided: on the central sports design process model (level 0), user involvement throughout the process is highlighted in pink. By selecting this area, the designer has the option to select the type of user involvement required for each of the four stages of the design process (level1) – exploratory for research, evaluation and feedback for conceptual design, product and user testing for design development and refinement. By selecting any of these four stages, the framework provides a link to the purple boxes (level 2) where more detail is provided on the nature of user involvement within each of these stages – for example: within research, a range of user groups are involved in exploratory research to understand their requirements. These requirements are used to inform the design brief, with this process repeated until the designer fully understands the user groups they are designing for.

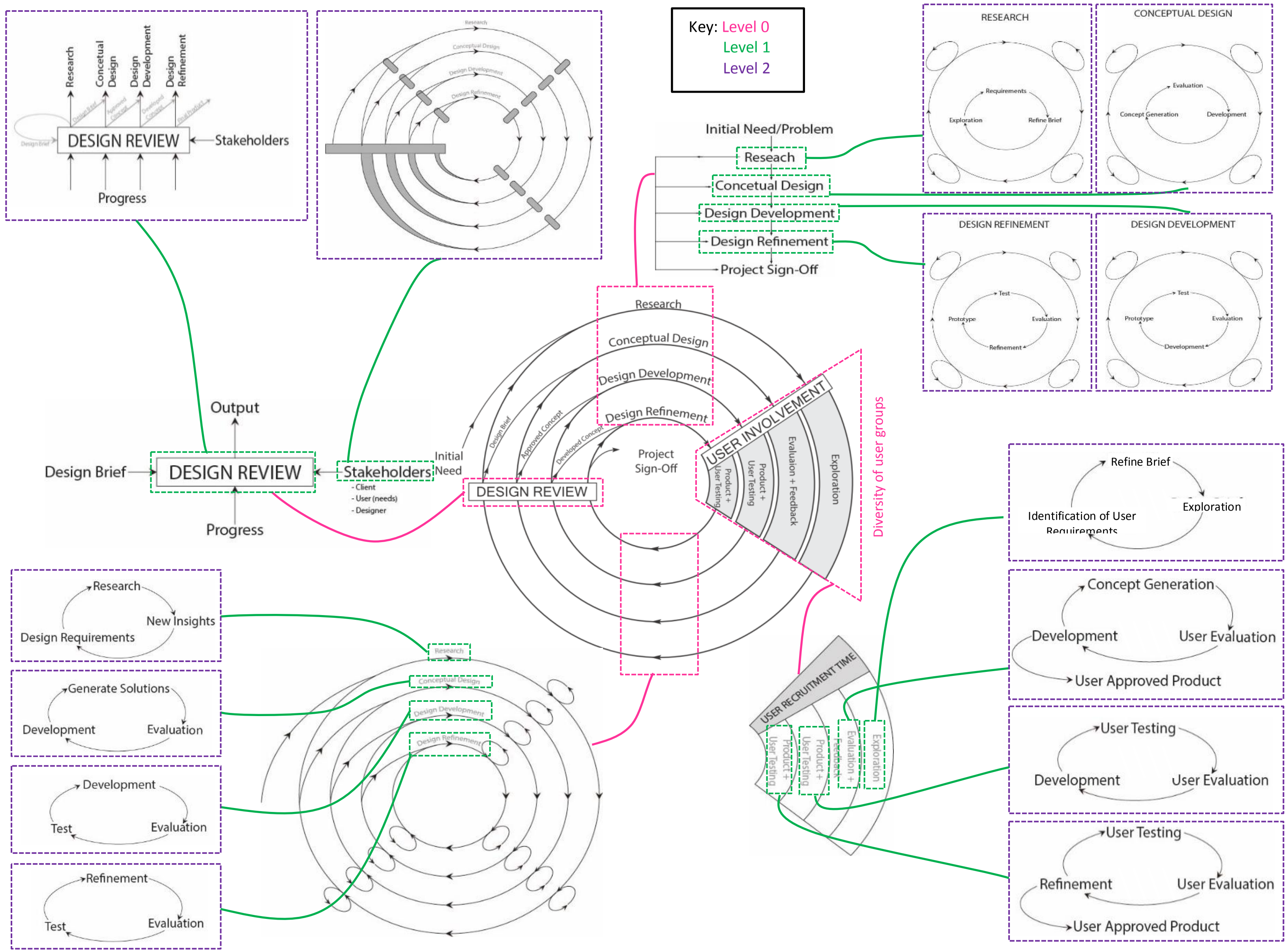


Figure 7.9 – Mind map of software interface

7.4. Overview of initial framework prototype

A prototype of the interactive framework was created using Microsoft Power Point. The structure shown within the mind map in Figure 7.9 was used as the structure that would link the framework. The images used within the prototype were based on those shown within Figure 7.9 but were improved on in terms of graphics. Power Point allowed the use of 'actions', which used hyperlinks to link certain slides together – for example, by clicking the mouse over an area of the sports design process model (level 0) that was outlined in pink, the software linked to the screen that showed the breakdown of that stage (level 1). This process was followed to create all the connections shown in the mind map in Figure 7.9.

The remainder of this section will provide a step-by-step overview of the initial prototype of the interactive framework, using a series of screen shots to illustrate the interactive nature of the framework. This section provides an overview of the breakdown of user involvement and the design review.

Level 0 – Home screen

The sports design process model forms the home screen image of the framework (level 0). The four areas highlighted in pink can be selected using the cursor to show further detail – the design process stages, user involvement, the design review stage and design process iterations.

Figures 7.11 to 7.13 present an overview of the framework based on the designer selecting user involvement, highlighted on the right of the home screen shown here. Figures 7.14 to 7.16 present the framework when the design review area on the left of the home screen image is selected.

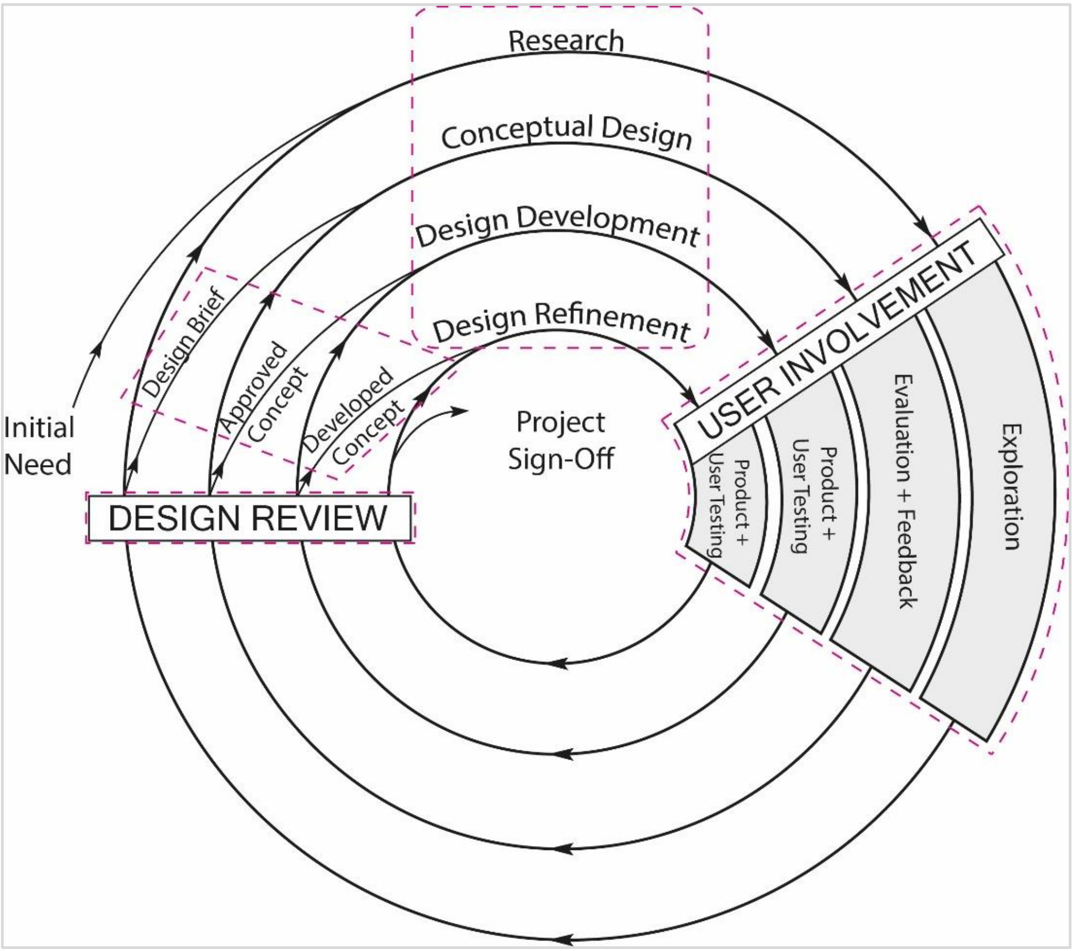


Figure 7.10 – Home screen image of the framework

Level 1 – User involvement

The image highlights the nature of user involvement within the four core stages of the inclusive design process. Each of these areas of user involvement, highlighted in green, can be selected for further detail on user involvement within each individual stage. The "home" icon on the top left of the screen allows the user to navigate directly back to the home screen (level 0), shown in Figure 7.10.

Within the image, recruitment time for user involvement within the inclusive design process is acknowledged before the collection of user data can start.

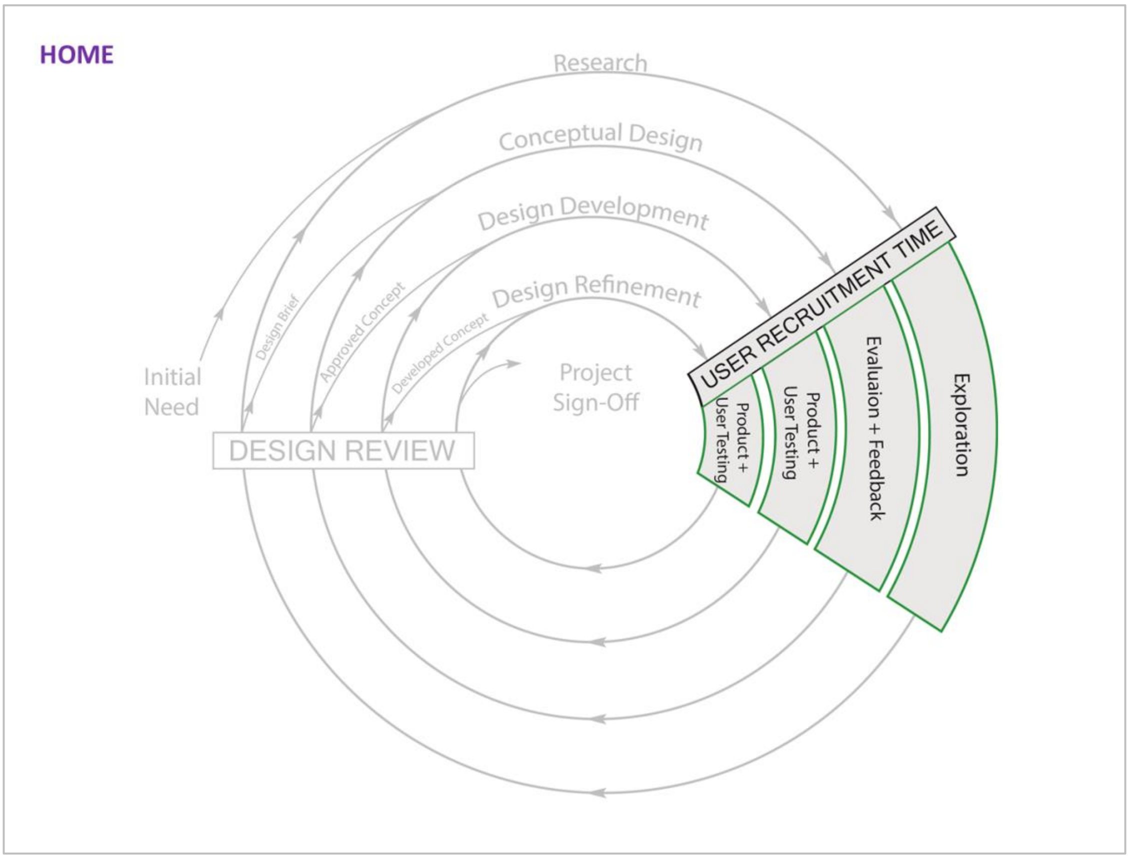


Figure 7.11 – Level 1: user involvement

Level 2 – User involvement: research

The image illustrates the exploratory nature of the user involvement within the research stage of the inclusive design process. Designers can add research methods to customise the framework. The conduction of exploratory research by the designer leads to the identification of user requirements that inform the design brief. The process is iterative until sufficient user information is captured. Diversity in the user groups recruited is required to ensure the final outcome is inclusively designed to accommodate a wider spread of the population.

As the lowest level of the framework, there are no further links provided within the image. The "home" icon as before will take the user directly back to the home screen (level 0) in Figure 7.10. The "back" icon takes the user back one level of the framework – in this case to the overview of the user involvement at level 1 of the framework, shown in Figure 7.11.

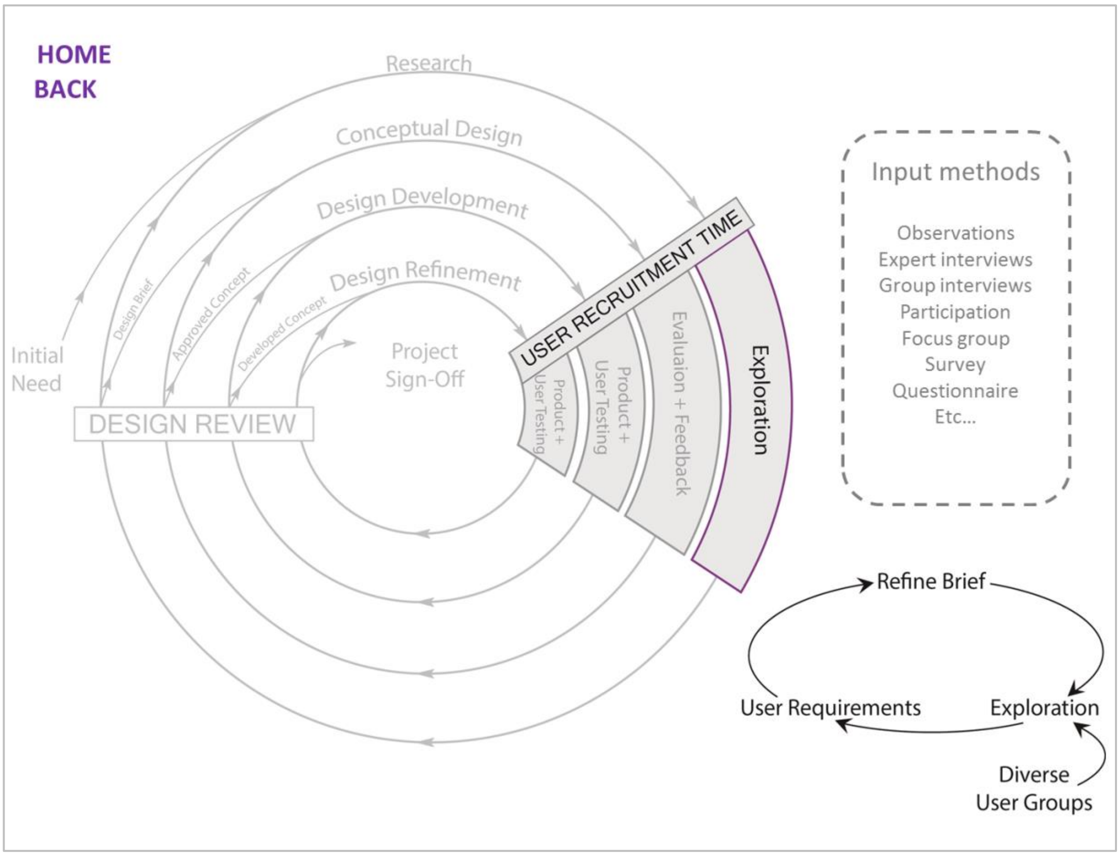


Figure 7.12 – Level 2: design process stage: research

Level 2 – User involvement: conceptual design

The image shows the nature of user involvement within the conceptual design stage of the inclusive design process – typically in the form of evaluation and feedback on generated concepts. Again, there is scope for the designer to add in project specific methods and activities. Within conceptual design, concepts are evaluated against user requirements and developed further within an iterative process of evaluation and development. The outcome will be a user approved concept that is progressed to the next stage of the design process.

As the lowest level of the framework, there are no further links provided within the image. The remaining two process stages (design development and design refinement) are illustrated in a similar way within the framework, showing the nature of user involvement within each stage. The "home" icon returns the user to the home screen on level 0 of the framework, while the "back" icon takes the user back one level to level 1.

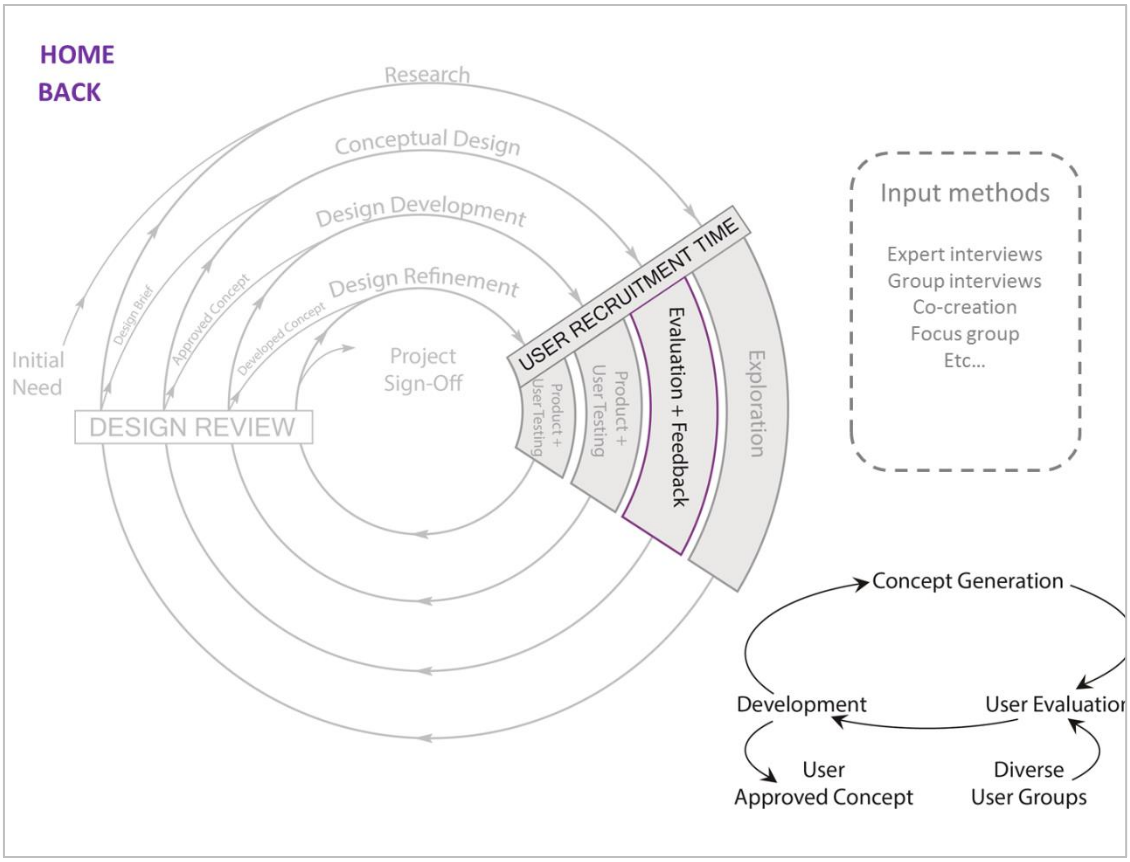


Figure 7.13 – Level 2: design process stage: conceptual design

Level 1 – Design review

The image shows the project progress from each stage of the process feeding into the decision making stage, based on the user selecting the design review from the home screen. Other inputs are the design brief which is used to inform the decision making process. Stakeholders involvement is also required in the decision making process – these are typically the designers themselves and the client. While the users are not normally physically involved in the design review, the needs of the users are central to any decision making within the inclusive design process (and should be reflected within the design brief). The output of the review is the decision to either progress to the next stage of the design process or repeat the stage until an appropriate solution is found.

Each of the two areas highlighted in green can be selected for further detail on each – the design review stage itself and the stakeholders involved. The "home" icon on the top left of the screen allows the user to navigate directly back to the home screen (level 0).

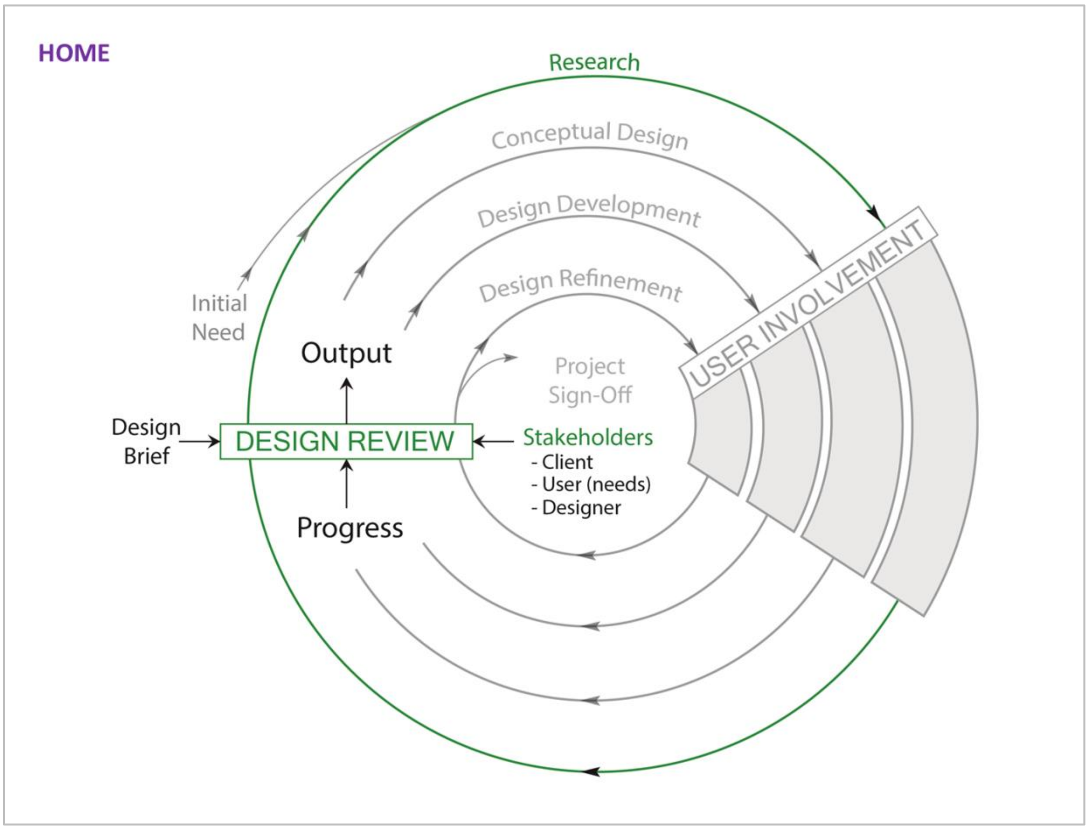


Figure 7.14 – Level 1: design review

Level 2 – Design review: outputs

The image shows the design review outputs for each stage of the inclusive design process:

Research – a completed design brief

Conceptual design – an approved concept(s)

Design development – developed concept

Design refinement – final prototype

If the stakeholders agree on progress, the project advances to the next stage. If the needs of the stakeholders are not met, the project re-iterates that stage of the design process until the decision is made to progress. In rare cases, a project can be terminated if not satisfying the needs of the stakeholders. The design brief, continually updated throughout the process, feeds into the design review to ensure the project is meeting the design requirements – specifically the needs of the identified user groups.

Again, as the lowest level of the framework, there are no further links provided within the image. The "home" icon takes the user back to the home screen, while the "back" icon takes the user back one level to the design review at level 1.

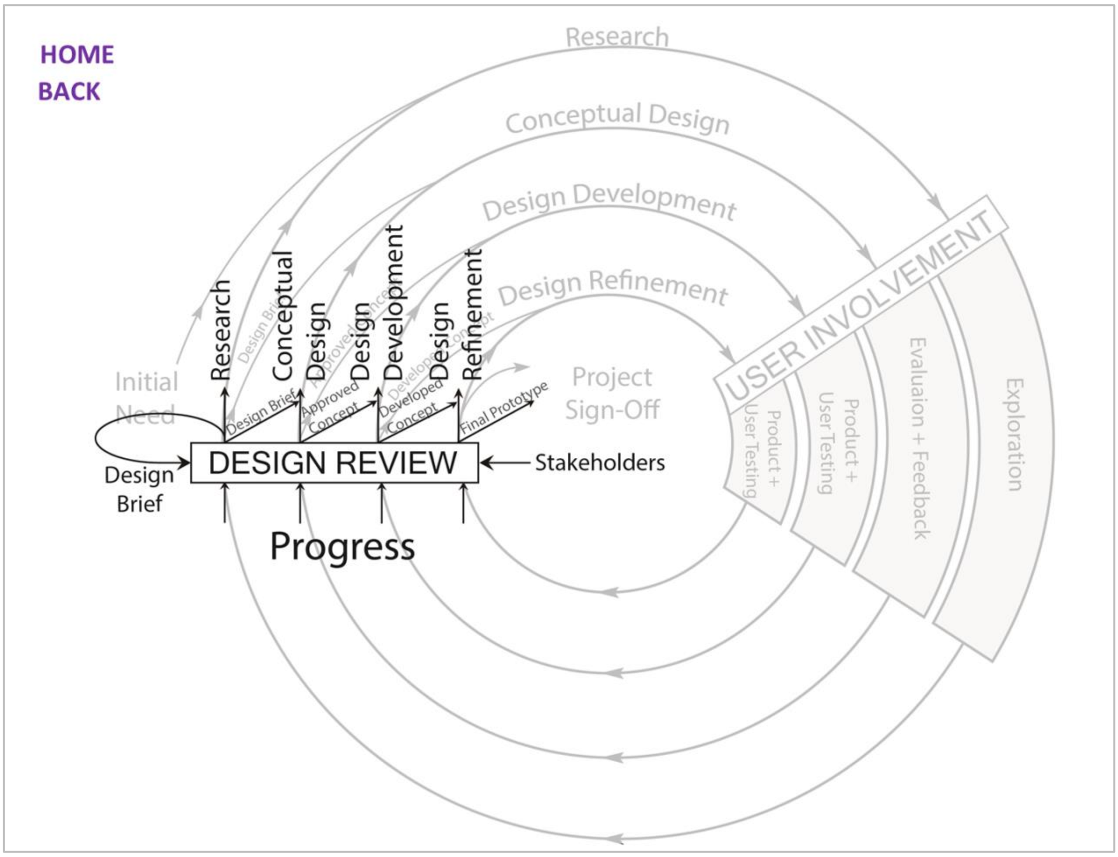


Figure 7.15 – Level 2: design review outputs

Level 2 – Design review: client involvement

The image illustrates levels of client involvement throughout the inclusive design process – this can be customised between projects. The client is a source of reference and information throughout each stage, illustrated here as grey tabs within each stage, with the client "dipping" in and out of the project. In the lead up to the design review, designers indicated that they would like the client to be phased in to the design review to ensure key decisions made were based on the client being informed of project progress. This is shown within the framework as an expanding level of client involvement in the lead up to the design review.

As before, there are no further links provided within the image, which illustrates the lowest level of the framework. The "home" icon takes the user back to the home screen, while the "back" icon takes the user back one level to the design review at level 1.

Figure 7.16 – Level 2: design review client involvement

7.5. Pilot of the framework

A pilot session was carried out, to assess the ease of interpretation and navigation of the interactive framework. The prototype presented in section 7.4 was used. There were six participants in the session – all were researchers, with three coming from a background in product design, therefore with a good understanding of the design process. The remaining three were not from a design background, therefore were representative of the client, who would be unfamiliar with the design process and whom the framework is aimed at communicating the inclusive design process to.

The pilot session was run as a workshop, with participants given an introduction to the inclusive design framework, including an overview of the purpose of the framework, before the researcher demonstrated how the interactive framework operated. Prompts were used to aid the discussion process to ensure areas such as ease of navigation of the framework, image quality and understanding of the inclusive design process were covered.

The following feedback was gained from participants:

- Navigation within the framework could be improved. The framework presents four core areas of the inclusive design process – the core design process stages, user involvement, iterations and design reviews – with more detail provided for each of those within the framework. However, participants found this method of structuring the framework confusing, making it difficult to keep track of where they were within the framework.
- A visual aid illustrating the breakdown and structure of the framework would benefit understanding and ease of navigation of the framework.
- The graphics could be improved. It was felt the colours used within the mind map could be used within the framework to connect levels of the framework and aid navigation of the tool. Participants also commented that some of the images were "cluttered" and the framework as a whole would benefit from cleaner, simplified images.
- The interactive framework aided the understanding of the inclusive design process for those participants not previously familiar with it. However, it was felt that the explanation of the framework provided by the researcher was necessary.

Participants commented that due to the difficulty in navigating the framework, it would be difficult for someone unfamiliar with the framework to understand it.

Based on feedback from the pilot session, the following changes were made to the inclusive design interactive framework.

- The structure of the interactive framework was changed so the design process was broken down into sub-levels that corresponded to the four core stages of the design process (research, conceptual design, design development, design refinement), rather than the four areas characteristic of inclusive design practice. Within each of those process stages, more information was provided on the characteristics – the process stages themselves, user involvement, iterations and the design review. This would aid ease of navigation through the framework and reduce confusion over location within the framework.
- To aid ease of navigation, the colours used in the mind map in Figure 7.9 were used to colour code the interactive framework and improve the images. The first level of the framework (the four core stages) was coloured pink. The second level (more detail on the design process stages, user involvement, iterations and design review) was coloured green and the lowest level (the breakdown within the design review stages), coloured purple.
- A tree diagram was added to the framework to provide a visual aid, illustrating the structure of the framework. Levels of the tree were coloured to match the levels of the framework and were added to each slide to illustrate how the levels of the framework connected.
- The overall quality of the images was improved. Based on feedback, text size was increased and additional information that was not necessary was removed to reduce clutter.

Based on the changes discussed above, it was concluded that the inclusive design framework would be easier to navigate as a result of the improved structure and visual aids. Further feedback on the development of the framework prototype discussed above was gained from the pilot participants individually, who felt the framework was significantly improved as a result. The following section provides a detailed description and illustration of the developed prototype of the inclusive design framework.

7.6. Presentation of the framework prototype

This section will discuss and present the refined prototype of the inclusive design framework developed to facilitate communication between designers and clients within the inclusive design process. Based on the recommendations made in the pilot study, the framework was developed further to improve ease of navigation through the framework. As before with the initial prototype of the framework, the developed prototype was created using Microsoft Power Point to allow the interactive exploration of the framework.

The framework is structured as shown in the tree diagram in Figure 7.17, which numbers each stage of the framework for ease of discussion. The colours in the tree correspond to the colours used in the levels of the framework and match those used previously in the mind map. An additional high level (home screen) has been added, illustrating the sports design process model alone, before linking to level 1 of the framework. The colour coding scheme used is as follows:

Black: Home screen (level 0) – sports design process model

Pink: Level 1

Green: Level 2

Purple: Level 3

The tree illustrates the structure of the interactive framework. The user of the framework (the designer) can select any of the four design process stages on the home screen – research, conceptual design, design development, design refinement – which will navigate to level 1 of the framework. Within each of the design process stages shown in level 1, any of the following areas can be selected to provide more detail – the design process stage itself, user involvement, iterations, design review. By selecting any of these four areas, the user is taken to level 2 of the framework, where the four areas are presented in more detail. Within the design review (shown in level 2) for each stage, there is an option to select either the review output or client involvement, for further detail of each (level 3 of the framework).

Figure 7.18 provides a visual accompaniment to the tree shown in Figure 7.17, illustrating the visual content of each level of the framework – a larger version of Figure 7.18 is included in Appendix 4. The numbers used within Figure 1.18 match those in Figure 1.17. An overview of part of the interactive framework is also provided here – starting from the sports design process model on the home screen and progressing down the far left side of the tree to research (level 1), then to user involvement (level 2). A second example is provided showing the design review for the research stage of the inclusive design process (level 2) and the output of the design review and levels of client involvement within the process (level 3).

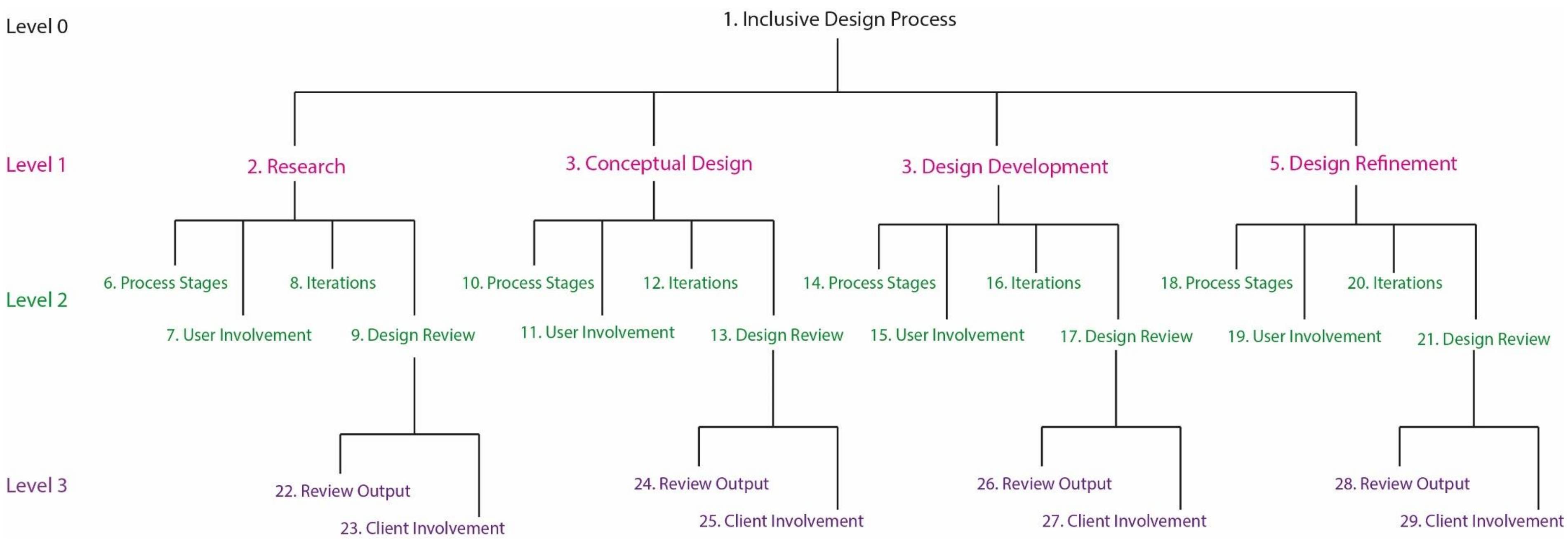


Figure 7.17 – Tree diagram of framework structure

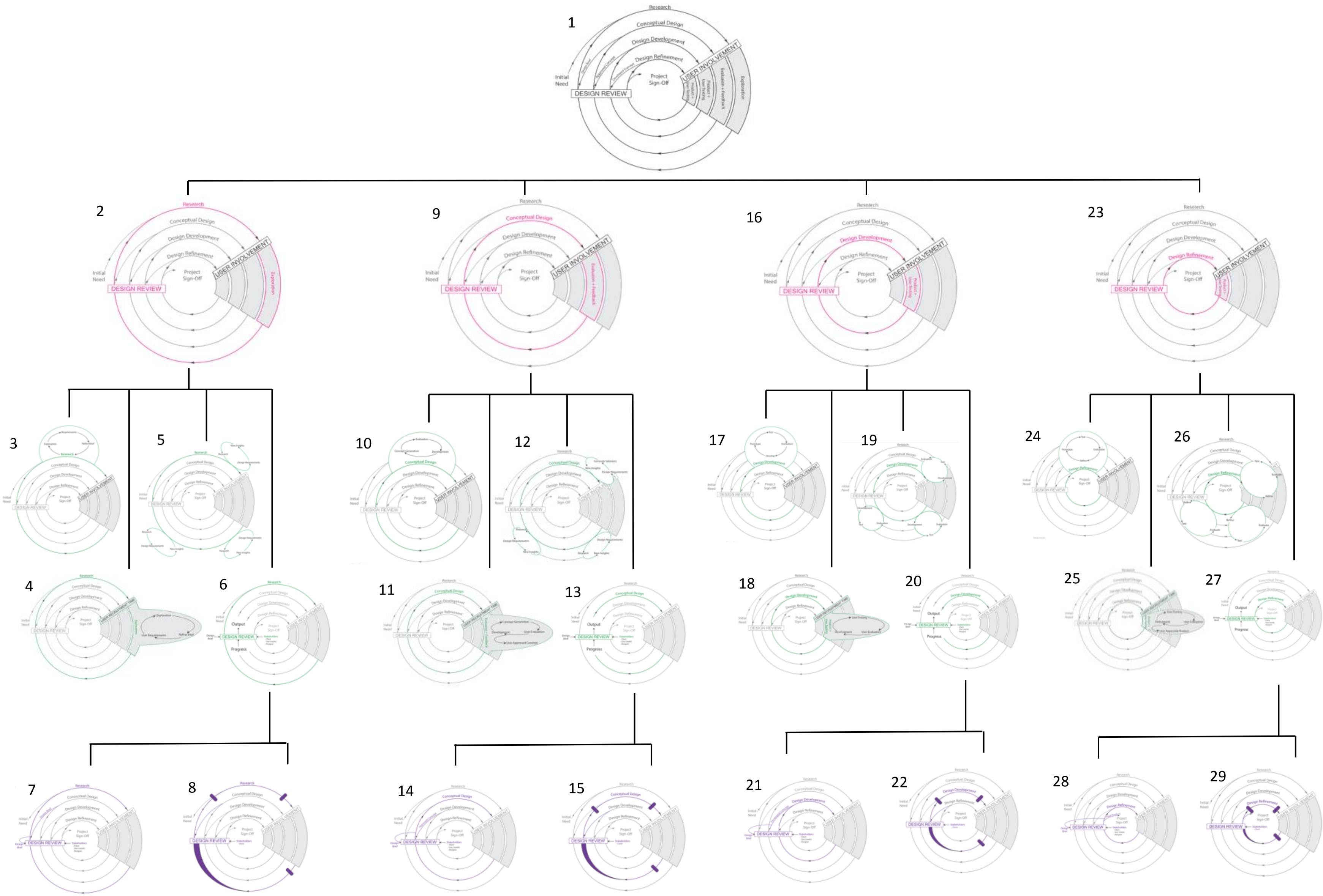


Figure 7.18 – Illustrated tree diagram of framework interface

Level 0 – Home screen

The sports design process model with each of the four design process stages highlighted is the home screen that can be returned to throughout the framework when the "home" icon is selected. Each of the four process stages (shown in pink) can be individually selected for further detail – the tree at the bottom of the screen highlights in pink level 1 of the framework, which are the options available for the user to navigate to at this stage of the framework.

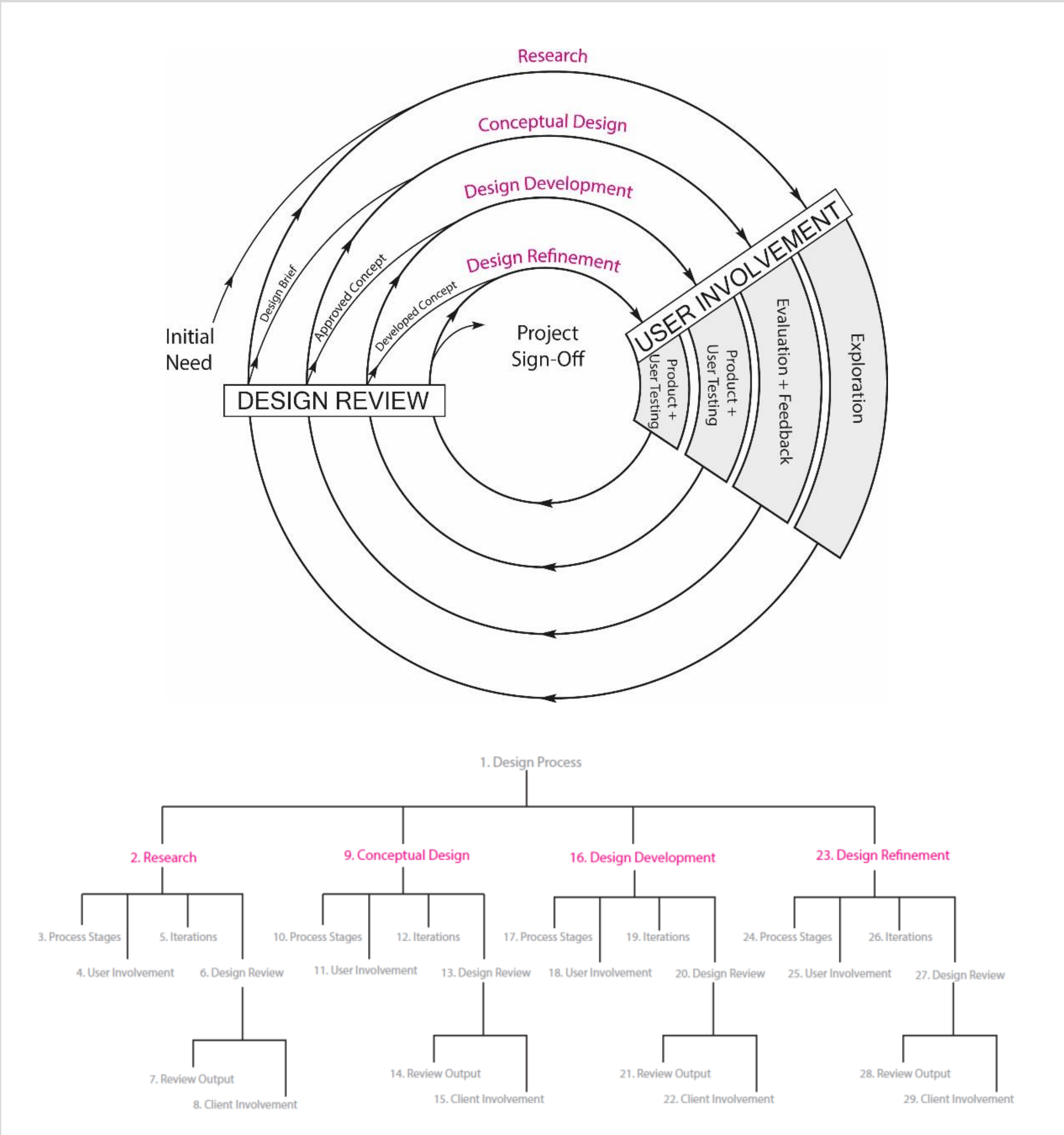


Figure 7.19 – Level 0: home screen

Level 1 – Design process stage: research

Within the research stage, any of the four highlighted areas can be selected – the research stage of the design process, user involvement, iterations, design review. The tree at the bottom of the image illustrates the section of the framework the user can interact with from the research stage. The next level of the framework (level 2) is illustrated in green, which is accessed directly by selecting one of the four available areas on the current image. The lowest level (level 3) shown in purple can be accessed through the design review stage.

The "home" icon will return the user to the previous image of the home screen at level 0 of the framework.

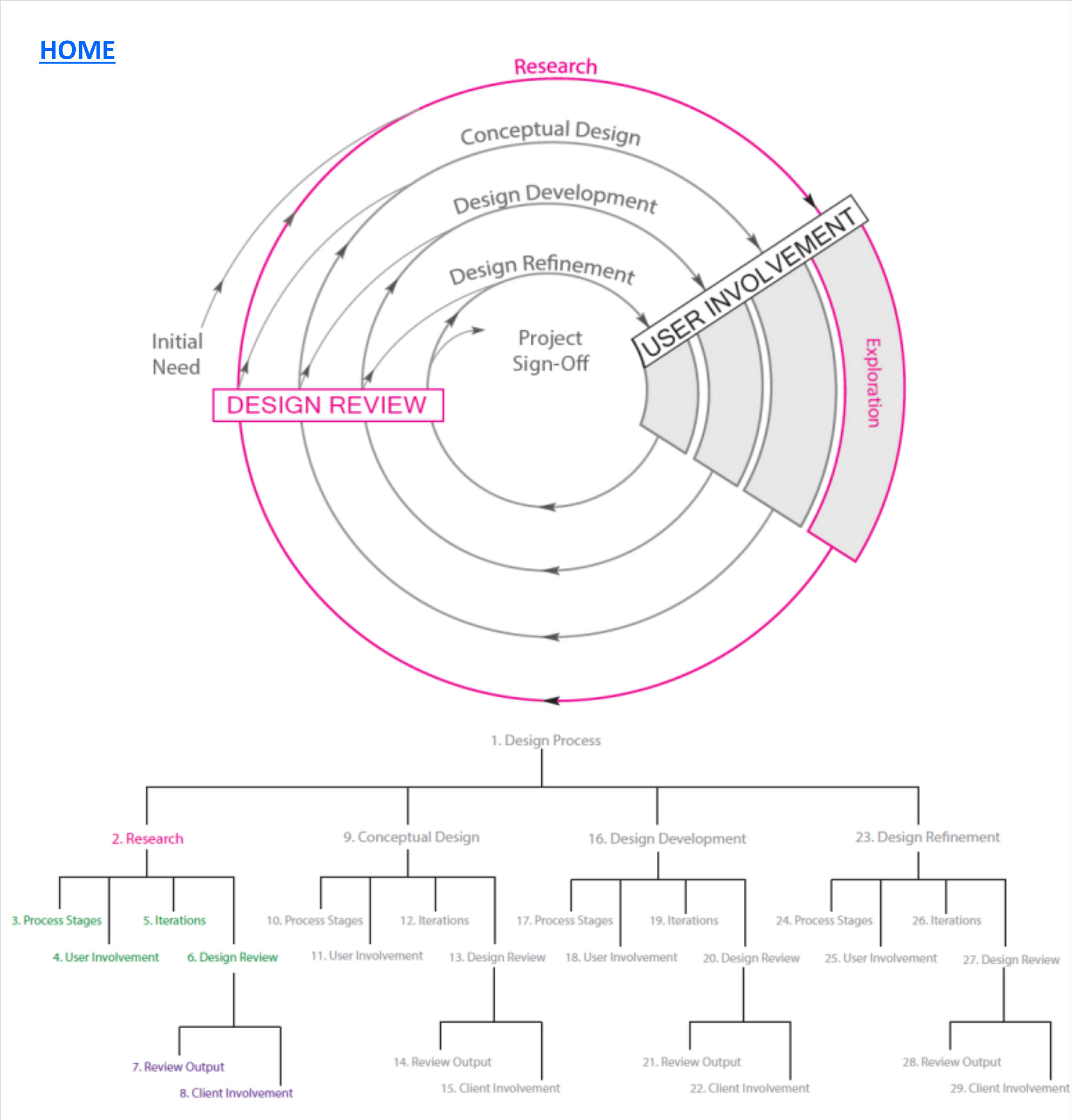


Figure 7.20 – Level 1: design process stage: research

Level 2 – Research: user involvement

When user involvement is selected within the research image (level 1), the user is presented with the following image (level 2). The framework illustrates the recruitment time required to source diversity in user groups involved in the inclusive design process. The nature of user involvement is often exploratory, leading to the identification of user requirements and the refinement of the design brief.

The tree illustrates in green the level in the framework the user is viewing (level 2). Within the current image, the user is can select the "home" icon to return to the home screen (level 0), while the "back" icon takes the user back one level of the framework to the overview of the research stage (level 1).

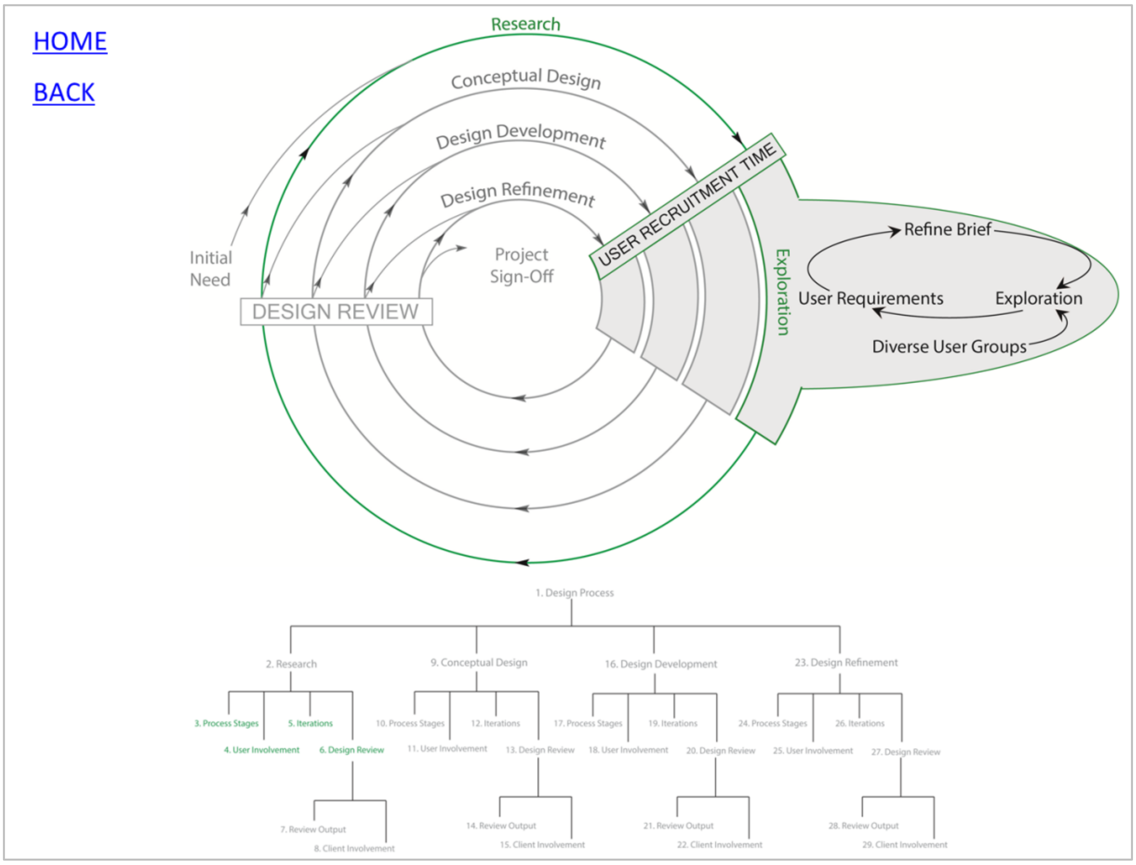


Figure 7.21 – Level 2: user involvement

Level 2 – Research: design review

When the design review is selected within the research image (level 1), the user is presented with the following image (level 2). The image illustrates project progress as an input to the design review, where it is assessed against the design brief. Stakeholders include the designer and the client, in addition to the user needs, which are expressed within the design brief. The output of the design review is illustrated in detail on level 3 of the framework.

The tree illustrates in green the level in the framework the user is viewing. Within the current image, the user is able to navigate directly to the review output and client involvement within level 3. The "home" icon returns the user to the home screen, while the "back" icon takes the user back one level to the overview of the research process stage (level 1).

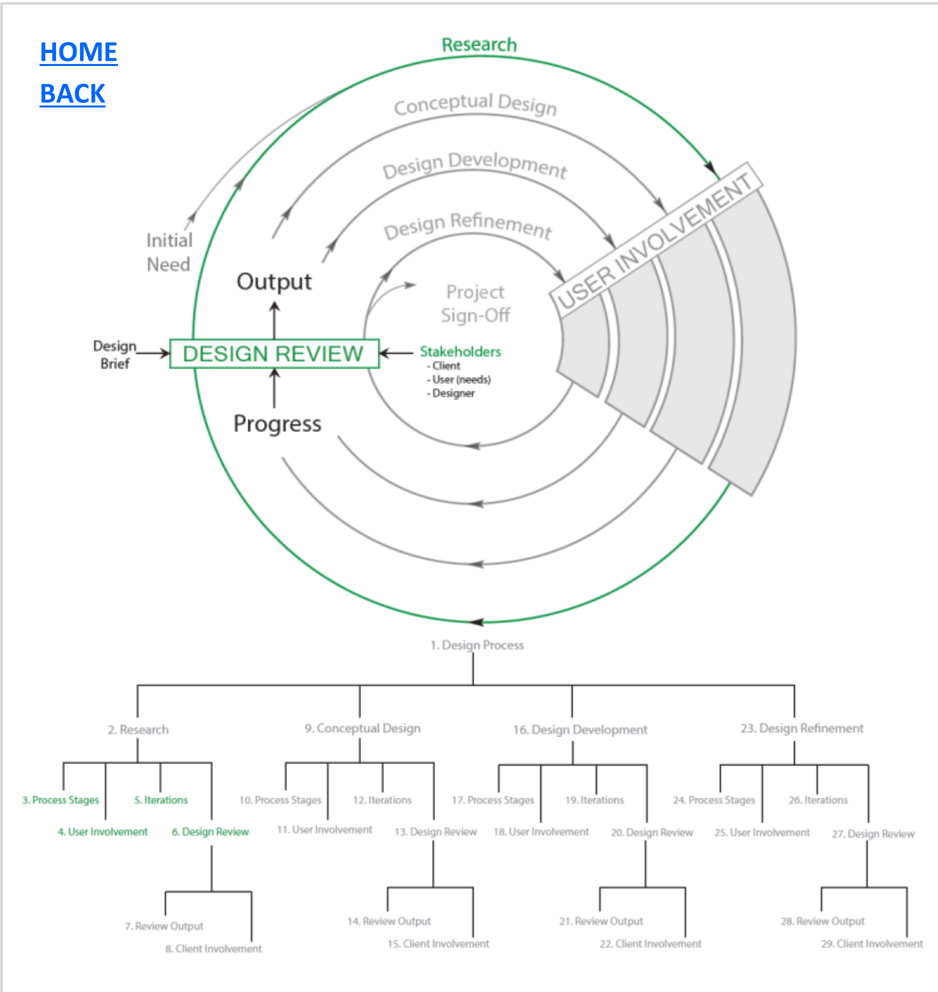


Figure 7.22 – Level 2: design review

Level 3 – Design review: outputs

The image illustrates the two potential outputs of the design review process for the research stage.

1. The outcome is satisfactory – at the research stage, this is the design brief. The project progresses to the next stage of the inclusive design process – in this case, conceptual design.
2. The outcome is not satisfactory. In this case, further research would be undertaken to ensure a comprehensive design brief is produced that all stakeholders agree on.

The tree illustrates to the user that they are on the lowest level of the framework. The "home" icon returns the user to the home screen (level 0), while the "back" icon takes the user back one level to the design review phase within the research stage (level 2).

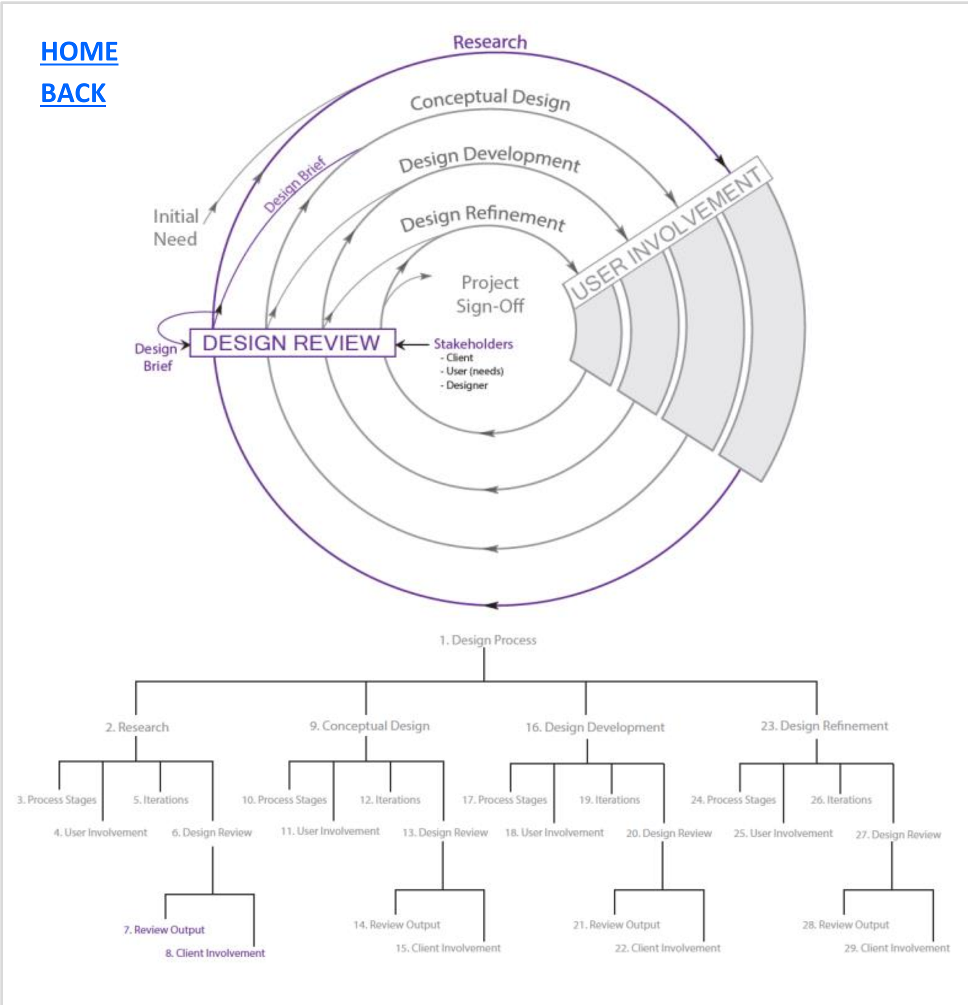


Figure 7.23 – Level 3: design review outputs

Level 3 – Design review: client involvement

The image illustrates potential levels of client involvement in an inclusive design project – this can be customised on a project-by-project basis. Intermittent involvement is shown throughout the design process stage for reference and information from the client. The client is then phased in before the design review stage where key design decisions are made.

The tree illustrates to the user that they are at the lowest level of the framework. The "home" icon returns the user to the home screen (level 0), while the "back" icon takes the user back one level to the design review stage within the research phase (level 2).

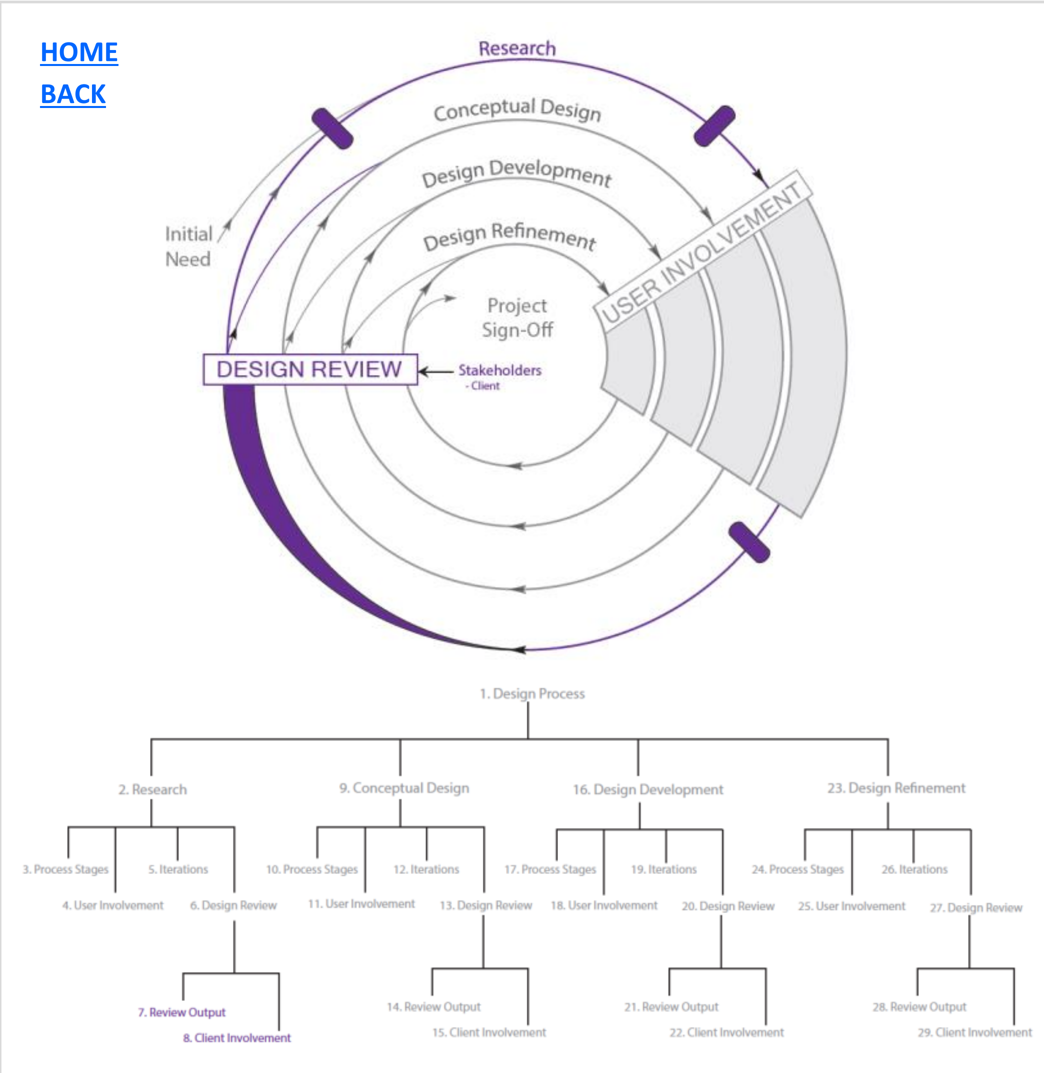


Figure 7.24 – Level 3: design review client involvement

7.7. Chapter Findings

This chapter presents an interactive framework developed from the sports design process model facilitates designer-client communication within the inclusive design process. The development of the framework followed a typical design process, summarised as follows:

- Research: Interviews conducted with industry designers and inclusive design experts (Chapter 6) identified the needs of the 'users' of the framework.
- Specification: the user needs identified as a result of these interviews were translated into design requirements – presented at the end of Chapter 6.
- Conceptual design: an iterative process of concept generation and evaluation against the requirements are reported within this chapter. A number of rough concepts were generated, evaluated and developed, leading to the selection of one developed concept.
- Design development: The construction of a prototype of the interactive framework, the piloting of that prototype and further development based on feedback from the pilot session are reported within this chapter.
- Design refinement: the validation of the developed prototype of the framework with inclusive designers and design clients will be reported within Chapter 8. Further refinements to the framework based on the feedback received are discussed, in addition the final interactive framework will be presented.

The developed inclusive design framework presented in Section 7.6 is progressed to Chapter 8, where it is validated by designers and clients, to ensure the framework is usable by both of its target user groups. The framework is intended to be used by the designers themselves, who must be able to navigate the interactive tool, with aspects of the inclusive design process that are important to them communicated clearly within the interactive framework. The framework is intended to educate the client of the inclusive design process, therefore must be understandable to those from a non-design background and communicate characteristics of the inclusive design process. Chapter 8 will present the validation of the interactive framework, further refinements made based on feedback gained from the designers and clients and will present the finalised version of the interactive inclusive design framework.

Chapter 8 – Validation and presentation of the inclusive design framework

Chapter 7 presented the development of the interactive inclusive design framework based on the requirements gained from the designer interviews and inclusive design expert workshop conducted in Chapter 6. The framework is an interactive resource that facilitates designer-client communication within the inclusive design process, illustrating characteristics of inclusive design practice – involvement of diverse user groups throughout the design process and an iterative process followed until an appropriate solution is reached. Following an iterative process of development and evaluation, a developed prototype of the interactive framework was presented at the end of Chapter 7.

There are two target users of the inclusive design framework. The first being the product designers who would use and operate the framework as part of their inclusive design practice. The second being the design clients who must experience an enhanced understanding of the inclusive design process and the need for early and continual user involvement and iteration within that process. This chapter presents the second part of Study 4 and provides a solution to the third research question – **how is the sports design process applicable to inclusive design?** The chapter reports on the validation of the framework with both user groups through interviews and questionnaires with each group. Based on feedback gained from both these groups, the framework was further refined – the final version of the interactive framework is presented at the end of this chapter.

The chapter is structured as illustrated in Figure 8.1. Following the introduction to the chapter, the validation of the framework is discussed – both the designer and client validation processes are presented, with an overall discussion of both. The final version of the interactive inclusive design framework is presented using screen shots of the framework along with a description of each image. The findings of the chapter are then concluded.

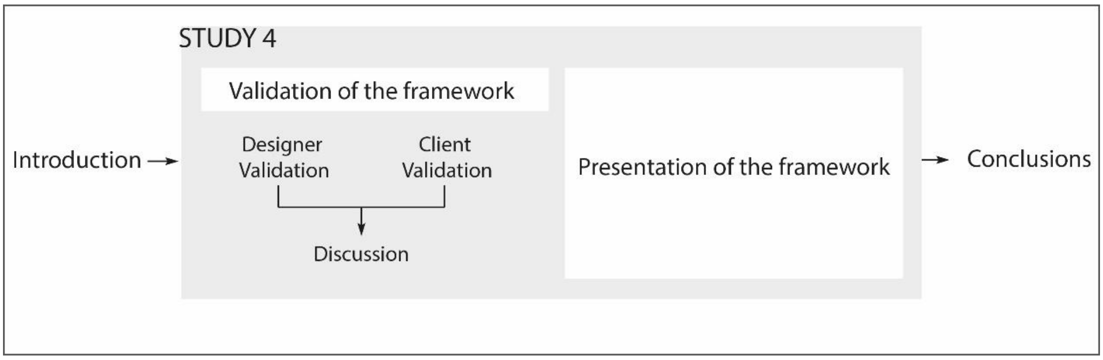


Figure 8.1 - Structure of Chapter 8

8.1. Validation of the framework

To ensure the framework would facilitate designer-client communication of the inclusive design process, both designers and clients were involved in the validation process. The designers were involved in the validation process to ensure the framework would be usable by them when communicating the inclusive design process to clients. As identified from the conclusions drawn in Chapter 6 and the results of the literature review in Chapter 2, the client is often a main barrier to inclusive design. The framework was developed to educate the client of the inclusive design process as a whole and in particular the need to involve a diversity of user groups throughout that design process. Clients were therefore involved in the study to ensure that the framework was beneficial in aiding their understanding of the inclusive design process.

Figure 8.2 illustrates the structure of the validation process followed within this study. Both the designers and clients were given an overview of the framework, details of which are given in Appendix 5. A series of semi-structured interview questions were asked of each group (six questions for the designers and seven for the clients). Questions included whether participants would like to see the framework improved in any way, such as the interface, the graphics and images and the content. The full set of interview questions (and additional prompts) for both the designers and clients are provided within Appendix 5. All the interviews were recorded and fully transcribed. As in previous chapters of this thesis, the transcripts were analysed using a general inductive approach (Thomas, 2006) with key themes and categories identified from the text. The analysis process was repeated with new themes identified and/or combined up to a point of saturation where no new themes were identified. Both designers and clients were also asked to complete a questionnaire following the completion of the interview questions. The full questionnaire is shown within Appendix 5.

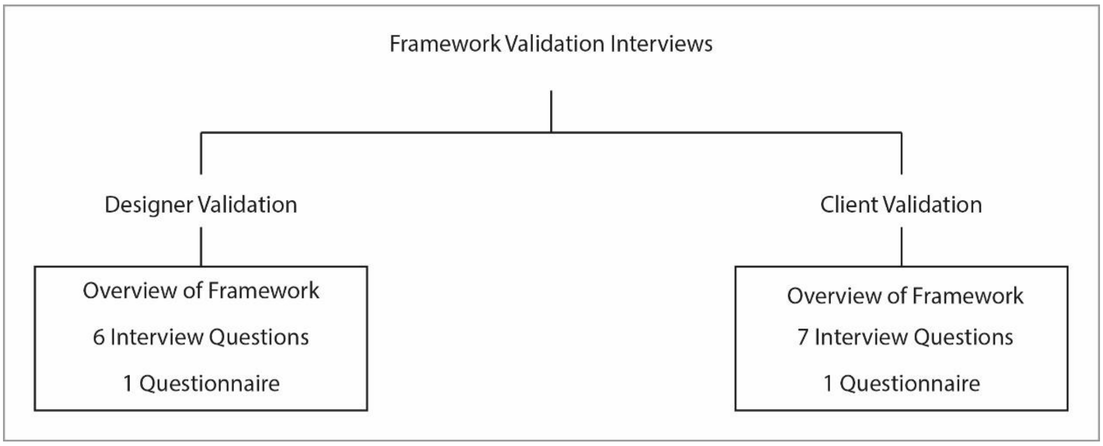


Figure 8.2 – Structure of the inclusive design framework validation

8.1.1. Designer validation

The three designers that participated in the validation of the framework had all previously been involved in the interviews conducted in Chapter 6, therefore enabling respondent validation to ensure the framework met the needs of the designers. The requirements identified from these designers in Chapter 6 formed the basis for developing the framework, therefore it was vital the framework met those needs. As discussed in Chapter 6, all the designers had experience in inclusive and/or user centred design, therefore would provide a suitable sample group for feedback on the framework intended to aid inclusive design practice.

The designer validation process began with an explanation of the framework by the researcher and what it intended to achieve – facilitation of communication between the designer and client within the inclusive design process. The framework was then demonstrated by the researcher, with the designer given an opportunity to operate the framework themselves. The designers were interviewed using a set of six semi-structured interview questions including how effective the framework was at communicating the inclusive design process, whether the framework highlighted the areas of the inclusive design process that were most important to the designer and whether it highlighted the importance of early research and user involvement throughout the design process, which were all identified as characteristics of the inclusive design process. At the end of the interview, designers were asked to fill out a short questionnaire, regarding the applicability of the framework to their current design practice. Details of the interview structure, questions and questionnaire are provided in Appendix 5.

Results from designer validation process

This section discusses the results for the designers interviewed as part of this study. Within this section, findings are reported based on key themes identified from the interviews.

Overall framework

All three designers responded enthusiastically to the interactive framework as a whole:

> *"I think your core idea is bang on".*
>
> *"It's all there – it's very detailed, but I don't think that's a bad thing".*
>
> *"What you've got there is really lovely, I like it".*

The concept of aiming to communicate with and educate the client of the inclusive design process was also well received:

> *"I think it's a really good idea that you're targeting it more towards the client, to educate the client as opposed to the designer".*

The framework provided a new means of representing the inclusive design process that the designers felt was lacking:

> *"So visually I haven't seen a diagram of any description that highlights the breadth of involvement of others, those who are not designers. I haven't seen anything that does anything like that".*

"It speaks for itself - it's the simplest I've seen".

Designers felt there was sufficient information within the framework to educate the client of the inclusive design process – there was no important information missing, with the framework presented in a format understandable to those not previously familiar with adopting an inclusive design approach:

"It is perfectly adequate if you're using it to illustrate the design process to somebody who doesn't know what the inclusive design process is."

<u>Designer communication with the client</u>

Designers were asked what methods they currently used when communicating with clients during the inclusive design process. One designer reported using a high level design process diagram, which emphasised different characteristics to, and lacked the detailed content of, the framework presented here. Two of the designers had no current visual tools that they used, with both commenting they felt this was something that was needed:

"Having something visual to illustrate it (the inclusive design process) would go a long way".

"We don't have sufficient tools at our disposal that illustrate to people what we do".

This lack of tools to facilitate designer communication of the inclusive design process proved problematic for the designers during discussions with clients:

"What we've never been able to do is give them something to enable them to grasp that they might spend money for a week or three months before we can find a feasible concept".

All three designers commented that clients were often unaware of the design process in general:

"When clients come to you, they are quite naïve about the design process, but they are also bombarded with so much information they can't absorb it all".

"Some people just don't understand that design is a complex process".

The designers felt that educating the client was an important part of the inclusive design process and that the interactive framework would provide them with a means of facilitating this process:

> *“Giving them this allows them to digest it, once the project's going on and they're over the first bit".*

It was noted that the framework would provide a means of educating the client in a professional manner, reassuring them of the design process that would follow:

> *"It gives the client a sense of reassurance that they know what's coming and you know you're getting a premium service from this agency as opposed to another one".*

Educating the client of the inclusive design process was often a time consuming process that designers felt they were constantly repeating between clients:

> *“It takes some considerable time to get them to a point where they’re beginning to grasp what has to be done and think about it. We would want somebody ideally if they’re coming to us to already have a bit of a grasp".*
>
> *“Your system of showing that is a very useful part of that process. So when they came in we wouldn’t be standing fresh every single time".*
>
> *"We should educate them so they're less intimidated about phoning up".*

<u>Recommendations for framework improvement</u>

Designers were questioned on improvements that could be made to the framework to meet their needs when working on an inclusive design project. The following areas were discussed:

- A high level version of the inclusive design process would be beneficial as the base line for the framework. The introductory slide was where designers felt the most value would be gained, therefore it was important that the slide was immediately understandable.
    - *"It's almost a little hard to wrap your head around at first".*

    - *"You almost need a higher level one and then when you get into the nitty gritty then use this one".*
    - *"I think it might scare my clients a little bit to take in that amount of detail. It may be useful to have a high level version of it and a detailed version of it".*
- All designers felt that it would be beneficial to have the framework customisable to the company and client, with this adding value to the framework:
    - *"If you can customise it as per your company and/or client that would add a huge amount of value to it".*
    - *"If it was customisable then they would see what they were getting differently from company A to B".*
    - *"An image bank would be useful to customise per project – they might use images from their own past portfolio if they're generic".*
- The visual representation of the cyclic design process stages was noted as confusing. The outer research circle appeared to represent a long and time consuming stage, with the smaller circle for design refinement representing a shorter timescale and a stage that would be easy to repeat:
    - *"Having an outer circle, it's a long way round to repeat the process, but if you repeat the detail design, it's not going to be as long. But actually it's almost the other way round".*
    - *"I think you do feel intuitively that because it's a bigger circle, it's a bigger project".*
- One designer commented that co-creation was an important part of their inclusive design approach that should be included within user involvement:
    - *"I would normally involve the user in concept generation, and then you're going to the users with a bit of concept generation, evaluation and development".*
- All three designers commented that the graphics of the framework would need to be improved:

  "At some point you will have to get a very good graphic designer… By its nature it is in development so it needs a bit of refinement visually".

  However, some suggestions were made for improving the overall visual presentation of the framework:

- *"When you go from the pink to the green, it feels like you've gone somewhere else, like you're not in conceptual design any more".*
- *"I don't think you need the tree if it just had a bit of user interface love!"*

- Navigation within the interactive framework was discussed with designers commenting that some refinements were needed to aid the ease of moving through the framework. It was noted that designers would be capable of learning new software:

  "You don't need to make it super easy for designers – they're used to learning new software. It doesn't need to be ultra-easy".

  However, it was also noted that the better the interface, the more inclined designers would be to use the framework.

  - *"One thing that did confuse me was going into design refinement and then when you loop to design refinement again, it felt like I was already in it so why am I going into it again?"*
  - *"When people come onto a website, they are the monkeys and they are looking for the banana and you want to make that as easy as possible for them. So fewer clicks."*
  - *"It just needs a bit of colour coding and a bit more interactive that takes you through it a bit more. I think if it's done well you can just hover over things and things pop up and it leads you through it a bit better".*

- The impact of design changes within the inclusive design process was noted as an area that clients were often unaware of. As such, it was noted that the framework should illustrate the impact of back tracking, particularly in the later stages of the design process:

  "If they make a design change, the contract and the timeframes may need to be re-evaluated".

Format of the framework

For the final representation of the framework, all designers agreed that an interactive version of the framework available through a website would be the best means of delivering the tool:

> *"The interactive nature (of the framework) does help and I suppose the nice thing about a website is that you could put the link on your own company website and send it to clients".*

Feedback on how best to introduce the designer to the framework was mixed – two designers felt that self-teaching would be best, with the improved interface letting designers guide themselves through the framework:

> *"If it's well designed, it won't need instructions".*

One designer felt that a short animated video would be ideal at providing an introductory overview of the framework. All agreed that written instructions would not suit designers' visual and practical ways of working.

Questionnaire results

Following the completion of the interview questions, each designer was asked to complete a short questionnaire regarding the applicability of the framework to their current design practice. Table 8.1 illustrates the responses to the questionnaire gained from the three designers.

All three designers commented that the framework would be of use to them and would improve communication between themselves and the client within the inclusive design process. The feedback from the interviews noted that the interactive, software version of the framework was highly beneficial in providing a simplistic overview of the inclusive design process, which was in agreement with the questionnaire responses where all three designers selected that they would use a software version of the framework. In response to the question, "is there enough detail in the model", all designers responded that they liked the model as it was presented and that the interactive framework provided sufficient detail of the inclusive design process, without over complicating it. However, small refinements to the framework were recommended by the designers, which are discussed earlier in this section. It was also noted that there are occasions where the designer does not have access to a computer device – all three designers selected that they would also use a hard copy of the framework if one was available. However, it was commented that this would involve a different representation of the inclusive design process to that used in the interactive framework.

In response to the usefulness of the interactive framework for representing the inclusive design process as a whole, in addition to the iterative nature of the inclusive design process and the nature of user involvement throughout that process, all designers scored the framework highly. Where the framework scored 4/5, it was commented that the feedback on recommendations for improvement of the framework, discussed earlier in this section, would help bring the up the rating of each selection.

Those that replied "maybe" in response to the last set of questions felt that the details listed were present in the framework but required an explanation by the researcher before they were clear to the designer. However, some recommendations were made (as discussed earlier) to improve the communication of these within the framework.

Please answer YES or NO:	Designer 1	Designer 2	Designer 3
Is the framework useful to you as a designer?	Yes	Yes	Yes
Will the framework improve communication between designer and client?	Yes	Yes	Yes
Would you use a software version of the framework?	Yes	Yes	Yes
Is there enough detail in the framework?	Yes	Yes	Yes
Would you use a hard copy of the framework?	Yes	Yes	Yes

Please rate (1 not useful – 5 very useful) the usefulness of the framework:	Designer 1	Designer 2	Designer 3
Representing the inclusive design process.	4	5	4
Representing the iterative nature of the inclusive design process.	5	5	5
Representing user involvement throughout the inclusive design process.	4	4	4
Highlighting benefits of user involvement (to the design project).	5	4	4

Will the framework improve client awareness of the importance of (yes/no/maybe):	Designer 1	Designer 2	Designer 3
User involvement throughout the inclusive design process.	Yes	Maybe	Maybe
The need to complete thorough research early in the inclusive design process.	Yes	Maybe	Maybe
The need to iterate within the inclusive design process.	Yes	Yes	Maybe

Table 8.1 - Questionnaire responses from designer interviews

Summary of designer validation

All designers felt that the framework would be beneficial in aiding designer-client communication of the inclusive design process:

> *"Your work is a perfect starting point for people like me".*

> *"I've always thought someone needs to sit down and say this is why/how you design something that costs you, because this is what needs done".*

The use of the framework at targeting the client rather than the designer was well received, as it was a lack of knowledge of the inclusive design process from the client that was a main barrier to the uptake of an inclusive design approach. The framework provided designers with a tool that was not previously available to them and communicated many of the characteristics of inclusive design. Feedback was received from the designers regarding how the framework could be improved further and included a high level version of the sports design process model, ease of navigation, the visual representation of the design process and the impact of design changes. In terms of further work, one of the designers noted that the framework would be particularly beneficial in aiding the quotation process of projects:

> *"Potentially it could be a really good way of quoting for a project. Seeing where their (the client's) money is going".*

Following the interviews, one designer requested permission to begin using the framework immediately to facilitate discussions with clients:

> *"We can put this in front of them and I think quite straightforwardly say to them, that covers a lot of stuff".*

8.1.2 Client validation

Three clients were involved in the validation process to ensure the framework aided their understanding of the inclusive design process as none were previously familiar with it. Clients were sourced through contact with the University of Strathclyde – final year design students at the University are required to undertake a group project with an industrial partner. Some of those partners are well established in the design field, while others are embarking on their first design project. Each of the clients involved in this research were in their first year of a small scale design project, therefore had not yet experienced the full design process but had some understanding of the communication process between themselves as the client and the undergraduate designers they were working with at the University.

None of the clients were familiar with inclusive design prior to the interviews. This was not unexpected, as the designers interviewed in Chapter 6 noted that there was a lack of awareness of inclusive design by clients. In these interviews, the framework was used to communicate the inclusive design process to the client and highlight the benefits of adopting an inclusive design approach to a typical design problem.

The client validation process began with an explanation of the framework, followed by a demonstration of the framework by the researcher. Unlike with the designers, the client was not given the opportunity to navigate the framework – the framework is intended for use by the designer, to illustrate the inclusive design process to the client. Clients were then interviewed, using seven semi-structured interview questions including how well the framework communicated the inclusive design process, did it aid clients understanding of the inclusive design process and did it highlight areas of that process that had not been previously given much thought by the client. Clients were also asked to fill out a short questionnaire, regarding how well their understanding of inclusive design had improved as a result of the presentation of the inclusive design framework. Details of the interview structure, questions and questionnaire are provided in Appendix 5.

Results from client validation process

This section discusses the results for the client interviews. Within this section, findings are reported based on key themes identified from the interviews.

Overall framework

All three clients understood the framework following a brief introduction from the researcher:

> *"It makes absolute sense to me".*
>
> *"I'm quite comfortable with the model".*
>
> *"I understand it at first sight. It works, it flows".*

In terms of the visual presentation of the framework, the simple, cyclical illustration was well received:

> *"I think that the circle thing is really good. It's quite clear; it's simple on the eye*".

All of the clients interviewed were in the early stages (within the first year) of their first design project. However, none of the clients had been shown anything by the designer that communicated the design process itself to them. Although at the time of interview they were starting to gain an understanding of what the design process entailed, all commented that the framework would have given them a better understanding of the process had they been presented with it at the start of their project:

> *"From what I've seen so far, this is something that's been missing in the process".*

Feedback on the level of detail provided within the framework was consistent between all three clients. All felt the framework provided sufficient detail, while keeping the inclusive design process simple:

> *"I'm very much a fan of keeping things simple and that's keeping it simple".*
>
> *"I think the general overview is enough and for what we're doing I think that works without getting over-complicated".*

One of the clients questioned whether the lowest level of the framework was needed. All agreed that the framework was understandable (none were from a design background) if they were taken through it by a designer or expert.

Client communication with the designer

All of the clients felt that the framework would be beneficial if used by a designer during discussions regarding the inclusive design process:

> *"I think it's a communication tool that you would use throughout the process… working to that model gives us some kind of structure".*

> *"Would you use the process when communicating with a designer? Yes, absolutely".*

It was commented that designers who provided a visual aid of their design process came across as being more professional:

> *"I think if you've got a good design process then you do come across as being a bit more professional and a client would be more willing to get involved and would trust you more".*

The framework would be beneficial to the client to ensure projects ran to time:

> *"I think it would be good because you can clearly identify we started here, a month later we're here… If you know they should be here, why are they not?"*

Additionally the framework would help ensure the client was aware of project costs in advance:

> *"I think this would be most useful in breaking down the cost structure for a designer to explain to a client that if they want to go all the way through each of these stages, this is what it will cost".*

> *"You want to get your product to market quickly and you want to know these things up front".*

Recommendations for framework improvement

To develop the framework further, the following improvements were suggested by the clients:

- More details on the testing process were requested. While the clients understood the value of user involvement and its impact on the design process, they were unclear of the activities and methods of user involvement that would be required.

  "It needs the addition of a process of how you test it. You find your user and you let them use it but you need to try and narrow down that user base".

- Costs and timings were the main source of interest to the clients and all commented that they would like to see these represented within the framework:
  - *"I think time is important because time is money. If a client is paying for a service, then they want to know a designer is maximising the time".*
  - *"If each of these stages had a cost attached – and you can see how far you want to go with them".*
  - *"The costs and how long each of these stages – what the designer expects to spend timewise on each of these stages".*

<u>Questionnaire results</u>

Following the interview questions, each client was asked to complete a short questionnaire regarding how beneficial they felt the framework was in educating them of the inclusive design process. Table 8.2 illustrates the responses to the questionnaire gained from the three clients.

In response to the first set of questions in Table 8.2, all clients responded "yes" to all questions. All three clients felt the framework had improved their knowledge of the inclusive design process and all would use the framework in the future when communicating with a designer. As with the responses gained from the designers, all clients were also open to the option of using a hard copy format of the framework in addition to the interactive framework that was presented to them. All clients were happy with the amount of detail provided within the framework, as it communicated core aspects of the inclusive design process without becoming overcomplicated.

All clients commented that the framework would be of use to them in representing the inclusive design process itself, in addition to characteristics of that process – user involvement throughout the process and the iterative nature of design. No recommendations for improvement were suggested by the client in this section of the questionnaire, although it is acknowledged that the lack of prior knowledge of the inclusive design process by the client may limit the level of feedback they were able to provide. However, it is concluded that the framework was successful in communicating the characteristics of the inclusive design process to the client.

In response to the final section of the questionnaire, both clients 1 and 2 understood why iteration and user involvement were required within the inclusive design process. Client 3 responded “maybe” to this last set of questions, commenting that those details were present within the framework, but had required explanation by the researcher. However, it is noted that the framework is intended to aid designer communication of the inclusive design process with the client and is not intended for the client alone, therefore the client will always receive an explanation of the framework from someone knowledgeable of the inclusive design process.

Please answer YES or NO:	Client 1	Client 2	Client 3
Has the framework improved your knowledge of the inclusive design process?	Yes	Yes	Yes
Would you use the framework when communicating with a designer?	Yes	Yes	Yes
Would you use a software version of the framework?	Yes	Yes	Yes
Is there enough detail in the framework?	Yes	Yes	Yes
Would you use a hard copy of the framework?	Yes	Yes	Yes

Please rate (1 not useful – 5 very useful) the usefulness of the framework:	Client 1	Client 2	Client 3
Representing the inclusive design process.	5	5	5
Representing the iterative nature of the inclusive design process.	5	5	5
Representing areas for user involvement throughout the inclusive design process.	5	5	5
Highlighting the benefits of user involvement (to the design project).	5	5	5
Highlighting the benefits of user involvement to you (the client).	5	5	5

Please indicate whether you understand the following (yes/no/maybe):	Client 1	Client 2	Client 3
That iteration is a necessary part of the inclusive design process.	Yes	Yes	Maybe
That user involvement will help to minimise design errors.	Yes	Yes	Maybe
That user involvement is needed to prevent design errors later in the design process.	Yes	Yes	Maybe

Table 8.2 - Questionnaire responses from client interviews

Summary of client validation

Feedback was positive from all clients regarding the use of the framework to facilitate their discussions of the inclusive design process with the designer. The simplistic overview of the process was well received, with clients able to understand what was presented to them, with more information provided within lower levels of the framework if required. Clients reported that they felt there were was a lack of tools available to educate them of the design process, with all commenting that they had not been shown anything that communicated the design process to them. It is concluded that the framework presented here was beneficial in educating the clients of the design process itself, in addition to raising client awareness of the need to include users within the design process.

Little feedback was received from the client on how the framework could be developed further – while all liked the framework and how it was presented, none of the clients were experienced enough in design to recommend how the framework could be improved. However, all commented that as costs and timings were the most important factor to the client, this could be brought out within the framework.

8.1.3. Discussion of framework validation process

The feedback on the inclusive design framework was positive from both designers and clients and it is concluded that the framework will aid in designer-client communication of the inclusive design process. There was little discussion within the feedback gained from the designers and clients regarding the content of the framework, leading to the conclusion that the core areas communicated within the framework meet the needs of both stakeholders. However, it is noted that the framework should be customisable to suit the needs of individual projects.

Following the interviews, one designer has begun using the framework as a communication tool with potential clients. The designer stated that the framework was the most comprehensive overview of the inclusive design process he had seen, presented in a way that both covered the detail important to the designer and communicated the design process in an understandable manner to the client. The framework is available within the company website accompanied by several detailed blog postings, providing an overview of the design process to clients before they contact the company. The designer stated that a large proportion of time was spent in the initial meetings with clients educating them of the design process and what it would entail, therefore the company hope that the simplistic overview of the design process provided by the framework will educate the client of the design process before that first meeting. The framework is also used by the company during client meetings, as a discussion tool to aid communication within the design process. While still in the early stages of implementation, feedback from the company has been highly positive to date.

This study utilised respondent validation, with the designers interviewed as part of this study also involved in Study 3 (Chapter 6), where initial feedback was gained on the sports design process model and the initial requirements identified for the framework. As the framework was based on feedback gained from these designers, there were little changes recommended to the content of the framework.

It is noted that within the client interviews, the client continued to discuss the framework and the design process, rather than the “inclusive design framework” and “inclusive design process”. Based on feedback from the study carried out in Chapter 6, it was noted that the term “inclusive design” was often perceived negatively by clients. Instead, the focus of the interviews was on gaining feedback from clients on how the framework communicated the design process as a whole, including the iterative nature of that process and the value of including different user groups throughout the process, rather than using the term “inclusive design” specifically.

It is acknowledged that this thesis intends to present a framework that facilitates communication of the inclusive design process. Based on feedback gained from designers in Chapter 6, it is apparent that user involvement itself is lacking from many product design processes. There is therefore a need to increase user involvement itself within the design process, before then addressing the need for diversity in those user groups. This framework intends to provide a platform to increase user involvement within the design process by communicating to the client the needs of the designer and the value of user involvement. There is then scope for diversity in the user groups involved to be added within the framework, once a solid foundation of user involvement has been established.

The framework presented to the designers and clients was a developed prototype, still in the development phase, therefore recommendations for improvement were welcomed.

The layout of the framework was kept simplistic to encourage feedback on a concept under development – a more finalised version may have resulted in interviewees holding back on recommendations for improvement. It was noted that feedback from the designers was much more detailed, focusing on the interface and aesthetics of the framework. In contrast, feedback from the clients focused on representing the time and cost elements of the design process. It is clear that both groups have different needs of the framework – the designers who must be able to navigate through the framework and communicate relevant aspects of the inclusive design process, while the client wants to see value for money in that process. The final refinement of the framework must firstly accommodate the needs of the designer, for whom the framework is intended as a tool for, in addition to the needs of the client, who must benefit from the use of the framework by the designer.

Following the feedback gained from the designer and client validation process, the following requirements list was generated to aid further refinements to the framework.

Framework requirements

<u>High Level Representation:</u>

- Provide a high level representation of the sports design process model as the introductory slide.
- Remove additional text from introductory slide (design review outputs and user involvement activities).

<u>Customisation:</u>

- The framework should be customisable to individual projects.
- Additional of design company and client logos would add a professional “look” to the framework.
- Allow designers the ability to add images to the framework, specific to each design project/company to communicate activities at each stage.

<u>Visual Representation:</u>

- The design process stages should be reversed – research should be the inner circle, representing less time and ease of repetition of the stage. Design refinement

should be the outer circle, representing a longer process of repeating if changes are necessary.
- General improvement needed on graphics – it was suggested this should be done by a graphic designer.
- Keep colours consistent for each process stage rather than for separate layers within the framework.

Navigation:

- Ease of navigation needs improved – improvement in graphics and visuals will help.
- Remove double loop (or double click) of process stages.
- Ensure fewer “clicks” are needed to navigate through the framework.

Framework content:

- Addition of co-creation activities within user involvement.
- Addition of visual impact of design changes.
- Additional details of user testing process.
- Costs and timings should be represented within the framework.

8.2 Presentation of the final framework

Based on the recommendations provided by designers and listed in the framework requirements, the final inclusive design framework was developed further, with a visual summary of the further developments shown in Figure 8.3. A modified high level version of the sports design process model has been added to the start of the framework to aid ease of interpretation for the client. Additional detail contained within the original sports design process model has been removed to ensure the model is easier for the client to absorb initially.

Feedback received from designers noted that reversing the design process stages would emphasise that repetitions were easier, less costly and less time consuming earlier in the design process. The design process stage names have been reversed as shown in Figure 8.3, with the research phase starting from the inner circle leading to design refinement in the outer circle. Clients indicated that they would like to see more emphasis on timings and costs within the framework – the reversal of the process stages will visually communicate the greater time and cost allocation to later stages of the inclusive design process.

The colour coding system has been revised – individual colours now represent each of the four process stages rather than levels of the framework. The colour coding system is as follows:

- Research: pink
- Conceptual design: green
- Design development: purple
- Design refinement: orange

To aid the ease of navigation and reduce the number of “clicks” required to move through the interactive framework, the lower level representation of each process stage has been removed (level 2 in the original framework), with the additional information added to the higher level (level 1 in the original framework). Additional information has also been added within the breakdown of the design review to illustrate the impact of design changes to the project.

Co-creation and specific user testing activities were not added to the model as these activities are likely to be project and company specific. Within the customisation of the framework, there is scope to add in these additional design activities. The framework is intended to be customisable to individual design projects, therefore the option to add company logos and images has been added.

The remainder of this section will present the final interactive framework. Figure 8.4 illustrates the final structure of the framework and reflects the changes made – separate colours are used for each of the four process stages and navigation has been improved by reducing the number of “clicks” required to move through the levels. It is noted that the framework is still a proof of concept, with further work required from a graphic designer to finalise the visuals and navigation through the software.

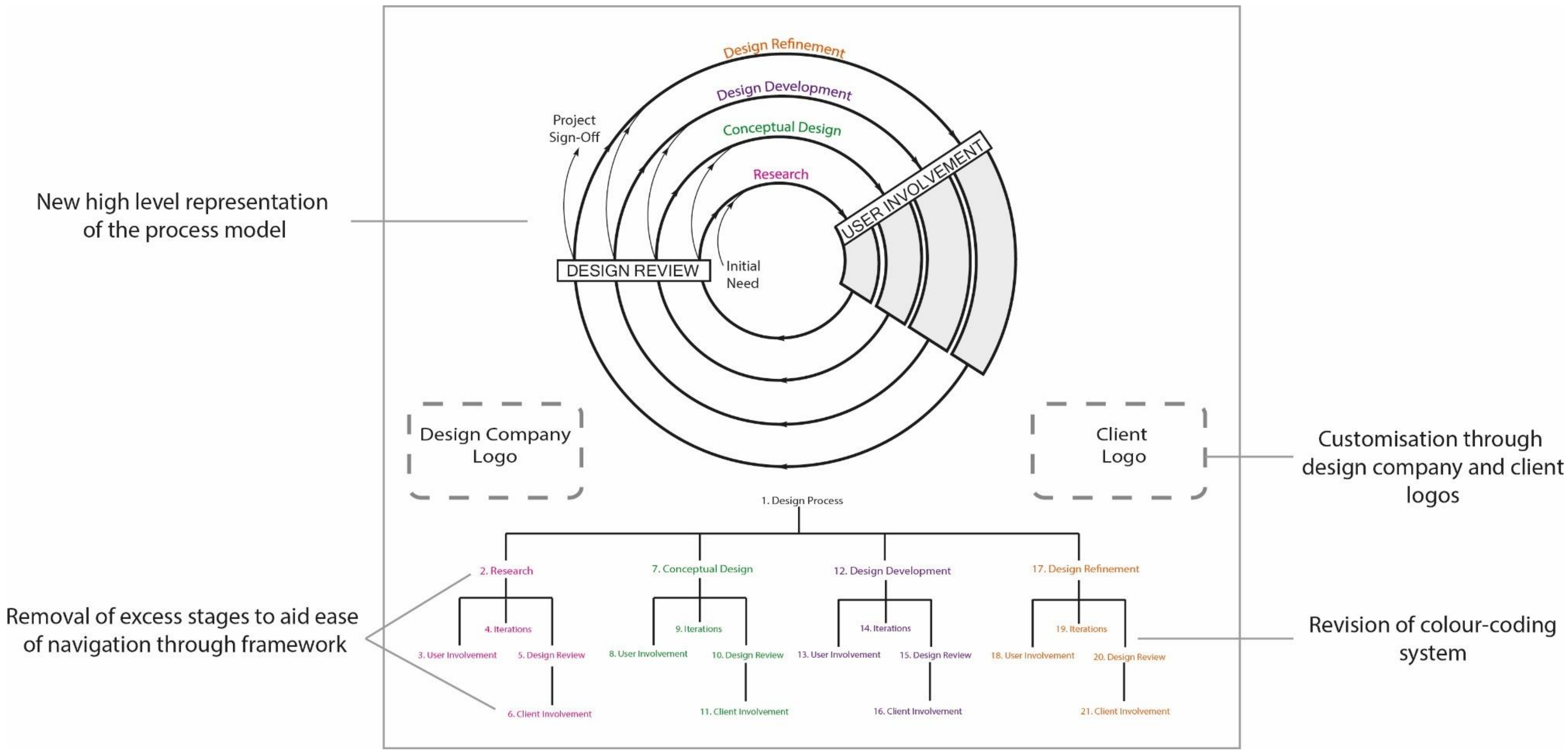


Figure 8.3 – Example slide from the final framework identifying the changes made

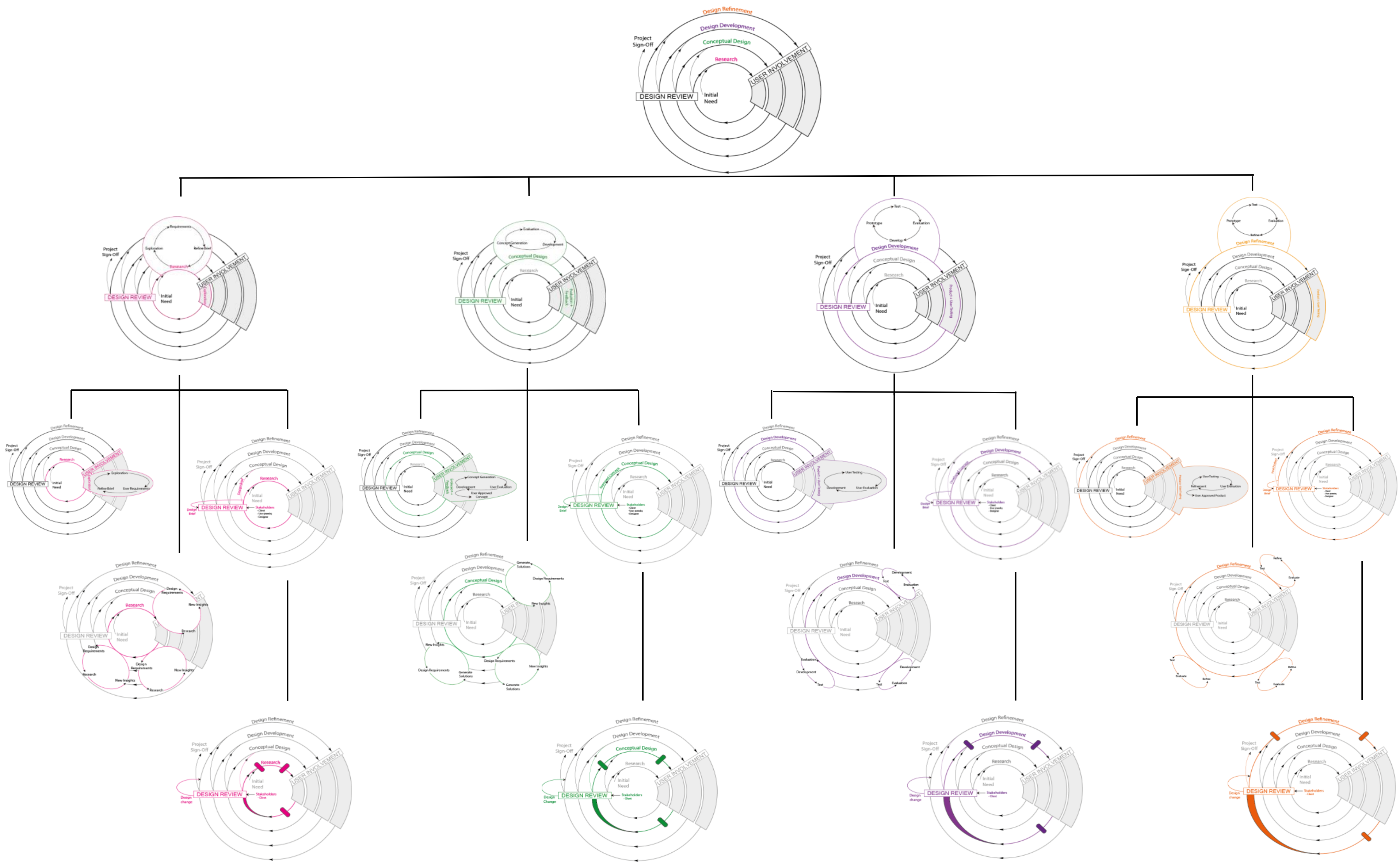


Figure 8.4 – Illustrated tree diagram of final framework interface

Level 0 – Home screen

The home screen of the framework now shows the research stage at the centre of the design process model, with the path of the design process moving outwards towards design refinement on the outer circle. This represents increased time and effort as the project progresses, making design changes more time consuming and costly in the later stages of the process. The process model is a higher level version of the original, with the outputs of the design review stage and the nature of user involvement removed from this page. Reducing the complexity of the initial process model will draw client attention to the central themes of the inclusive design process (iterations and user involvement throughout) without over complicating the model. The colour used for the process stage names in the model reflects the updated colour coding used in the framework structure shown at the bottom of the image. These colours continue throughout the interactive framework.

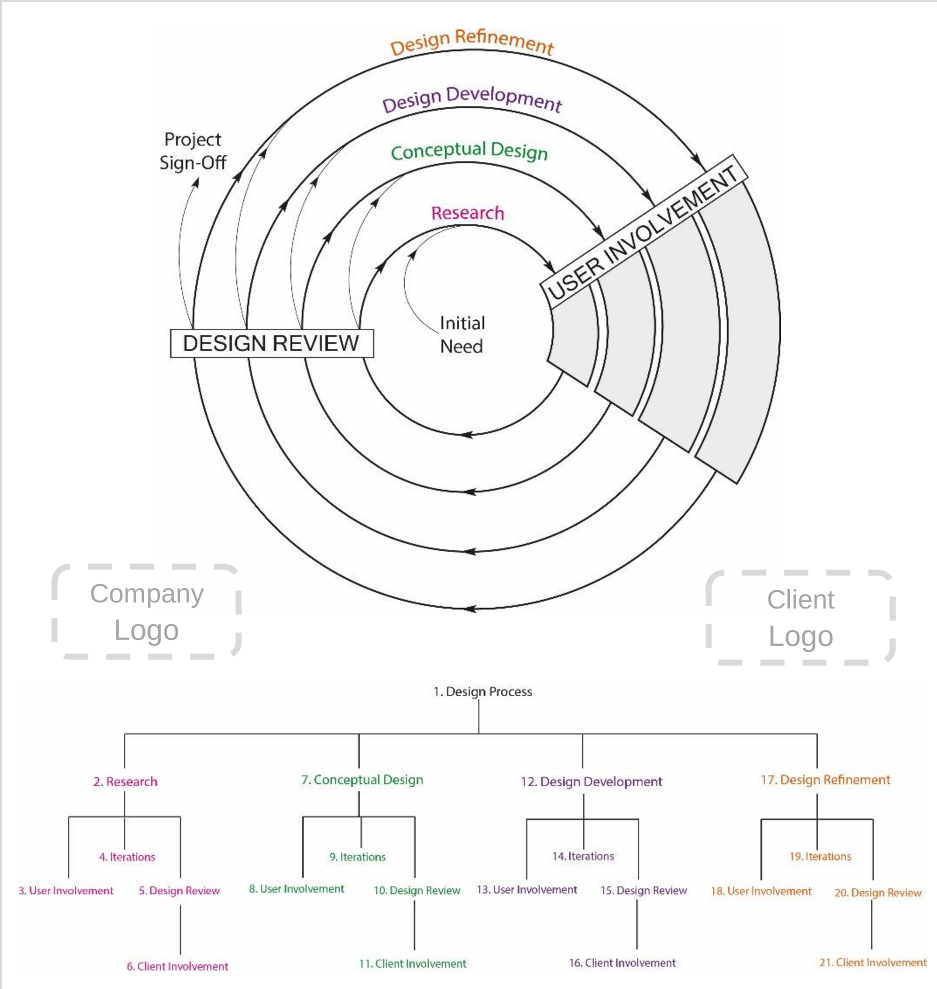


Figure 8.5 – Level 0: home screen

Level 1 – Research: process stage

To aid navigation of the framework and reduce the number of "clicks" required to move through it, the additional detail for the process stage (previously shown in level 2) is now incorporated within the image shown here. The research phase is made up of an iterative process of exploration to determine design requirements, which in turn inform the design brief. This process is repeated until the design brief is finalised and the project progresses. The home tab at the top left of the image returns the user to the home screen at level 0.

The tree at the bottom of the image illustrates that the user is on level 1 of the interactive framework and within the screen has three options available to them for additional information – user involvement, iterations and the design review. Each of the options can be selected by clicking the mouse over the respective coloured areas of the screen.

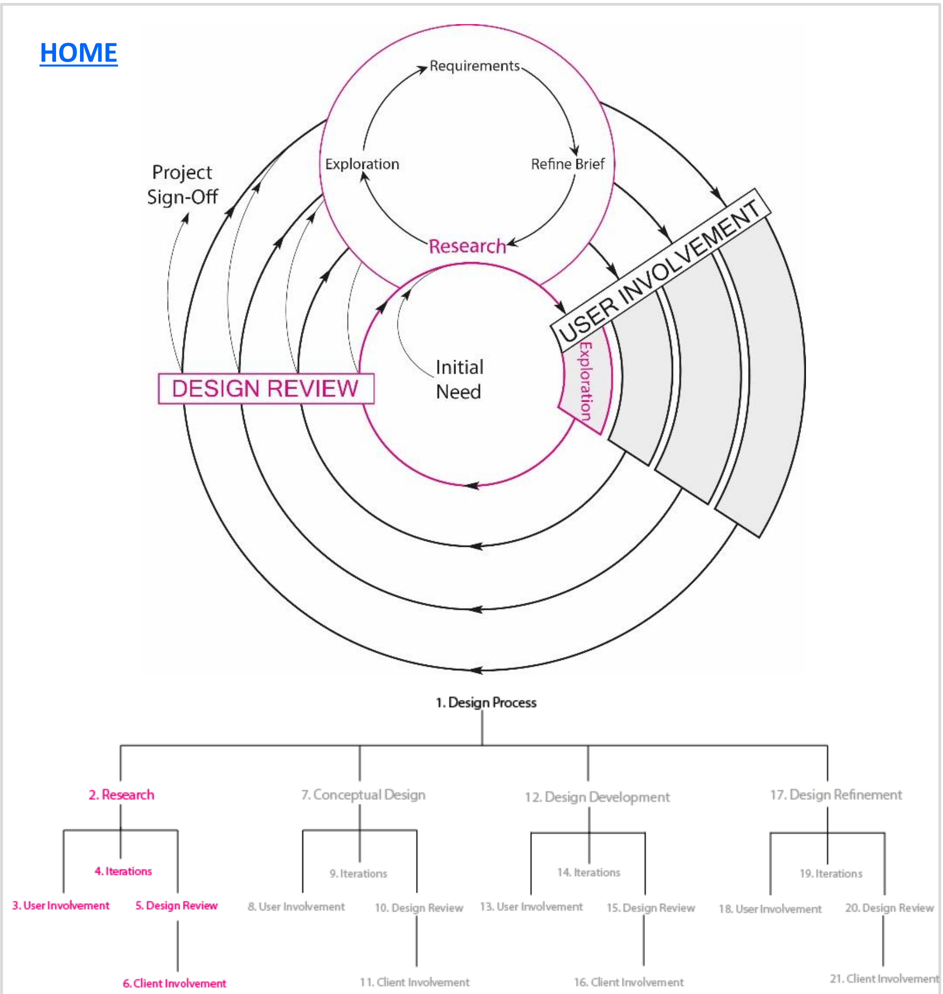


Figure 8.6 – Level 1: research stage

Level 2 – Research: user involvement

The image illustrates that there is time involved in sourcing the appropriate user groups – something designers noted clients did not allow for. Within the research stage of the process, user involvement is often exploratory, with the goal of identifying user requirements that in turn inform the design brief. It is also essential that within the inclusive design process, a diversity of user groups is included. It is acknowledged that the nature of user involvement will vary on a project-by-project basis. The framework allows designers the option to customise to illustrate project specific methods and activities.

The tree at the bottom of the image illustrates that the user is on level 2 of the interactive framework and cannot go any lower in the framework from this area. The home tab at the top left of the image returns the user to the home screen at level 0. The back tab takes the user back one level – in this case to the research stage on level 1.

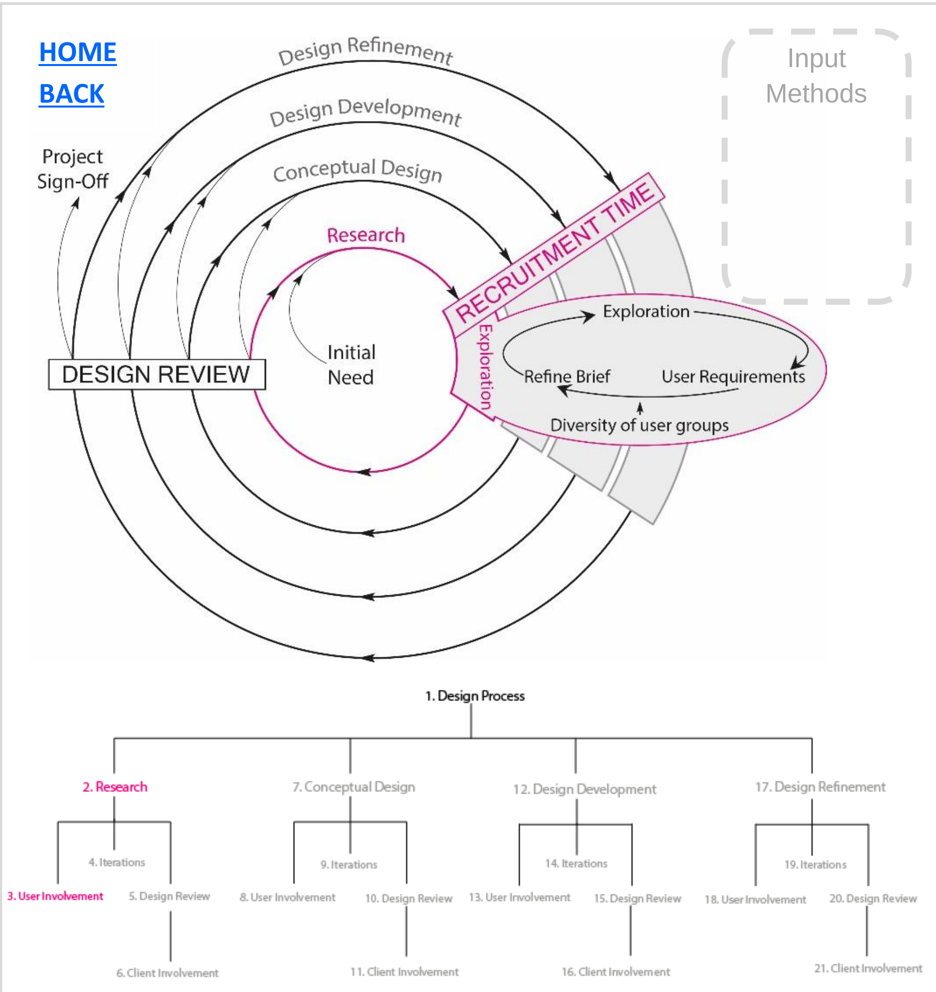


Figure 8.7 – Level 2: research user involvement

Level 2 – Research: iterations

The image illustrates that the research stage is a series of constant iterations – involving the designer researching the design problem and gaining new insights as a result. These insights are translated into design requirements. The iterations are repeated until the designer has sufficient knowledge of the design problem to progress.

The tree at the bottom of the image illustrates that the user is on level 2 of the interactive framework at the iterations of the research stage. The home tab at the top left of the image returns the user to the home screen at level 0. The back tab takes the user back one level – in this case to the research stage on level 1.

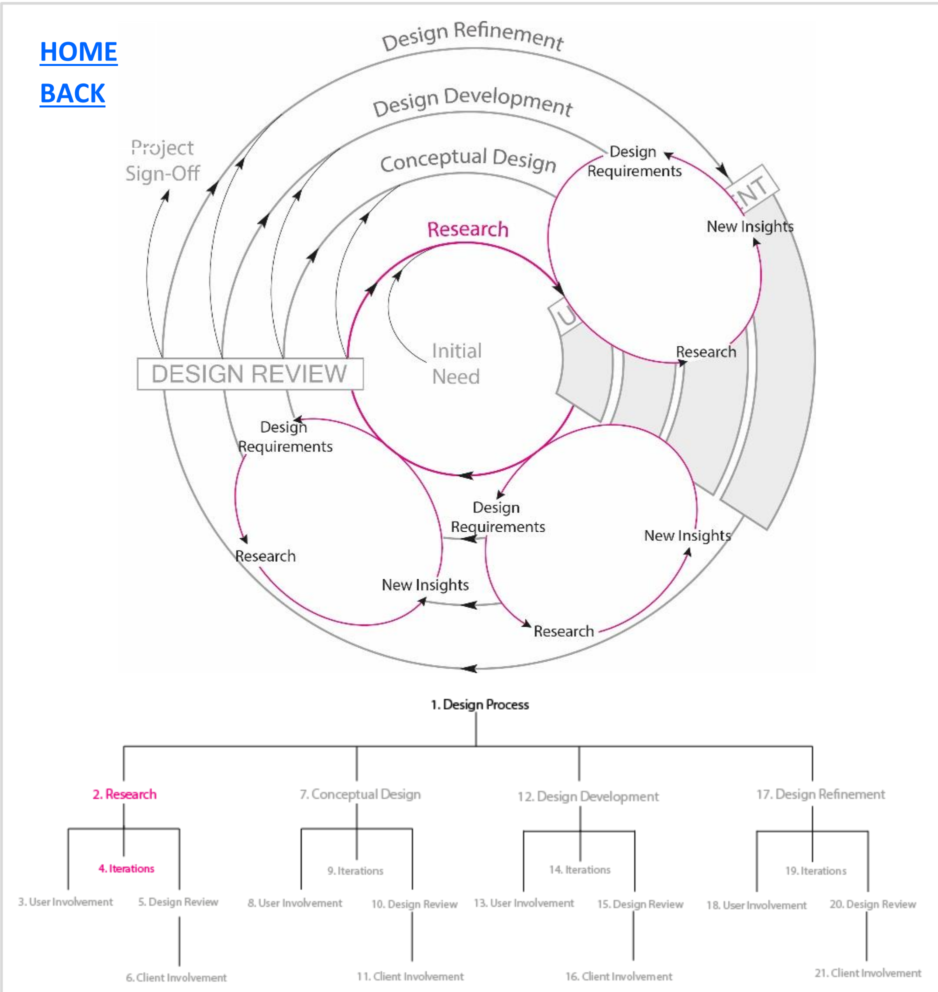


Figure 8.8 – Level 2: research iterations

Level 2 – Research: design review

The image shows the design review as a decision making point at the end of the research stage. Project progress and research results feed into the design review. Those involved in the decision making process are stakeholders within the process – the client, the designer, the needs of the user (it is unlikely that the user themselves will be present at the design review, but user needs are reflected in the design brief). Those involved in the design review can be customised by the designer on a project-by-project basis. The design brief (a dynamic document) informs the design review and is used to ensure the project meets requirements. There are two possible outcomes of the review:

1. The project meets the requirements – the outcome of the research is a design brief agreed upon by the stakeholders, and the project progresses to conceptual design.
2. The project does not meet the requirements – the design brief is insufficient and the research phase is repeated until the brief is agreed upon.

The tree at the bottom of the image illustrates that the user is on level 2 of the interactive framework at the design review of the research stage. The "home" tab at the top left of the image returns the user to the home screen at level 0. The "back" tab takes the user back one level – to the research process stage on level 1.

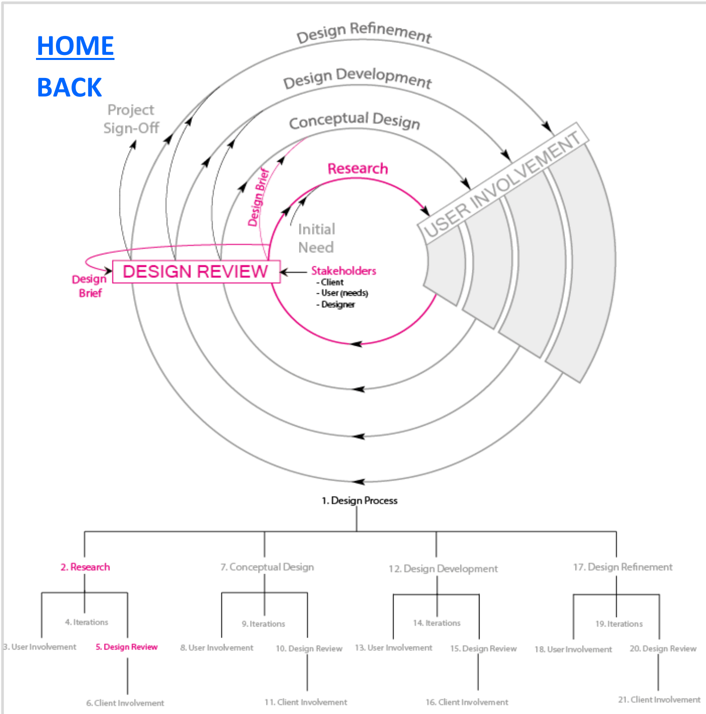


Figure 8.9 – Level 2: research design review

Level 3 – Research: design review

The image illustrates expected client involvement within the research stage of the design process. Designers noted that the client was often a source of information and reference throughout the process, which is illustrated here using small tabs to mark intermittent involvement – this can be customised per project. In the lead up to the design review, designers requested that the client should be phased in, so as not making decisions uninformed. The effect of design changes made by the client is also illustrated here, based on feedback gained from the designer and client validation interviews. On this image, the effect of design changes at the research stage is not too severe, with further work resulting in iterations of the research stage. However, design changes made later in the process result in backtracking – the further through the design process, the greater the impact design changes will have.

The tree at the bottom of the image illustrates that the user is on level 3 of the interactive framework, focusing on client involvement at the design review phase of the research stage. The "home" tab at the top left of the image returns the user to the home screen at level 0. The "back" tab takes the user back one level – in this case to the design review phase of the research process stage on level 2.

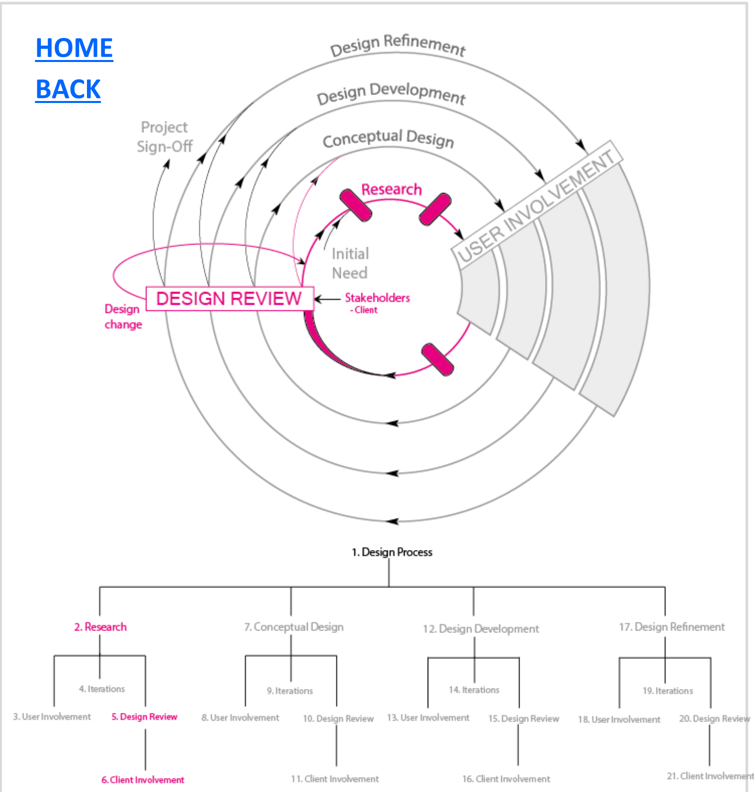


Figure 8.10 – Level 3: research design review

The images presented in this section provide an overview of the research phase of the interactive framework. The content of the framework for the remaining process stages shows variations in terms of the outputs and activities of each of the process stages. There are no variations in terms of how each level of the framework links to the next. All images of the framework are presented in a similar visual manner.

8.3. Conclusions

The development of the inclusive design framework in Chapter 7, in addition the validation and refinement of that framework within this chapter provide a solution to the third research question – **how is the sports design process applicable to inclusive design?** The outcome is an interactive framework, based on the sports design process model that facilitates designer-client communication within the inclusive design process. Sports design has several characteristics that are representative of inclusive design practice: an iterative design process, with user involvement throughout that process and direct interaction between the designer and the user. The framework builds on these characteristics, communicating them in a manner that will aid client understanding of their benefit and value to the inclusive design process, as the client is frequently found to be a barrier to inclusive design uptake in practice.

This chapter presents the validation of the inclusive design framework through respondent validation with designers previously involved in interviews in Chapter 6, in addition to further validation from design clients. It is therefore concluded that the sports design process model, developed into an interactive framework, will aid inclusive design practice by facilitating designer-client communication of the inclusive design process. The outcome of this study and contribution to knowledge is therefore an interactive framework that facilitates designer-client communication within the inclusive design process.

The inclusive design framework presented here addresses the following needs of an inclusive design process, discussed earlier in this thesis in Chapter 2:

- Clarkson and Coleman (2015) report that the inclusive design process is iterative, with new knowledge gained, resulting in continuous design improvement and customer satisfaction. The framework presented here illustrates the iterative nature of inclusive design, communicating to the client the need to iterate within the design process. The framework also illustrates the continual involvement of users, where new insights are gained, to help inform the decision making process at the design review.

- Waller, et al. (2013) state that inclusive design thinking should play a key role in the decisions made throughout the design process. The inclusive design framework developed here emphasises the importance of the design review at each stage of the inclusive design process, where all stakeholders should be involved in ensuring the project addresses its requirements. The framework also illustrates the impact of design changes later in the design process, where the time and cost of those changes is significantly higher.
- Ielegems, et al. (2015) report on the need to implement user testing early in the design process as part of good inclusive design practice. This continuous process of user testing can significantly reduce the need for re-design (and the associated costs) compared to only carrying out user testing in the later stages of the design process. As illustrated within the framework presented here, user testing should be carried out throughout the inclusive design process, with the impact of user requirements on the design brief and the decision making process at the design review stages emphasised.

Based on the findings from Study 3 (reported in Chapter 6), it is apparent there is a lack of user involvement within the design process in practice. It is recommended that general user involvement itself needs to be established more firmly within design practice before a greater diversity of user groups can be included. As stated by Vanderheiden and Tobias (2000), inclusive design is a process, not an end product. There is therefore a need for a means of implementing an inclusive design process within industry that addresses the barriers to the uptake of inclusive design. It is recommended that “in developing such tools, an inclusive design research methodology should be adopted – involving users (designers) throughout the process” (Dong, et al., 2015). This research reports on an iterative process of development, evaluation and validation of an interactive framework that will facilitate designer-client communication within the inclusive design process. This research has involved both designers (as user of the framework) in addition to clients (often cited as a main barrier to inclusive design uptake) to ensure the needs of both groups are accommodated within the development process of the framework.

Chapter 9 – Summary and conclusions

This chapter concludes the research undertaken within this thesis by providing a summary of the research, discussing the research approach and the four studies conducted to address the research questions identified from the literature review. The limitations of the research will be discussed, in addition to the contribution to knowledge, impact and identification of further work.

9.1. Overview of the research

Sports design is a young and evolving area of design, with rapid developments being made in the field of sports equipment and technologies. Sports design views the equipment and the athlete as a system, which must work together to facilitate sporting performance. However, to date there is no existing design process model that captures the characteristics of sports design practice as a whole. Like sports design, inclusive design is a highly user centred discipline. With the global ageing population, there is an increasing need for greater awareness and adoption of inclusive design, to accommodate the diversity in capabilities of this older population. This research proposed that lessons may be transferrable between the two areas to aid the uptake and/or implementation of inclusive design within industry. As such, the aim of the research, identified in Chapter 1 was:

> **To investigate how the sports design process can be used to improve inclusive design practice.**

To address this aim, the following objectives were identified:

1. To understand what differentiates the sports design and traditional product design processes in practice.
2. To determine what characterises the sports design process and to capture that process in a design process model.
3. To investigate the applicability of the sports design process to inclusive design practice.
4. To investigate how to improve the uptake of inclusive design in industry.

5. To validate the outcomes of the research.

The objectives were met within this thesis through the use of a two-part study, as illustrated within Figure 9.1 – Part 1 documented two descriptive studies, while Part 2 documents two prescriptive studies. The objectives were met as follows:

1. Study 1 followed a triangulation approach to identify what differentiates and characterises the sports design process from the product design process in practice (Chapter 4). The approach allowed for confidence in results, through the use of a multi-method approach.
2. Study 2 identified and captured the first process model of the sports design process as a whole, illustrating the identified characteristics of sports design practice. A five step process of identification, evaluation, development and validation (reported in Chapter 5) was followed. Respondent validation was utilised in Chapter 5 to ensure the outcome was a process model truly representative of sports design practice. The literature review identified the lack of research into sports design process and the lack of a published process model that captured the sports design process as a whole. This thesis reported on a practical study involving designers from industry, in addition to researchers and students, with a contribution to knowledge being a process model that is descriptive of sports design practice in industry.
3. Following the identification of the sports design process, Study 3 assessed the applicability of the sports design process model to aid inclusive design practice using designer interviews and a workshop conducted with the Helen Hamlyn Centre for Design (reported in Chapter 6).
4. The findings of Study 3 (Chapter 6) identified that the sports design process model would be of use in aiding the uptake of inclusive design in industry if developed further into an interactive framework to facilitate designer-client communication within the inclusive design process. The output from Study 3 was a set of requirements, detailing the needs of the inclusive design framework.
5. Study 4 reported the iterative process of the development of the interactive framework, developed to facilitate designer-client communication within the inclusive design process (Chapter 7). Chapter 8 reported on the validation of that framework using interviews with designers and design clients and presented the final framework.

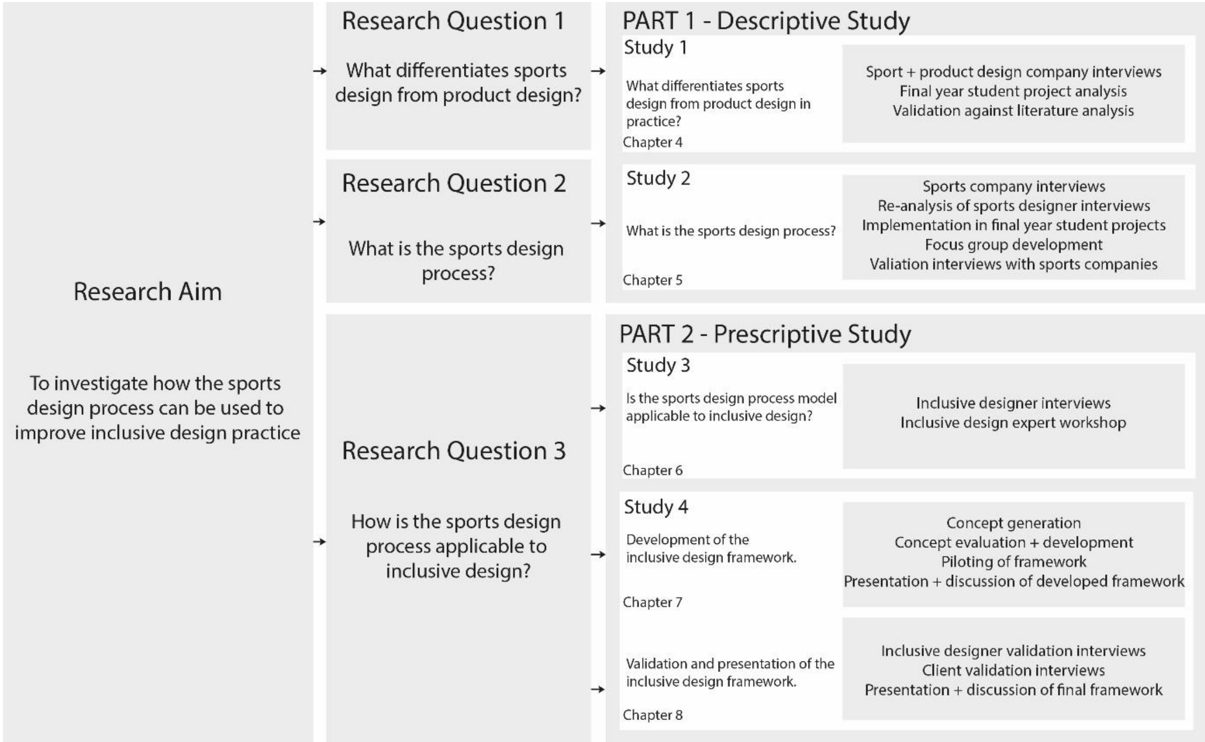


Figure 9.1 - Structure of the research

9.2 Research questions

Following the literature review conducted in Chapter 2, the following research questions were identified:

1. **What differentiates the sports design process from the product design process in practice?** (Addressed in Chapter 4)

2. **What is the sports design process?** (Addressed in Chapter 5)

3. **How is the sports design process applicable to inclusive design?** (Addressed in Chapters 6, 7 and 8)

To address each of these research questions, four studies were conducted as illustrated in Figure 9.1. A brief overview of each of the studies is given here, in addition to the main findings of each.

Study 1 – What differentiates the sports design process from the product design process in practice?

Study 1 addressed the first research question through the comparison of the sport and product design processes in industry practice. A triangulation approach was followed to ensure validity in the study – interviews were conducted with sport and product design companies to identify differences between each in practice, final year university sports engineering student projects were analysed to validate the findings from the interviews and the findings of each were compared with the findings from the literature review to ensure validity and identify the contribution to knowledge. The study identified that sports design differs from traditional product design with iterations occurring within process stages rather than between and direct designer-user involvement throughout the design process. The findings of the literature review identified that there was no existing, published model of the sports design process as a whole. Interviews with sports designers in industry and analysis of student projects provided further evidence of the lack of a sports design process – many reported following existing design process models, adapted to reflect the needs of the sports design process. The study concluded that there is therefore a need for a design process model that captures the characteristics of the sports design process.

Contributions to knowledge gained from this chapter come from the identification of a lack of a design process model that captures the sports design process as a whole. The study also provided further knowledge of what characterises the sports design process, focusing specifically on industry practice.

Study 2 – What is the sports design process?

Study 2 addressed the second research question and followed an iterative five step process of development, evaluation and validation to ensure the outcome was a true descriptive representation of the sports design process within industry. The outcome of the study and contribution to knowledge is the first design process model to capture the sports design process as a whole. The model incorporates key characteristics of the sports design process including the iterative nature of the process within process stages and the continual involvement of the user throughout the design process.

Study 3 – Is the sports design process model applicable to inclusive design practice?

Study 3 goes some way to addressing the third research question by determining the applicability of the sports design process model to inclusive design practice. Interviews were conducted with product designers from industry with experience in inclusive and/or user centred design, in addition to a workshop carried out with designers from the Helen Hamlyn Centre for Design, which specialises in inclusive design. The study identified differences between inclusive design practice in industry and "best practice" inclusive design carried out at the Helen Hamlyn Centre for Design and indicated that the sports design process model was representative of good inclusive design practice. Interviews with industry designers found that many designers were not following an inclusive design approach, with most not involving any users within their design process. It was reported that this came from the client lacking understanding of the design process and the needs of the designer. It was concluded that the sports design process model would be most beneficial if developed into an interactive framework that would facilitate designer-client communication within the inclusive design process. Requirements from those involved in the study informed the development of the framework.

Study 4 – Development and validation of the inclusive design framework

Study 4 concluded the research and provided a solution to the third research question. Based on the recommendations of the designers interviewed as part of Study 3, an interactive framework was developed to facilitate designer-client communication within the inclusive design process (Chapter 7). The framework was validated through interviews with both designers and clients (Chapter 8). As identified within Study 3, there is a general lack of user involvement within the design process. The framework developed here is intended to increase client awareness of the needs of the inclusive design process – the need for user involvement throughout the design process and the need for iterations. Other factors specified by the designers are also included in the framework (for example: the impact of late design changes). The contribution to knowledge of this study is an interactive framework that facilitates designer-client communication within the inclusive design process.

9.3. Conclusions

This research provides a number of conclusions that address the aim of investigating how the sports design process can be used to improve inclusive design practice. It was found that sports design practice in industry differs from traditional product design, with a number of characteristics that distinguish it. The sports design process shows iterations within design process stages, but rarely back-tracked through the process, while product companies reported some backwards iteration between process stages. Sports companies also showed high levels of user involvement throughout the design process with the designer actively engaged with the user throughout, providing the designer with a primary source of user information. In contrast, product designers typically involved the user at the start and end of the process rather than throughout, with the designer themselves rarely coming into direct contact with the user, instead relying on secondary user information. It is therefore concluded that the sports design process is both iterative and highly user centred throughout.

This research also presents the first design process model to capture the sports design process as a whole. By capturing the characteristics of the sports design process, the outcome is a descriptive model of sports design practice, illustrating the iterative nature of the sports design process and the involvement of the user throughout. The model was developed through an iterative process involving both practicing sports designers and sports engineering students, before being validated by sports designers.

This research agrees with previous studies in that the client is often a main barrier to inclusive design practice. It is also noted that designers in industry are aware of the core stages of the design process and what the inclusive design process should entail, therefore a new design process model targeted at the designers themselves is unlikely to change established ways of working. It was identified that in order to increase the inclusivity of the design process, there is a need to educate the client of the design process itself, in addition to the value that a more inclusive, user centred approach to the process would bring.

The outcome of this research is an interactive framework that facilitates designer-client communication within the inclusive design process. Based on feedback received from the designer and client validation interviews, it is concluded that the framework provides a means of educating the client of the inclusive design process by capturing the characteristics of that process, in addition to the needs of the designers within the framework.

Dong (2004) recommends that to increase inclusive design within industry there needs to be:

1. An increase in awareness, understanding the context of inclusive design and the opportunity it brings to business.
2. More information to develop strategies for combating barriers and being better informed to respond to the challenge.
3. Build up more experience through hands-on practice.

By improving client awareness of the inclusive design process, it is concluded that this research addresses these recommendations as follows:

1. The framework increases client awareness of inclusive design and the value brought to the design process by continual user involvement throughout the process.
2. The framework provides a foundation on which to overcome a key barrier to inclusive design (the client) by providing a means of educating the client of the inclusive design process.
3. The framework is targeted at design practice in industry, therefore encourages a practical approach to incorporate inclusive design into everyday design practice.

9.4. Limitations of the study

Within practical, people-based research such as this, there will be a number of influences that affect the project. In order to overcome these biases, a thorough approach of iterative analysis, development, evaluation and validation was followed to minimise errors within the research. This section will address the limitations of this research and discuss the steps that were taken to minimise them.

Involvement of industry

The boundaries of the study (e.g. what was classified as "sports" and "product" design) may be considered a limitation as no existing guidelines were in place to constrain the selection of companies included in this study. However, efforts were made to ensure the interviewees involved were representative of their design discipline and comparable in terms of their design processes. More details on these constraints and selection criteria for each of the studies are provided within the relevant chapters.

It is noted that the results of this research are dependent on what the interviewees chose to divulge during the interviews. Selection of companies was dependent on those prepared to discuss their design process openly, with all designers aware in advance of what would be asked during the interviews. Steps were taken to reduce the impact of designer's with-holding information through the use of a triangulation approach, respondent validation and a rigorous approach utilising many sources, as discussed earlier in this chapter.

Sample size

For each of the four studies, sample sizes of interviewees varied, as illustrated in Table 9.1. Within the scope and timescales of the research, it would not have been feasible to include higher numbers of participants within the studies. The difficulty in sourcing relevant participants should also be noted. In terms of the companies involved, it is difficult to source companies willing to talk openly about their design process and with the time available to participate in research. In the case of the students, fourth and fifth year groups were small, limiting the pool of potential participants.

To ensure that findings would not be skewed by random results and validity within the study, steps were taken within each study to minimise errors. A triangulation approach was followed within Study 1 – a set of interviews were conducted with sports and product design companies to identify differences between each in practice, final year university sports student projects were analysed to validate the findings from the interviews and the findings each were compared with the findings from the literature review to ensure validity and identify the contribution to knowledge. Study 2 utilised an iterative process of development and evaluation, in addition to respondent validation to ensure the outcome was a truly descriptive model of the sports design process. Studies 3 and 4 followed an iterative process of development and evaluation of the framework against the requirements provided by designers and inclusive design experts. Study 4 utilised respondent validation to ensure the framework met the needs of the designers it was intended for. Overall, these steps helped to improve the quality of the research and provided a holistic view of the sport and inclusive design processes.

Study	Method	Participants
1	Individual designer interviews	12
	Analysis of student projects	17
2	Individual designer interviews	6
	Implementation within student projects	5
	Focus group development	5
	Designer validation interviews	5
3	Product designer interviews	5
	Inclusive design workshop	3
4	Designer validation of the framework	3
	Client validation of the framework	3

Table 9.1 - Sample sizes of studies

Researcher involvement in the process

Within this research, the researcher was the facilitator of the studies carried out and analysed the interview transcripts. The interpretation of qualitative data is dependent on the background of the researcher, therefore it is important that any conclusions drawn from the data are not based on assumptions made by the researcher. To minimise researcher bias, a general inductive approach was used to analyse the interview transcripts (described earlier in Chapter 3).

Within qualitative research, there is a possibility of the words of the interviewee being taken out of context, resulting in the meaning of the data changing. It is therefore important that the original raw data is continually referred back to, to ensure that any results are in-keeping with the original meaning of the interview (Densombe, 2010). All interview recordings and transcripts were retained and referred back to throughout the research to ensure key findings were reassessed within their original context.

There can be variations in the interpretation of the data between different researchers. To minimise this error, steps were taken within the research to ensure reliability and repeatability of results. In Study 1, the initial designer interviews and their analysis formed part of a triangulation approach, to improve the overall quality of the research and to reduce bias. In Study 2, an iterative approach using both workshops and interviews was undertaken to validate results from multiple sources. In Study 3, interviews and a workshop were conducted and the results compared to ensure the final framework was developed from a reliable set of requirements. The final study involved two separate subject groups for the interview process to reduce bias within sample groups, with respondent validation utilised to reduce bias in researcher analysis.

It is acknowledged that within Studies 2 and 4 where the sports design process model and the inclusive design framework were developed, the outcomes may not be repeatable between researchers. Both the sports design process model and the inclusive design framework were developed based on conclusions and requirements drawn from the four studies undertaken. These studies followed a rigorous approach so it is concluded that the results gained from these studies (and therefore the requirements that both the sports design process model and the inclusive design framework were developed from) would be repeatable if carried out by another researcher. The visual representation of the model and the framework were based on the researcher's visualisations of the results and conclusions, therefore while the content and core characteristics of each would be repeatable, the aesthetic presentation of each may vary between researchers.

9.5. Contribution to knowledge

This research has contributed to knowledge within the disciplines of sports design and inclusive design, by making the following contributions:

1. Identification of the lack of a sports design process model that represents the sports design process from project initiation through to project sign off.

2. Identification of the characteristics of the sports design process as a whole within industry.
3. Presentation of the first design process model to capture the sports design process as a whole.
4. Identification of the need for a tool to aid designer communication with the client of the inclusive design process.
5. Presentation of a validated interactive framework to facilitate designer-client communication of the inclusive design process.

As discussed in the literature review (Chapter 2) there has been a lack of research conducted into the sports design process. The findings of Study 1 identified the lack of a sports design process model within the literature, in addition to the lack of such a model existing within industry. The adaption of existing process models by sports students within their projects reiterates the need for a model that reflects the characteristics of the sports design process.

The work carried in this research offers new insight into sports design, with previous work lacking in-depth research into sports design practice in industry. Study 1 found agreement with previous work regarding the characteristics of sports design but provides additional insight into what characterises the sports design process as a whole, which has been lacking in previous work.

Study 2 presents the first sports design process model, which itself is a contribution to knowledge. As reported in Study 1, there is no evidence of an existing process model that captures the characteristics of the sports design process as a whole. However, findings from designer interviews and analysis of student projects indicate there is a need for one. This research therefore presents the first process model to capture and visualise the characteristics of sports design practice within a design process model.

Study 3 concluded that an inclusive design process model targeted at the designers themselves would have limited impact in practice. Findings from this research agree with previous work that the client is a major barrier to inclusive design uptake in industry, and goes further in identifying the need for a tool that enables the designer to communicate the needs of the inclusive design process to the client. This research also assesses “model” inclusive design practice as carried out at the Helen Hamlyn Centre, and makes the comparison to inclusive design practice in industry. The requirements identified in Chapter 6 are based on the characteristics of “good” inclusive design practice, in addition to the needs of industry designers.

Study 4 presents the inclusive design interactive framework, intended to facilitate designer-client communication within the inclusive design process. The framework takes the approach of educating the client of the value of incorporating a diversity of users throughout the design process, in addition to illustrating the nature of design practice itself. This is in contrast to many other inclusive design tools that typically focus on the designer.

9.6. Impact

This thesis reports on practical research, carried out with practicing designers from industry. As a result, the outputs of the research have many applications with potential benefits within industry, education and to the users themselves. The five identified contributions to knowledge are discussed here in relation to these three groups.

Industry

The literature review identified that companies following a formalised design process were more successful. The contribution of the first process model to capture the sports design process as a whole will be of benefit to sports companies, who will have access to a process model that reflects the characteristics of sports design practice. This will aid in structuring design practice and identify areas of improvement within the company. As discussed in Chapter 5, two of the sports companies interviewed in the validation of the sports design process model indicated that they would like to start using the model as a means of aiding discussions and the structure of their process. There is therefore a demand from sports design companies for a design process model that illustrates their design process to aid design practice.

The findings from Study 3 noted that there is a need within industry for a tool that enables designers to communicate the needs of the inclusive design process to clients. Designers reported that existing design process models were not in a format understandable to those not from a design background and did not provide a comprehensive breakdown of the inclusive design process. The contribution of the interactive framework developed to facilitate designer-client communication within the inclusive design process will therefore benefit designers in industry. The use of layers within the model allows an appropriate level of detail to be provided to individual clients, with designers able to customise the framework to reflect individual company and project needs. One of the designers interviewed in the validation of the inclusive design framework (Chapter 8) is currently using the framework to aid in the communication of the design process with potential clients. The designer also noted at the time of interview that this was the first tool to effectively break the process down in a format that was usable to communicate with those from a non-design background. The designer currently using the framework discusses it within the company website – ACE Product Design.

Education

As discussed in the literature review, sports design is a young, evolving discipline. Sports engineering courses are now established in several universities, including those in the UK, Australia, America and Europe. The contribution of this work in identifying the characteristics that differentiate sports design practice, in addition to the developed model that captures the sports design process, will be of benefit within an educational setting, helping to educate sports designers and to aid them in structuring their work. The need for a design process specific to sports design was evidenced by the adaption of existing product design process models by sports design students (Chapter 4) to meet the needs of their projects, and the uptake of the sports design process model by all students in Chapter 5. As the contributions of this research originate from industry, the results will also educate undergraduate designers of industry practice.

There is also the potential for the contribution of the interactive inclusive design framework to aid in the education of product designers, providing a tool to increase awareness of inclusive design and how the approach should be accommodated within the design process. The focus of this research is on sport and inclusive design practice within industry. However, a Master’s student at the University of Strathclyde has undertaken a research dissertation based on the research presented within this thesis to assess the need for a more structured approach to inclusive design within education. Following interviews with design educators and a survey of design students, the research found that while the opinions of the lecturers remained mixed, there was a clear need from the students for a framework or process that reflected the inclusive design approach. There is therefore potential for the inclusive design framework to aid in the education of inclusive design within undergraduate design courses.

Users

As previously discussed, the literature review identified that companies using a formalised design process were more likely to produce successful products. The contribution of the sports design process model presented here therefore has the potential to improve current industry practice with these benefits passed on to the user – potentially through improvements in the design of the equipment, resulting in improved customer satisfaction, and/or performance and through greater efficiency in the design process, with savings passed onto the customer. With the rise in sports participation and size of the global sporting market it is important that companies continue to keep up with the demands of the user in order to maintain a competitive advantage.

The contribution of the inclusive design framework will aid in facilitating designer-client communication within the inclusive design process, raising client awareness of inclusive design, in addition to designer needs within the inclusive design process. This will have a positive impact on the designer, with the client aware of the importance of the designer engaging with the user. The benefits of the designer gathering primary user data are discussed in the literature review, and include improved understanding of user groups, identification of user problems and improved creativity from engaging with visual, primary data. The impact of using the inclusive design framework within design practice will result in a greater inclusion of a diversity of users within the design process, resulting in a product that not only meets the needs of more diverse users, but will also improve usability for able-bodied users. While inclusive design applies to a diversity of user groups, the ageing population is discussed as a motivator for this research. With population ageing set to become one of the most significant social transformations of the twenty-first century, the impact of designing for this older population could have far reaching benefits, improving usability of many everyday products. Further benefits include the potential for older people to continue working for longer and maintaining independence in later life.

9.7. Recommendations for further work

The sports design process model presented within this research is finalised and validated by designers as a descriptive model of the sports design process. Further work using the sports design process model would involve the implementation of the process model within companies. The model is descriptive of sports design practice, therefore implementation of the model should not significantly alter sports design practice. However, it would be of interest to assess the benefits of sports companies implementing a sports specific design process model to structure their design process and aiding designer discussions and decision making – as discussed in the literature review, the use of a structured design process results in more successful products.

The inclusive design framework has been validated in terms of its content, ease of interpretation and navigation. The research concluded that the interactive framework was well received by both designers and clients as a means of facilitating designer-client communication within the inclusive design process. Based on recommendations for improvement made by designers and clients during the validation interviews, the framework has been further developed. However, it was commented that there was a need to involve a graphic designer to improve the graphics and ease of navigation through the interactive tool. This work is recommended to take the framework from the prototype presented within this thesis to a fully working piece of software.

Based on finalising the framework development, further work would include case studies to assess the success of implementing the framework within inclusive design practice. The aim would be to assess whether the use of the framework to aid designer-client communication throughout the design process would result in a more inclusive outcome.

There is a need to implement inclusive design within an undergraduate academic setting to aid in the training new young designers (Clarkson & Coleman, 2015). The way in which inclusive design is taught and communicated will play an important role in encouraging students to engage in inclusive design projects. It is therefore recommended that the inclusive design framework should be adopted within a university setting as a means of educating undergraduate designers of the inclusive design process.

9.8. Concluding remarks

Sports design is a young and evolving discipline, with a lack of research currently published on the topic. This research presents the first design process model to capture the sports design process, visually communicating the characteristics of that process. The process model was developed based on interviews with sports design companies, analysis of student projects and workshop feedback, with the final model validated as a descriptive model of the sports design process.

Feedback on the sports design process model from inclusive designers and experts indicated that the model could be of use if developed further into a framework to facilitate designer-client communication within the inclusive design process. The client is cited throughout the literature as a barrier to the uptake of inclusive design, therefore it is hoped that by educating the client of the inclusive design process and illustrating the value of adopting an inclusive approach to design, the client will be more willing to adopt a more inclusive approach. This research presents an interactive framework, validated by designers and clients, that facilitates designer-client communication within the inclusive design process.

Both the sports design process model and inclusive design framework are based on industry practice and feedback from practicing designers. However, there is also potential for both the sports design process model and the interactive inclusive design framework to be used to educate those within industry through CPD (continuing professional development) engagement with universities to enhance current practice. Other educational benefits of both the model and the framework include aiding in the education of undergraduate designers. Both the model and the framework are currently being used within industry by designers that were involved in the research, highlighting the practical benefits and impact of the research.

References

Americans with Disabiltiies Act, 1990. *Public Law 101-336. 108th Congress, 2nd session.*

AT Kearney, 2011. *The sports market: Major trends and challenges in an industry full of passion,* Chicago: A. T. Kearney Inc..

Bechtold, U. & Sotoudeh, M., 2013. Assistive technologies: Their development from a technology assessment perspective. *Gerontechnology,* 11(4), pp. 521-533.

Beitz, W., 1985. *Systematic approach to the design of technical systems and products.* Dusseldorf: VDI.

Benktzon, M., 1993. Designing for our future selves: the Swedish experience. *Applied Ergonomics,* 24(1), pp. 19-27.

Bennett, A., 2002. Interactice aesthetics. *Design Issues,* 18(3), pp. 62-69.

Best, K., 2006. *Design management: Managing design strategy, process and implementation,* AVA.

Blessing, L. T. M., 1996. Comparison of design models proposed in prescriptive literature. In: *The role of design in the shaping of technology.* Lyon: Proceedings from the COST A3 and COST A4 workshop, pp. 187-212.

Boehm, B., 1988. A spiral model of software development and enhancement. *Computer,* 21(5), pp. 61-72.

Bouma, H., 2013. Accommodating older people at work. *Gerontechnology,* 11(4), pp. 489-492.

British Standard 7000-6: 2005, 2005. *Design management systems - managing inclusive design - guide.*

British Telecommunications, 2010. *Designs on a bigger market - a guide to inclusive design,* London: British Telecommunications plc.

Bruder, R., 2000. *Ergonomics as a mediator within the product design process.* San Diego, pp. 20-23.

Bruseberg, A. & McDonagh-Philp, D., 2000. User-centred design research methods: The designer's perspective. In: *Integrating Design Education Beyond 2000 Conference.* Brighton: University of Sussex, pp. 179-184.

Bruseberg, A. & McDonagh-Philp, D., 2001. New product development by eliciting user experience and aspirations. *International Journal of Human-Computer Studies,* Volume 55, pp. 435-452.

Bruseberg, A. & McDonagh-Philp, D., 2002. Focus groups to support the industrial/product designer: A review based on current literature and designer's feedback. *Applied Ergonomics,* 33(1), pp. 27-38.

Bryman, A., 2012. *Social research methods.* 4th ed. Oxford: Oxford University Press .

Cardoso, C. & Clarkson, P. J., 2012. Simulation in user-centred design - helping designers to empathise with atypical users. *Journal of Engineering Design,* pp. 1-22.

Carse, B., Thomson, A. & Stansfield, B., 2010. Use of biomechanical data in the Inclusive Design process: packaging design and the older adult. *Journal of Engineering Design,* 21(2-3), pp. 289-303.

Choueiri, L., 2003. Diagrams of the design process. In: *5th European Academy of Design Conference.* Spain: University of Barcelona, pp. 1-11.

Clarkson, J. & Coleman, R., 2010. Inclusive design. *Journal of Engineering Design,* 21(2-3), pp. 127-129.

Clarkson, J., Coleman, R., Keates, S. & Lebbon, C., 2003. *Inclusive desgin: Design for the whole population.* London: Springer-Verlag.

Clarkson, J., Dong, H. & Keates, S., 2003. Quantifying design exclusion. In: *Inclusive design - Design for the whole population.* London: Springer-Verlag, pp. 423-436.

Clarkson, P. J. & Coleman, R., 2015. History of inclusive design in the UK. *Applied Ergonomics,* Volume 46, pp. 235-247.

Clarkson, P. J. & Eckert, C. M., 2005. *Design process improvement - a review of current practice.* Springer.

Clarkson, P. J. & Hamilton, J. R., 2000. 'Signposting', A parameter-driven task-based model of the design process. *Research in Engineering Design,* Volume 12, pp. 18-38.

Clarkson, P. J. et al., 2000. A model for inclusive design. In: *Design for excellence: Proceedings of the Engineering Design Conference,* pp. 203-212.

Coleman, R., Lebbon, C. & Myerson, J., 2003. Design and empathy. In: J. Clarkson, R. Coleman, S. Keates & C. Lebbon, eds. *Inclusive design - Design for the whole population.* London: Springer, pp. 478-499.

Combe, N., Harrison, D., Craig, S. & Young, M. S., 2012. An investigation into usability and exclusivity issues of digital programmable thermostats. *Journal of Engineering Design,* 23(5), pp. 401-417.

Companies Act 2006, 2006. [Online]
Available at:
http://www.companieshouse.gov.uk/companiesAct/implementations/apr2008ExemptionThreshold.shtml
[Accessed 21 November 2014].

Cooper, R. G., 2001. *Winning at new products: Accelerating the process from idea to launch.* 3rd ed. Cambridge: Perseus Publishing.

Corbin, J. M. & Strauss, A. L., 2015. *Basics of qualitative research: Techniques and procedures for developing grounded theory.* 4th ed. Thousand Oaks: SAGE.

Corbin, J. & Strauss, A., 2015. *Basics of qualitative research.* 4th ed. Los Angeles: SAGE Publications Ltd.

Costa, D. G. et al., 2015. *Towards the next generation of design process models: a gap analysis of existing models.* Milan, International Conference on Engineering Design.

Crilly, N. & Clarkson, P., 2006. The influence of consumer research on product aesthetics. In: *9th International Design Conference - DESIGN 2006.* Glasgow: The Design Society.

Cross, N., 2000. *Engineering design methods - strategies for product design.* 3rd ed. Chichester: John Wiley and Sons Ltd.

Demirbilek, O. & Demirkan, H., 2004. Universal product design involving elderly users: a participatory design model. *Applied Ergonomics,* Volume 35, pp. 361-370.

den Ouden, E., Yuan, L., Sonnemans, P. J. M. & Brombacher, A. C., 2006. Quality and reliability problems from a consumer's perspective: An increasing problem overlooked by businesses?. *Quality and Reliability Engineering International,* Volume 22, pp. 821-838.

Densombe, M., 2010. *The good research guide: For small-scale social research.* 4th ed. Buckingham: Open University Press.

Department of Social Security , 2000. *Disability follow-up to the 1996/97 family resources survey,* Corporate Document Services.

Design Council, 2005. *The Double Diamond process model,* Design Council.

Design Council, 2007a. *Eleven lessons: Managing design in eleven global companies - desk research report,* London: Design Council.

Design Council, 2007b. *Eleven lessons: Managing design in eleven global brands - a study of the design processes,* London: The Design Council.

Disability Discrimination Act, 1995. London: HMSO.

Dong, H., 2004. *Barriers to inclusive design in the UK,* University of Cambridge: PhD Thesis.

Dong, H., 2010. Strategies for teaching inclusive design. *Journal of Engineering Design,* 21(2-3), pp. 237-251.

Dong, H., Clarkson, P. J., Ahmed, S. & Keates, S., 2004. Investigating perceptions of manufacturers and retailers to inclusive design. *The Design Journal,* pp. 3-15, 7, 3.

Dong, H., Clarkson, P. J., Cassim, J. & Keates, S., 2005. Critical user forums - an effective user research method for inclusive design. *The Design Journal,* 8(2), pp. 49-59.

Dong, H., McGinley, C., Nickpour, F. & Cifter, A. S., 2015. Designing for designers: Insights into the knowledge users of inclusive design. *Applied Ergonomics, 46,* pp. 284-291.

Easterby-Smith, M., Thorpe, R. & Jackson, P., 2012. *Management Research.* 4th ed. London: SAGE.

Eckert, C. et al., 2015. *Integrated product and process models: Towards an integrated framework and review.* Milan, International Conference on Engineering Design.

Equality Act, 2010. *Definition of disability under the Equality Act 2010.* [Online]
Available at: https://www.gov.uk/definition-of-disability-under-equality-act-2010
[Accessed 17 December 2014].

Fisk, A. D.; Rogers, W. A.; Charness, N.; Czaja, S. J.; Sharit, J. (2009) *Designing for older adults: Principles and creative human factors approaches.* CRC press.

Flick, U., 2009. *An introduction to qualitative research.* 4th ed. Hamburg: Rowohlt Taschenbuch Verlag.

Flick, U., 2011. *Introducing research methodology - A beginner's guide to doing a research project.* London: SAGE.

Forbes, 2015. *Sports industry to reach $73.5 billion by 2019.* [Online]
Available at: http://www.forbes.com/sites/darrenheitner/2015/10/19/sports-industry-to-reach-73-5-billion-by-2019/#706f4e6c1585
[Accessed 19th September 2016].

Foresight, 2000. *The age shift - Prioroties for action. Ageing population panel.* [Online]
Available at: http://www.bis.gov.uk/assets/foresight/docs/ageing-population/age-shift-priorities-for-action-dec-2000.pdf
[Accessed 29 October 2013].

Formasa, D., 2009. *Six real people.* Seoul, International Association of Societies of Design Research.

French, M., 1985. *Conceptual design for engineers,* London: Design Council.

Gericke, K. & Blessing, L., 2012. *An analysis of design process models across disciplines.* Dubrovnik, Design 2012.

Gericke, K. & Eckert, C., 2015. *The long road to improvement in modelling and managing engineering design processes.* Milan, International Conference on Engineering Design.

Glaser, B. G. & Strauss, A. L., 1968. *The discovery of grounded theory: Strategies for qualitative research.* London: Weidenfeld and Nicolson.

Goodman-Deane, J., Langdon, P. & Clarkson, J., 2010. Key influences on the user-centred design process. *Journal of Engineering Design,* 21(2-3), pp. 345-373.

Goodman, J., Dong, H., Langdon, P. & Clarkson, P., 2006. Increasing the upake of inclusive design in industry. *Gerontechnology,* 5(3), pp. 140-149.

Goodman, J., Langdon, P. & Clarkson, P. J., 2007. Formats for user data in inclusive design. In: *Universal Access in Human Computer Interaction. Coping with Diversity.* Heidelberg: Springer Berlin, pp. 117-126.

Gray, D. E., 2014. *Doing research in the real world.* 3rd ed. London: SAGE Publications Ltd.

Grey, C. & Malins, J., 2004. *Visualising research: A guide to the research process in art and design.* Hants: Ashgate Publishing Ltd.

Haik, Y., 2003. *Engineering design process.* Pacific Grove: Brooks/Cole.

Herriott, R. & Jensen, B. G., 2013. Students' responses to inclusive design. *Design Studies,* 34(4), pp. 438-453.

Howard, T., Culley, S. J. & Dekoninck, E., 2008. Describing the creative design process by integration of engineering design and cognitive psychology literature. *Design Studies,* Volume 29, pp. 160-180.

Huppert, F., 2003. Designing for older users. In: *Clarkson, J.; Coleman, R.; Keates, S.; Lebbon, C..* London: Springer-Verlag, pp. 30-49.

Ielegems, E., Herssens, J. & Vanrie, J., 2015. *A V-Model for more. An inclusive design model and supporting interaction between designer and user.* Milan, International Conference on Engineering Design.

Isa, S. S., Liem, A. & Steinert, M., 2015. *The value of prototypes in the early design and development process.* Milan, International Conference on Engineering Design.

IDEO, 2015. The Field Guide to Human-Centred Design. IDEO, 1st ed.

IDEO, 2017. Methods Cards. [Online]
Available at: https://www.ideo.com/us/post/method-cards
[Accessed 27th January 2017].

ISO 9241-11, 1998. *Ergonomic requirements for office work with visual display terminals (VDTs) - Part 11: Guidance on usability ,* Geneva : International Standards Organisation.

Jenkins, P. E., Plaseied, A. & Khodaee, M., 2010. UCD sports engineering program. *Procedia Engineering,* 2(2), pp. 2757-2762.

Jesson, J. K., Matheson, L. & Lacey, F. M., 2011. *Doing your literature review: Traditional and systematic techniques.* London: SAGE Publications Ltd.

Johnson, D., Clarkson, J. & Huppert, F., 2010. Capability measurement for inclusive design. *Journal of Engineering Design,* 21(2-3), pp. 275-288.

Kahmann, R., 2000. *Inclusive design: Excluding users in a conscious way.* San Diego, P901-904, Proceedings of the International Ergonomics Association/Human Factors and Ergonomics Society Congress.

Keates, S. & Clarkson, P. J., 2003. Countering design exclusion: Bridging the gap between usability and accessibility. *Universal Access in the Information Society,* 2(3), pp. 215-225.

Keates, S., Clarkson, P. J., Harrison, L. A. & Robinson, P., 2000a. Towards a practical inclusive design approach. In: ACM, ed. *Proceedings on the 2000 conference on Universal Usability.* Proceedings on the 2000 Conference on Universal Usability, pp. 45-52.

Keates, S., Lebbon, C. & Clarkson, J., 2000b. *Investigating industry attitudes to universal design.* Orlando, Proceedings of the RESNA 2000 Annual Conference.

Kett, S. G. & Wartzack, S., 2015. *Integration of universal design principles into early phases of product design - a case study.* Milan, International Conference on Engineering Design.

Kranz, M., Spiessl, W. & Schmidt, A., 2007. *Designing ubiquitous computing systems for sports equipment.* s.l., Proceedings of the 5th annual IEEE International Conference on Pervasive Computing and Communications.

Kremer, S. & Lindemann, U., 2015. *A framework for understanding, communicating and evaluating user experience potentials.* Milan, International Conference on Engineering Design.

Krueger, A., Witte, K. & Edelmann-Nusser, J., 2006. Approach of a model for the interaction between athlete, sports equipment and environment. In: *The Engineering of Sport 6.* Springer New York, pp. 17-22.

Kumar, R., 2014. *Research methodology: A step-by-step guide for beginners.* 4th ed. Los Angeles: SAGE.

Langley, J., Janson, R., Wearn, J. & Yoxall, A., 2005. 'Inclusive' design for containers: Improving openability. *Packaging Technology and Science,* Volume 18, pp. 285-293.

Lawson, B., 2006. *How designers think: The design process demystified.* 4th ed. Elsevier: Architectural Press.

Lee, C. & Coughlin, J. F., 2015. *User involvement in product design practices: A case study on technologies for older adults.* Milan, International Conference on Engineering Design.

Leonard, D. & Rayport, J. F., 1997. Spark innovation through emphatic design. *Harvard Business Review,* Volume 75, pp. 102-115.

Lim, Y. & Nickpour, F., 2015. *Inclusive design: From physical to psychosocial - A literature analysis toward a definition of psychosocial dimensions in design.* Milan, International Conference on Engineering Design.

Lindemann, U., 2003. Methods are networks of methods. In: *International Conference on Engineering Design (ICED).* Stockholm: The Desgin Society.

Li, X. & Gunal, M., 2012. Exploring cognitive modelling in engineering usability design. *Journal of Engineering Design,* 23(2), pp. 77-97.

Maffin, D., 1998. Engineering design models: Context, theory and practice. *Journal of Engineering Design,* 9(4), pp. 315-327.

Maier, A. M. & Storrle, H., 2011. *What are the characteristics of engineering design processes?.* Copenhagen, International Conference on Engineering Design.

Margolin, V., 1997. Getting to know the user. *Design Studies,* Volume 18, pp. 227-236.

Marshall, R. et al., 2010. HADRIAN: A virtual approach to design for all. *Journal of Engineering Design,* 21(2-3), pp. 253-273.

McGinley, C. & Dong, H., 2009. Accessing user information for use in design. In: *HCII2009.* San Diego: Springer Berlin.

McGinley, C. & Dong, H., 2011. Designing with information and empathy: Delivering human information to designers. *The Design Journal,* 14(2), pp. 187-206.

McGinley, C. G., 2012. *Supporting people-centred design through information and empathy,* Brunel University: PhD Thesis.

McGinley, C. & Macredie, R., 2011. Towards diversity and empathy in design development. *Zoontechnica: The Journal of Redirective Design,* 1(1), pp. 187-206.

Medwell, P. R., Brooks, L. A. & Medwell, B. S., 2011. Analysis of the lawn bowl trajectory as a teaching tool for sports engineering: Development of a graphical user-interface. *Procedia Engineering,* Volume 13, pp. 531-537.

Medwell, P. R., Grimshaw, P. N., Robertson, W. S. & Kelso, R. M., 2012. Developing sports engineering education in Australia. *Procedia Engineering,* Volume 34, pp. 260-265.

Microsoft, 2004. *The wide range of abilities and its impact on computer technology,* Forrester Research, Inc.

Mival, O., 2004. *Crossing the chasm: Developing and understanding support tools to bridge the research design divide within a leading product design company.* Dubrovnik, International Conference on Engineering Desgin.

Mugge, R. & Schoormans, J. P. L., 2012. Newer is better! The influence of a novel appearance on the perceived performance quality of products. *Journal of Engineering Design,* 23(6), pp. 469-484.

Muller, M., 2011. *Enhancing sport - Sports technology design in the context of sport motive, motion task and product feature,* Munich: Technische Universitat Munchen.

Muller, M., Senner, V. & Lindemann, U., 2007. *Specific characteristics of sports equipment.* Paris, International Conference on Engineering Design.

Naess, I. R. & Oritsland, T. A., 2005. *Inclusive, mainstream products.*

Norwegian Design Council, 2010. *Inclusive Design - a people centred strategy for innovation.* [Online]
Available at: http://inclusivedesign.no/
[Accessed 27th January 2017].

North Carolina State University, 1997. *The 7 Principles of Universal Design.* [Online]
Available at: https://www.ncsu.edu/project/design-projects/sites/cud/content/principles/principles.html
[Accessed 7th September 2016].

O'Donnell, F. J. & Duffy, A. H. B., 2001. *Design activity modelling - a performance viewpoint.* Glasgow, International Conference on Engineering Design.

Office for National Statistics, 2015. *National population projections: 2014-based statistical bulletin.* [Online]
Available at:
http://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/bulletins/nationalpopulationprojections/2015-10-29
[Accessed 1st August 2016].

Ostroff, E., 2011. Universal Design: An evolving paradigm. In: W. F. E. Preiser & K. H. Smith, eds. *Universal Design Handbook.* London: McGraw-Hill, pp. 1.3 - 1.11.

Pahl, G. & Beitz, W., 1984. *Engineering design: a systematic approach.* 1st ed. London: Design Council.

Pepe, C. et al., 2011. *Development of a framework for improving the engineering processes.* Copenhagen, International Conference on Engineering Design.

Persad, U., Langdon, P. & Clarkson, J., 2007. Characterising user capabilities to support inclusive design evaluation. *Universal Access in the Information Society,* Volume 6, pp. 119-135.

Preiser, W. & Ostroff, E., 2001. *Universal Design Handbook.* New York: McGraw-Hill.

Pugh, S., 1986. Design activity models: Worldwide emergence and convergence. *Design Studies,* 7(3), pp. 167-173.

Pugh, S., 1990. *Total design - Integrated methods for successful product engineering.* Harlow: Pearson Education Limited.

Pugh, S., 1996. *Creating innovative products using total design - The living legacy of Stuart Pugh.* Reading, MA: Addison-Wesley Inc.

Pullin, G., 2009. *Design meets disability.* Massachusetts: Massachusetts Institute of Technology.

Ramaswamy, V., 2008. Co-creating value through customers' experiences: The Nike case. *Strategy and Leadership,* 36(5), pp. 9-14.

Randolph, J. J., 2009. A guide to writing a dissertation literature review. *Practical Assessment, Research and Evaluation.*

Rawson, K. J. & Tupper, E. C., 2001. *Basic ship theory.* Oxford, Butterworth-Heinemann.

Restrepo, J., 2004. *Information processing in design.* Delft, Netherlands: Delft University Press.

Robson, C., 2011. *Real world research.* 3rd ed. Chichester: John Wiley & Sons Ltd..

Roozenburg, N. F. M. & Cross, N. G., 1991. Models of the design process: integrating across the disciplines. *Design Studies,* 12(4), pp. 215-220.

Royal Academy of Engineering, 2012. *How can sport drive engineering innovation?* London: Conference Report.

Saunders, M., Lewis, P. & A., T., 2016. *Research methods for business students.* Harlow, Pearson Education Limited.

Shapiro, D., Sommer, A. F. & Clarkson, P. J., 2015. *An investigation of design process changes.* Milan, International Conference on Engineering Design.

Silverman, S., 2013. *Doing qualitative research: a practical handbook.* 4th ed. Thousand Oaks: Sage Publications.

Sim, J. & Wright, C., 2000. *Research in health care: Concepts, designs and methods.* 2nd ed. Cheltenham: Stanely Thornes Publishers Ltd..

Sims, R., 2003. *Design for all: Methods and data to support designers,* University of Loughborough: PhD Thesis.

Slater, S. F. & Narver, J. C., 2000. Intelligence generation and superior customer value. *Journal of the Academy of Marketing Science,* 28(1), pp. 120-127.

Sport England, 2016. *Who plays sport?.* [Online]
Available at: https://www.sportengland.org/research/who-plays-sport/
[Accessed 19th September 2016].

Stefanyshyn, D. J. & Wannop, J. W., 2015. Biomechanics research and sport equipment development. *Sports Engineering,* 18(4), pp. 191-202.

Tahera, K., Eckert, C. & Earl, C., 2015. *Highlighting the importance of testing in the product development process.* Milan, International Conference on Engineering Design.

Thomas, D. R., 2006. A general inductive approach for analyzing qualitative evaluation data. *American Journal of Evaluation,* 27(2), pp. 237-246.

Topalian, A., 2005. New British Standard on managing inclusive design. *Accessibility and Computing,* 5(82).

Ulrich, K. T. & Eppinger, S. D., 1995. *Product design and development.* 1st ed. New York: McGraw-Hill.

Ulrich, K. T. & Eppinger, S. D., 2012. *Product Design and Development.* 5th ed. New York: McGraw Hill.

Unger, D. W. & Eppinger, S. D., 2011. Improving product development process design: a method for managing information flows, risks and iterations. *Journal of Engineering Design,* 22(10), pp. 689-699.

United Nations, 2015a. *World population ageing,* New York: Department of Economic and Social Affairs Population Division.

United Nations, 2015b. *World population prospects: Key findings and advance tables 2015 revision,* New York: Department of Economic and Social Affairs Population Division.

United Nations, 2015c. *World population ageing 2015: Highlights,* New York: Department of Economic and Social Affairs.

University of Cambridge, 2013. *Inclusive design toolkit.* [Online]
Available at: http://www.inclusivedesigntoolkit.com/betterdesign2/
[Accessed 31 March 2015].

Van Kleef, E., Van Trijp, H. C. M. & Luning, P., 2005. Consumer research in the early stages of new product development: A critical review of methods and techniques. *Food and Quality Preference,* Volume 16, pp. 181-201.

Vanderheiden, G. & Tobias, J., 2000. *Universal design of consumer products: Current industry practice and perceptions.* San Diego, pp. 19-22.

VDI-Richtlinie 2242 (1986) *Engineering design of products in accordance with ergonomics.* Beuth Verlag, Berlin, Koeln.

Waller, S., Bradley, M., Hosking, I. & Clarkson, P. J., 2013. Making the case for inclusive design. *Applied Ergonomics,* Volume 46, pp. 297-303.

Waller, S. D., Langdon, P. M. & Clarkson, P. J., 2008. Converting disability data into a format suitable for estimating design exclusion. In: *Designing Inclusive Futures.* London: Springer, pp. 3-13.

Warburton, N., 2003. Everyday inclusive design. In: *Inclusive design: Design for the whole population.* London: Springer-Verlag, pp. 250-268.

Wilkinson, C. R. & Angeli, A. D., 2014. Applying user centred and participatory design approaches to commercial product development. *Design Studies,* Volume 35, pp. 614-631.

Wodehouse, A., Ion, W. & Mair, G., 2011. *Sports engineering: Developing an integrated, cross-disciplinary engineering design degree.* London, Proceedings of E&PDE 2011, the 13th International Conference on Engineering and Product Design Education.

Appendices

Appendix 1

A1.1. Sport and product designer interview questions (Chapter 4)

Interview questions are highlighted in bold. As interviews were semi-structured, additional prompts are included to ensure relevant points are covered.

1. **What is your design process?** What design process/methodology do you use? What are the core stages? What are the sub-stages? How do you decide to move on from one stage? How often do you iterate?
2. **Can you indicate the length of time (% of the design process) spent on each stage?** What stage is the emphasis of the company on?
3. **How flexible is the design process?** Is there variation between projects? What do designers feel they need/don't need within the design process? Do timescales depend on the project?
4. **Where does the design brief come from?** How is the user identified? Is user research included in this? Use of primary/secondary data.
5. **Does your company conduct its own user research?** How is this done? What methods are used to collect data? How is the data presented to the designers? How is this data then used?
6. **How are competitor products evaluated/tested?** By designers, users, others? When in the process?
7. **What additional methods are used and at what stage of the design process are they implemented?** When is user testing implemented within the design process? Do methods vary between projects?
8. **How is the product finally deemed a success?** What evaluation/testing methods are used? Where in the design process does this happen?
9. **Do you play the sport you are involved in the design of (sports designers only)?** If yes, does this help? If no, would it help? What insights does sports participation have for the design process?

Appendix 2

A2.1. Structure of focus group (Chapter 5)

Aim: Evaluation and further development of the sports design process model.

General points to consider throughout:

- Do the models communicate the characteristics of the sports design process?
- Do the models appeal visually?
- Are they easy to understand without prior knowledge?
- Do they align with the needs of the designer?

Workshop Structure

- Overview of the workshop (aims, objectives, timings).
- Any initial questions from participants.
- Presentation of the sports design process models.
- Group discussion questions.
- Group brainstorm activity – may form part of group discussion.
- Completion of individual questionnaires.

A2.1.1. Participant handouts

Workshop Overview

- **Aim** – evaluation and further development of the sports design model.

Focusing on the content and presentation requirements of the model.

How well does the model align with designer's needs?

Does the model reflect sports design practice?

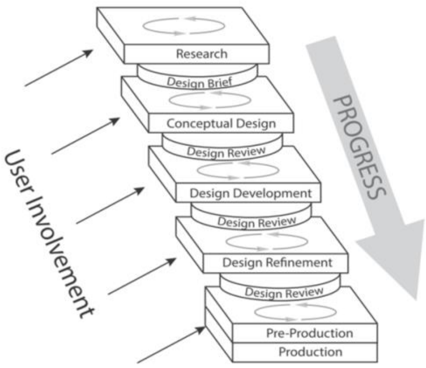
Sports Process

- **Aim:** visual representation of the sports design process

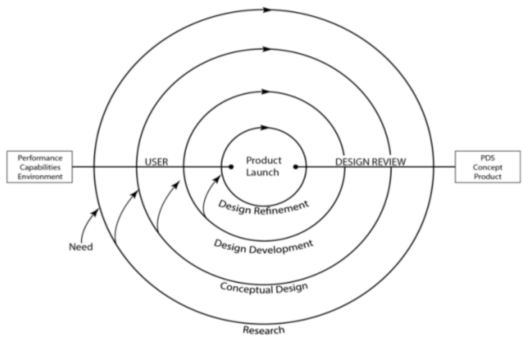
The model should address:

1. Core stages of the process.
2. Emphasise user involvement throughout the process.
3. Communicate an iterative, progressive process.

Linear Sports Process Model



Cyclic Sports Process Model



Brainstorming Activity

- Individual session
- 5 minutes
- **Aim:** develop the sports process model further.
- Characteristics should be kept.
- Illustrate possible visuals to represent model.

A2.1.2. Focus group discussion questions

The discussion followed a semi-structured approach, with questions in bold used as guides for the discussion. Additional prompts were used if needed.

1. **Which model do you prefer?** Why?
2. **What are the disadvantages of each model?**
3. **Are the core characteristics of the sports design process captured?** Iterations, user involvement, performance of sporting equipment, designer interaction with the user.
4. **What are your thoughts on the visual representations of each model?** What is visually attractive to you, what grabs your attention, what captures the nature of the sports design process?
5. **How can the models be improved?** Information contained within the model, visual representation, interpretability of the model.

A2.1.3. Focus group questionnaire

Please rank the linear and cyclic representations of the sports models:

Design requirements (process model)	**1st**	**2nd**
Communication of core stages of sports design process		
Visual appeal of the model		
Ease of understanding the sports design process		
Emphasis on user involvement		

Please rate and rank the following features in the order you feel are most important, and which model addresses these best. Add in any others you feel are relevant.

Design requirements (visual)	**Important (Y/N)**	**Ranking**	**Best Model**
Interpretability (without background reading)			
Visual appeal			
Showing desired outputs from each stage			
Linear illustration of process			
Iterative illustration of process			

Please comment on your thoughts on the proposed sports model against current design models you are familiar with.

A2.2. Designer validation interviews (Chapter 5)

Structure of interviews:

- Question 1 (interpretability of the model) is asked with no introduction to the model given.
- The model is described to the designer by the researcher.
- Questions 2-5 are asked regarding the sports design model.

Interviews were semi-structured, with questions in bold used to question designers. Additional prompts were used where necessary.

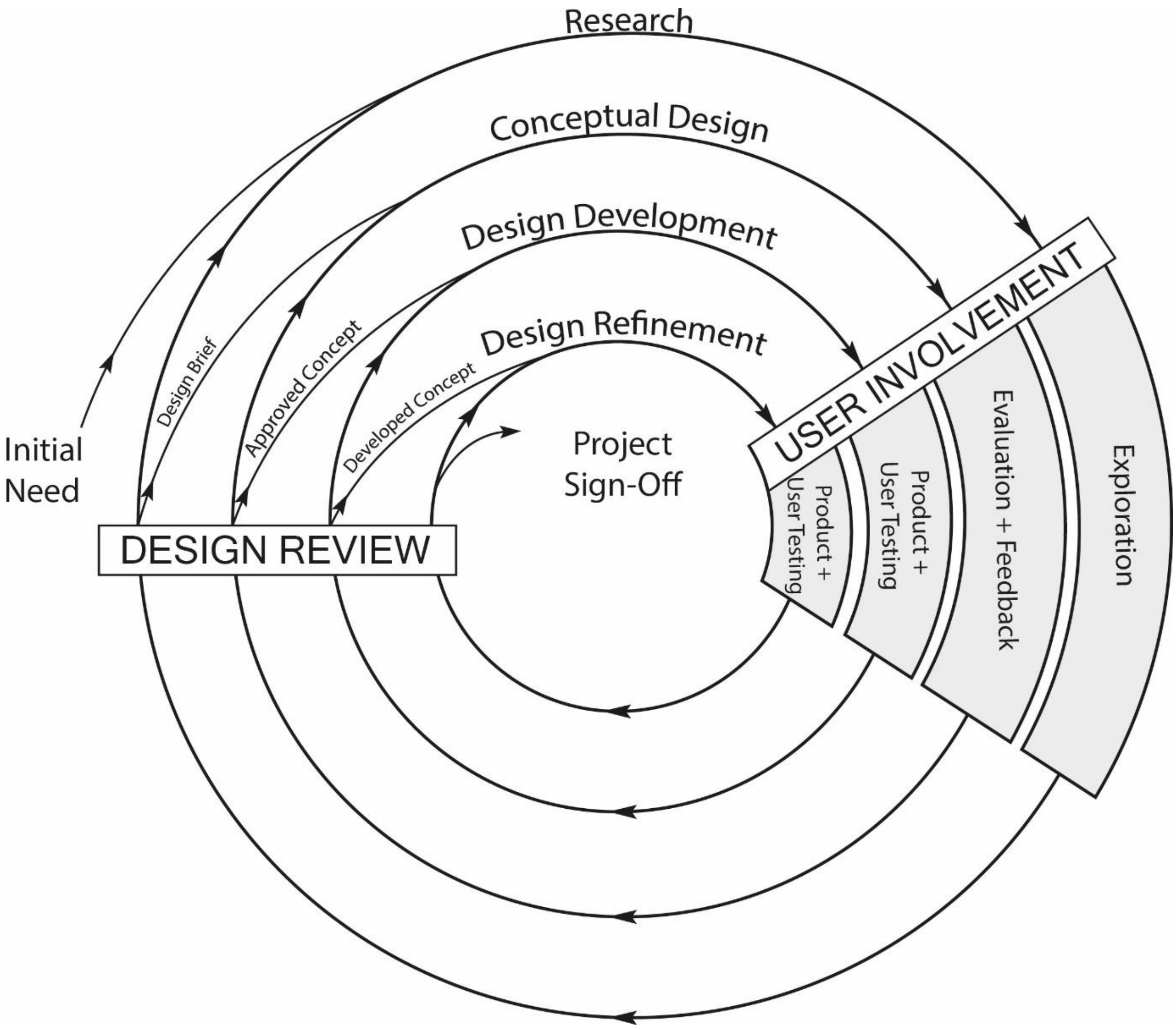
1. **Do you understand the model:**
    a. Do you have any questions regarding the model?
    b. Do you understand it? Can you interpret it? Is there anything that isn't clear?
    c. Do you have any further questions regarding the model?
    d. Was anything described by the researcher that you don't understand, hadn't picked up on yourself?
2. **Was the sports design process model representative of the company's own practice?**

    Core stages, iterations, emphasis of the process. Are there any additional stages you would add in or any to remove?
3. **What modifications would be needed to ensure the model was an accurate visual representation of the sports design process in practice?**
    a. How would you develop the model further? In terms of interpretability, visual appeal, structure? Additional information, less detail?
    b. Would you use the model within your company practice?

    If yes, would it need to be changed as all? Why is it relevant? What benefits would be brought by the sports model?

    If no, why? Would any changes help?

A2.2.1. Sports design process model and overview



The core stages of the sports design process are shown at the top of the model, moving from the research stage to conceptual design, design development, design refinement and finally to project sign off. The model represents the design process, therefore the commercialisation process is not shown and would occur once the project has been signed off.

The user should be involved in the design process at each stage. The methods of user involvement vary between companies and projects, so an indication of the type of involvement is given within the model. At research, involvement is exploratory to understand the user problems and needs. At conceptual design, the involvement is typically centred on evaluation and feedback of concepts at varying stages of development. At both design development and design refinement the user is involved extensively in product testing (this can include performance, wear, fit and durability testing). The bulk of the performance requirements should be met at the design development stage, with design refinement typically focussing on minor performance modifications and aesthetics. As the model indicates the design process followed by sports designers, it is intended that the designer is involved with the user throughout this process.

The sports design process is iterative within design process stages – typically two to three iterations were reported at each stage. Unlike with product designers, sports designers only reported iterations within design process stages, rather than between process stages.

A design review was reported at the end of each design process stage, where various stakeholders in the process were involved in design decision making. While the user themselves were not reportedly involved at this stage, their needs, feedback and testing results were central to influencing the decision making process. At the design review, if the project was considered satisfactory, it was progressed to the next stage of the design process. If further work was needed, the stage was repeated until the decision was made to progress.

Appendix 3

A3.1. Product designer interviews (Chapter 6)

The interviews were structured as follows:

- Questions 1-3 were asked.
- The sports design process model was introduced by the researcher.
- Questions 4-7 were asked.

Interview questions are highlighted in bold. As interviews were semi-structured, additional prompts are included to ensure relevant points are covered. The interview was structured in three parts: the inclusive design process followed by the company itself, feedback on the sports design process model and discussion over further development of the sports design process model.

<u>Company inclusive design process</u>

1. **What is your company's design process?** What are the core stages? Where are the iterations? What methods/activities feed into the process? When is the user involved in the process? What is your definition of inclusive design?
2. **Do you include diverse users in the design process?** How often does this happen? When does it happen? How diverse would you accommodate? Do you involve the users or emphatic design? How do you test the inclusivity of the product? What limits inclusive design? Why does this happen?

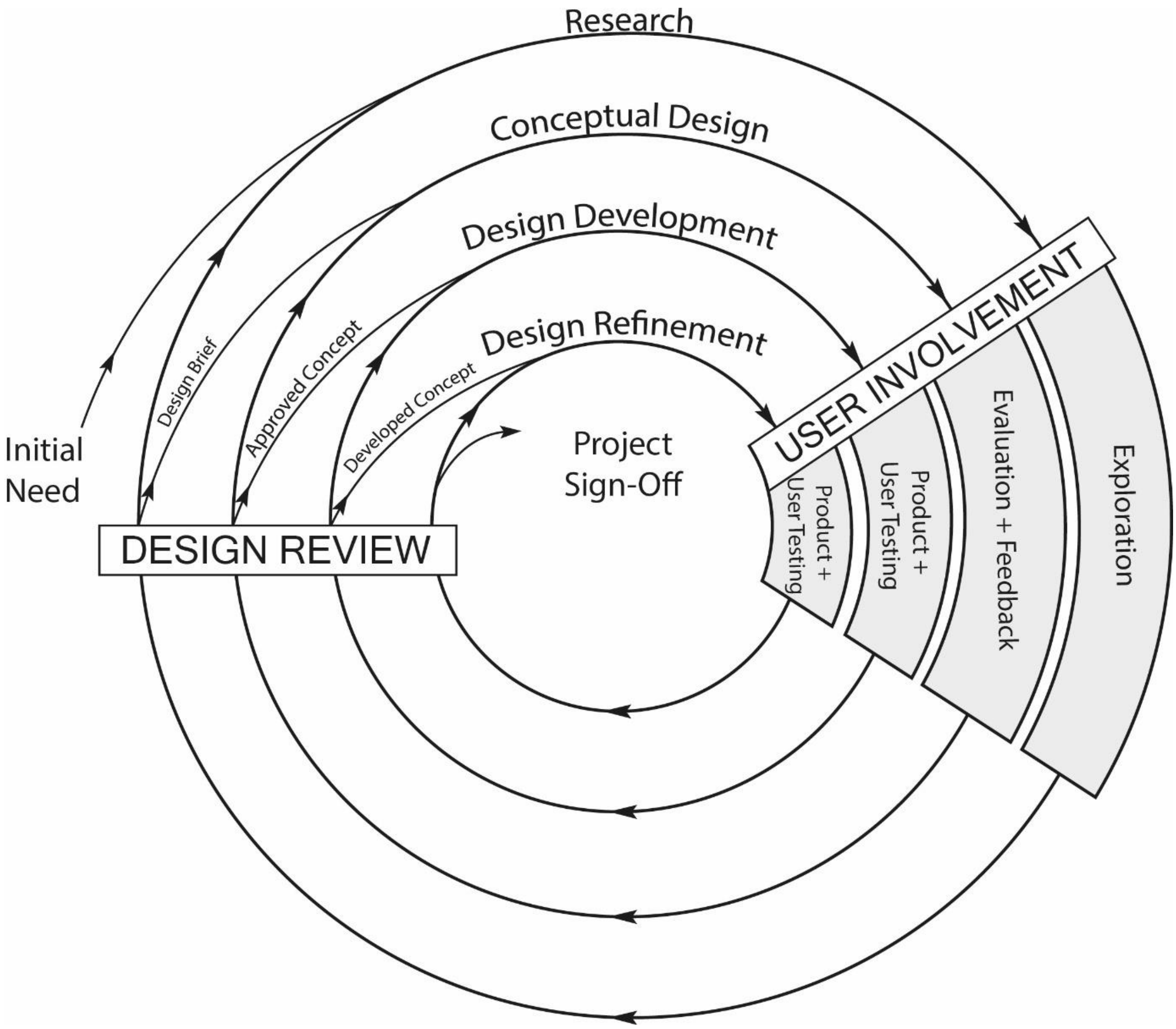
<u>Feedback on the sports design process model</u>

3. **What are your thoughts on the sports design process model initially?** Was there anything you didn't understand? Are you able to follow it? What was your first impression on how it is presented? What did you like about it? What could be done to aid your understanding? Would additional information be needed?
4. **After going through the remaining slides, did you learn anything new that wasn't apparent when you first looked at the model?** Did the breakdown of aspects of the model aid your understanding? Is there anything that is still unclear in the model?

Further development of the sports model for inclusive design

5. **How feasible would it be to implement the sports design process model in design practice?** Are prescribed models often followed? If so, how closely? Would it be used as a prescriptive model or as an educational tool? Would a prescribed model be used? What would need to be changed in how it is presented? As a diagram and in terms of how it is communicated.
6. **Do you as a company follow separate processes when designing inclusively?** Would a model such as this be of benefit to you as a company? How would it be used within design practice or as a training/education tool?
7. **In terms of developing the model further, what additional information do you feel would be beneficial to be added?** Should the use of design methods be shown within the model? Who should the model be targeted at? Clients, designers, managers? In what format should the model be presented?

A3.1.1. Sports design process model and overview



The core stages of the sports design process are shown at the top of the model, moving from the research stage to conceptual design, design development, design refinement and finally to project sign off. The model represents the design process, therefore the commercialisation process is not shown and would occur once the project has been signed off.

The user should be involved in the design process at each stage. The methods of user involvement vary between companies and projects, so an indication of the type of involvement is given within the model. At research, involvement is exploratory to understand the user problems and needs. At conceptual design, the involvement is typically centred on evaluation and feedback of concepts at varying stages of development. At both design development and design refinement the user is involved extensively in product testing (this can include performance, wear, fit and durability testing). The bulk of the performance requirements should be met at the design development stage, with design refinement typically focussing on minor performance modifications and aesthetics. As the model indicates the design process followed by sports designers, it is intended that the designer is involved with the user throughout this process.

The sports design process is iterative within design process stages – typically two to three iterations were reported at each stage. Unlike with product designers, sports designers only reported iterations within design process stages, rather than between process stages.

A design review was reported at the end of each design process stage, where various stakeholders in the process were involved in design decision making. While the user themselves were not reportedly involved at this stage, their needs, feedback and testing results were central to influencing the decision making process. At the design review, if the project was considered satisfactory, it was progressed to the next stage of the design process. If further work was needed, the stage was repeated until the decision was made to progress.

A3.2. Workshop with Helen Hamlyn Centre (Chapter 6)

The workshop at the Helen Hamlyn Centre was structured as follows:

- Introduction : purpose of workshop
    - To understand in detail the design process carried out at Helen Hamlyn.
    - To identify a means of representing and populating a supporting framework to aid implementation of the process model.

  Distribute consent forms

- Interview questions (design process at Helen Hamlyn Centre) and discussion of Helen Hamlyn process.

  Use A3 paper, post-its.

- Allow time to look at the slide of the sports design process model.
    - Presentation of the sports model.
    - Stop me if anything is unclear but questions can be asked at the end.
    - Fill in questionnaire 1.

  Handouts: slides for sports design process model and questionnaire 1.

- Discussion of further development of the sports design process model, using framework development interview questions.
    - Group discussion with A3 templates, post-its.
    - Use HH process model if needed.

  Handouts: A3 paper, post-its.

- Fill out questionnaire 2.
    - Any other questions?

A3.2.1. Participant consent forms

Participant Information Sheet for Interviews with the Helen Hamlyn Centre

Name of department: Department for Design, Manufacture and Engineering Management

Title of the study: Understanding the Inclusive Design process and development of an Assistive Framework

Introduction

This workshop has been organised by Nicky Wilson (nicky.wilson.2013@uni.strath.ac.uk), a postgraduate research student at the University of Strathclyde. The workshop forms part of a 3 year PhD research project.

What is the purpose of this investigation?

This workshop aims to gain an understanding of the design process followed by designers at the Helen Hamlyn Centre, to gain feedback on an existing process model that has been developed by the researcher and to discuss possible options for developing the model further.

Do you have to take part?

Participants will be asked to take part in discussions regarding existing design processes and discussion/brainstorming exercises to develop an existing model further. Participants will also be asked to fill out a questionnaire

Participation in this workshop is the participant's decision and is entirely voluntary. Participants have the right to refuse to participate or withdraw from participation without reason at any time.

What will you do in the project?

Participants will be asked to take part in discussions regarding existing design processes and discussion/brainstorming exercises to develop an existing model further. Participants will also be asked to fill out a questionnaire.

The workshop will be conducted at a location of the participant's choice on Wednesday 19th August 2015.

Why have you been invited to take part?

Participants should have experience in working on design/research projects at the Helen Hamlyn Centre with an understanding of the design processes followed. Participants should also have a design background with an understanding of existing design processes/methods.

What happens to the information in the project?

This workshop will be recorded and photographed with the participants permission. Information gained will be used to aid further development of the researchers PhD. All information will be stored securely and will not be disclosed to any third parties. All interview recordings will be solely for the researchers benefit. Where papers/thesis have been written based on the research, all participants will remain anonymous and no sensitive/confidential information will be released.

The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998.

Thank you for reading this information – please ask any questions if you are unsure about what is written here.

What happens next?

Explain that if the participant is happy to be involved in the project, please sign the consent form to confirm this.

Following the workshop, participants can receive research updates if requested. Results will be published as part of the researchers PhD thesis and potentially in additional publications. As stated, all participants will remain anonymous.

Researcher contact details:

Nicky Wilson

DMEM, 75 Montrose Street, Glasgow, G1 1XJ

nicky.wilson.2013@uni.strath.ac.uk

Consent Form for Interviews with the Helen Hamlyn Centre

Name of department: Department for Design, Manufacture and Engineering Management

Title of the study: Understanding the Inclusive Design process and development of an Assistive Framework

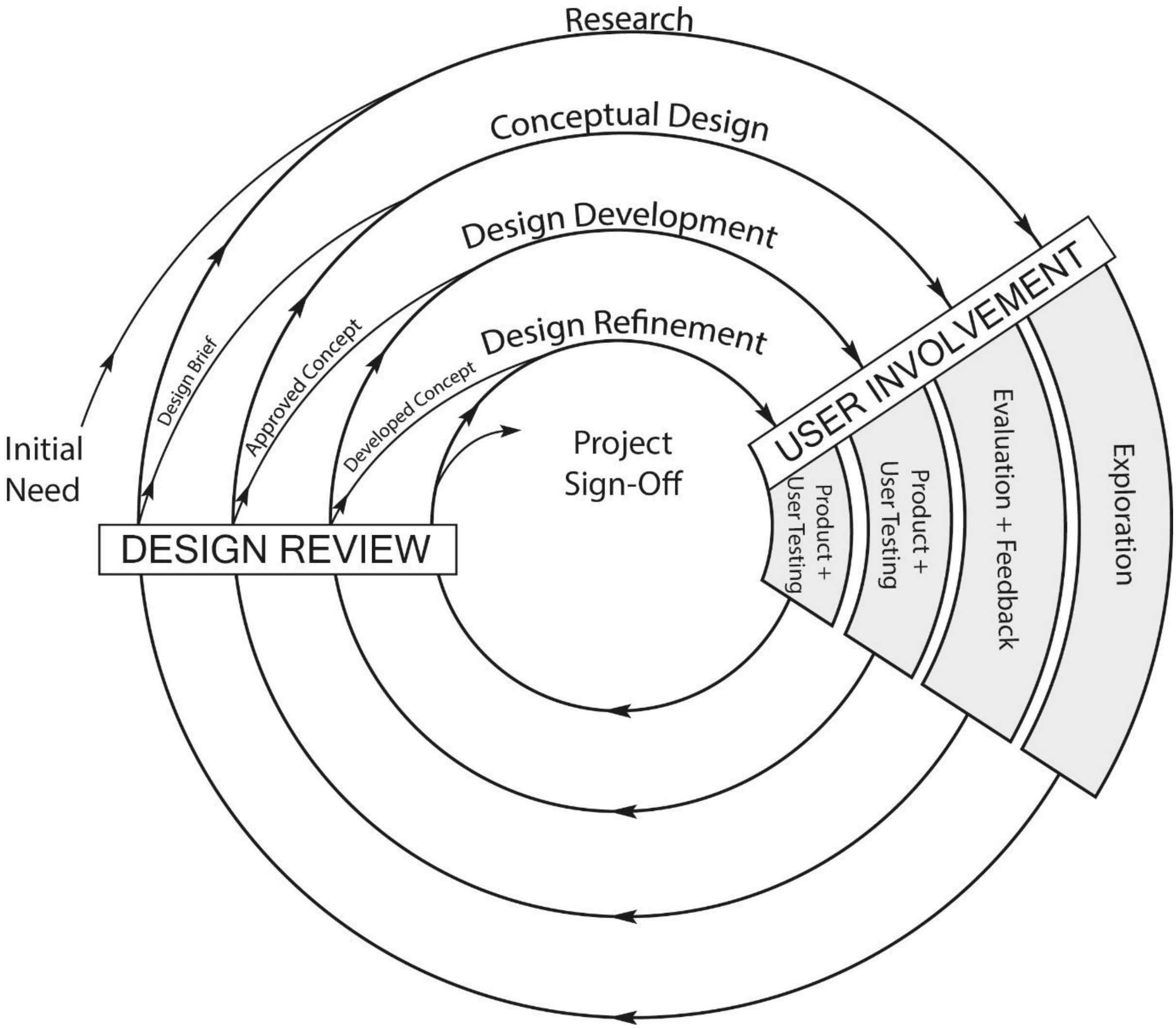
- I confirm that I have read and understood the information sheet for the above project and the researcher has answered any queries to my satisfaction.
- I understand that my participation is voluntary and that I am free to withdraw from the project at any time, up to the point of completion, without having to give a reason and without any consequences. If I exercise my right to withdraw and I don't want my data to be used, any data which have been collected from me will be destroyed.
- I understand that I can withdraw from the study any personal data (i.e. data which identify me personally) at any time.
- I understand that anonymised data (i.e. .data which do not identify me personally) cannot be withdrawn once they have been included in the study.
- I understand that any information recorded in the investigation will remain confidential and no information that identifies me will be made publicly available.
- I consent to being a participant in the project
- I consent to being audio and/or video recorded as part of the project

(PRINT NAME)	
Signature of Participant:	Date:

A3.2.2. Interview questions – design process at Helen Hamlyn Centre

1. **What design process is followed by the Helen Hamlyn Centre?**
    a. Does the Helen Hamlyn Centre follow a set design process?
    b. What are the core stages?
    c. Where are the iterations?
    d. What are the sub-stages?
    e. How much variation between designers/projects?
2. **Where is the user involved in the process?**
    a. When, at what stages?
    b. What activities?
    c. What user groups?
    d. Why at these stages of the process?
    e. How is the designer actively involved with the user?
3. **What other activities/methods are used throughout the process?**
4. **Where is the client involved?**
    a. What activities?
    b. How often?
    c. What activities are used to aid client communication?
    d. What effect does the client have on actions/decisions?
5. **Where are areas of improvement within the process?**
    a. Communication?
    b. Validation (testing, user involvement)?
    c. Client funding?

A3.2.3. Sports design process model – handout



A3.2.4. Questionnaire 1

How easy is the model to understand?	Please tick one
Very easy - no help required	
Easy - understood after some explanation	
OK - understood after detailed explanation	
Hard - some areas are still unclear	
Very hard - no understanding of the model	
How well is the importance of user involvement communicated?	**Please tick one**
Very well - physical user involvement is key to all stages of the process	
Well - the user is of some importance throughout the process	
OK - user needs should influence the design process to some extent	
Not well - limited understanding of user needs is required	
Not at all - no user involvement is required at any stage of the process	
How would the model be of most use?	**Please select all relevant**
To aid designers own processes	
As a communication tool with the client	
As a learning tool (in companies or education)	
To standardise company processes	
Other (please specify)	
How can the model be developed further?	
Detail of design methods?	
Detail of user involvement?	
Detail of client involvement?	
Other…	

A3.2.5. Interview questions – framework development

The questions in bold were used to aid the group discussion, with additional prompts if needed. Questions were kept vague at this stage to encourage designers to pursue their own chain of thought.

1. **How can the model be developed further to improve user awareness?**
    a. Supporting framework.
    b. Targeted at client communication.
2. **What format should it be presented in?**
    a. Software program?
    b. Hard copies?
    c. Additional framework to the model?
    d. Mind map?
3. **What methods should be included?**
    a. User involvement?
    b. Designer involvement?
    c. Client input?
    d. Design review activities?

A3.2.5. Questionnaire 2

How can the model be used to aid client communication?	Please select all relevant
To improve levels of user involvement?	
To assign project funding?	
To influence the decision making process?	
Other (please specify)	

In what format would the process (and accompanying framework) be of most use?	Please select all relevant
Webpage	
Other software program	
Hard copy	
Other (please specify)	

What methods/tools are currently in place for communicating with the client?

What should be included in the framework?	Please select all relevant
Methods/tools (general)	
Methods/tools (user centred only)	
Indication of physical user involvement	
Indication of designer involvement	
Indication of client involvement	
Breakdown of design review activities	
Other (please specify)	

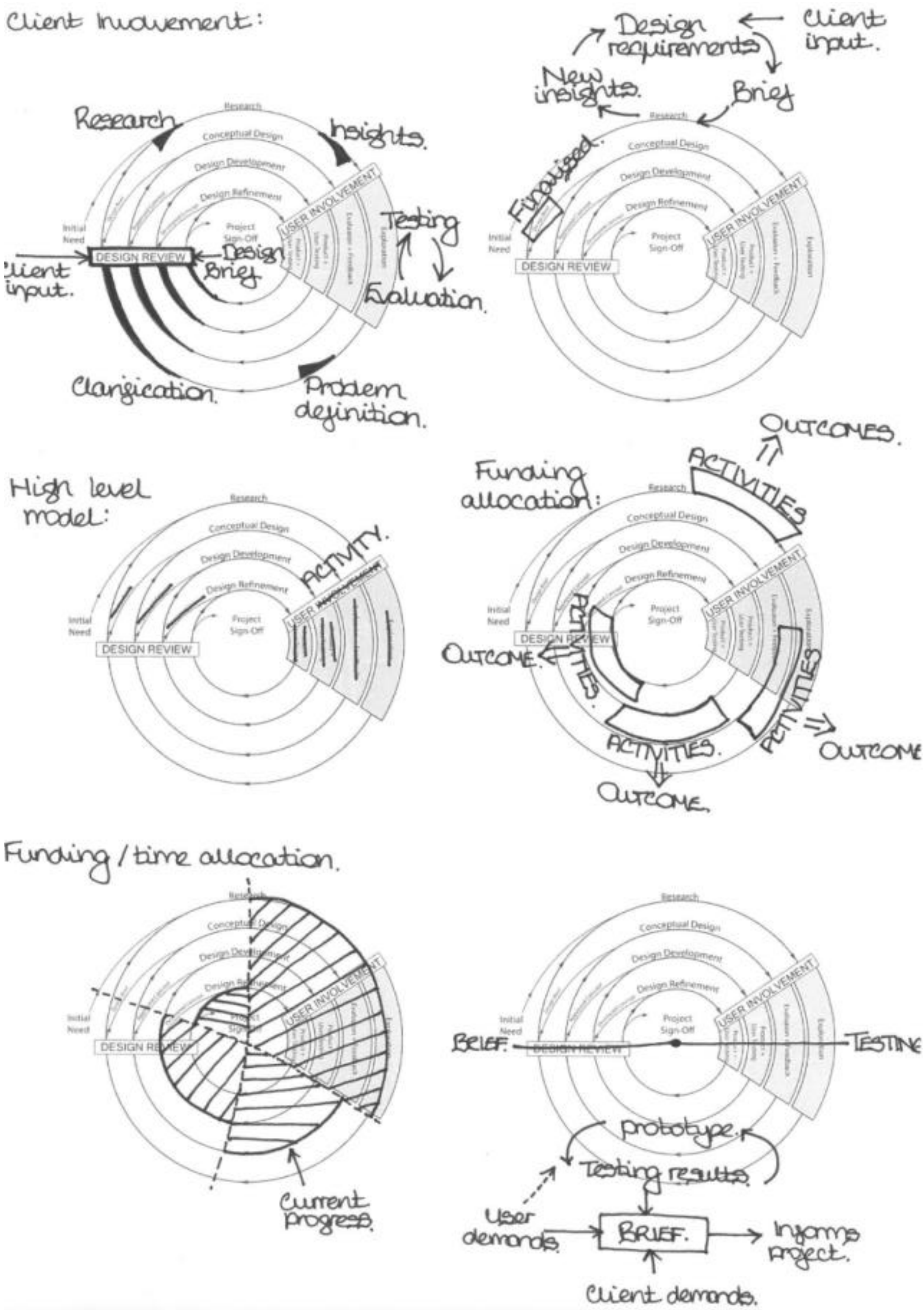
Would you be likely to use the process model and proposed framework?	**Please select one**
Yes	
No	
Please give reason for your choice	

Please rate the MODEL in terms of usefulness (1 being low and 10 being high) in terms of:
A process model to follow in every day design activities
Methods/tools (user centred only)
As a learning/educational tool
To communicate with clients
To increase levels of user involvement throughout the whole design process

Please rate the PROPOSED FRAMEWORK in terms of usefulness (1 being low and 10 being high) in terms of:
A process model to follow in every day design activities
Methods/tools (user centred only)
As a learning/educational tool
To communicate with clients
To increase levels of user involvement throughout the whole design process

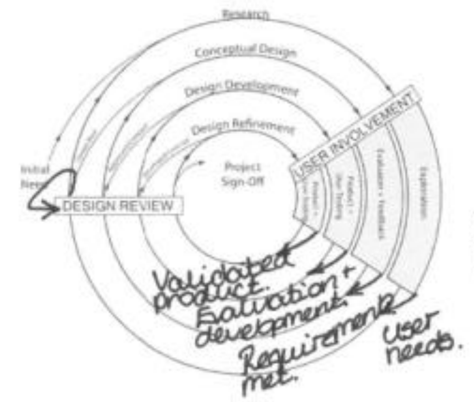
Appendix 4

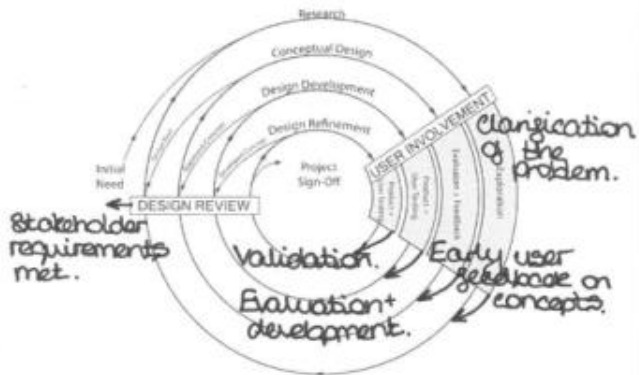
A 4.1. Framework brainstorm exercise (Chapter 7)



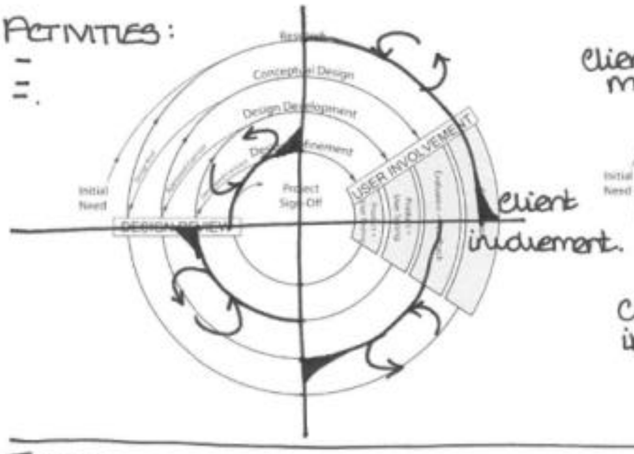
OUTPUTS:

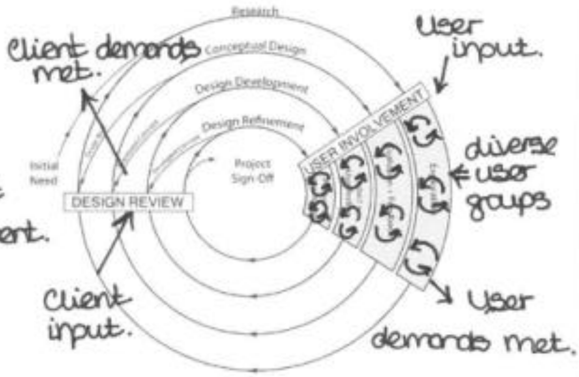
Value to designer:



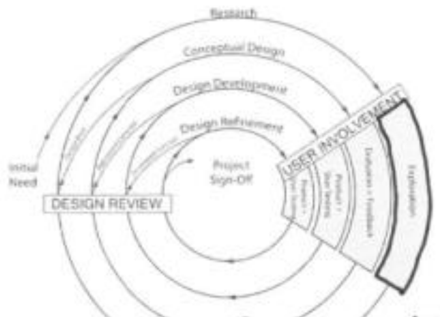


ACTIVITIES:
-
=.

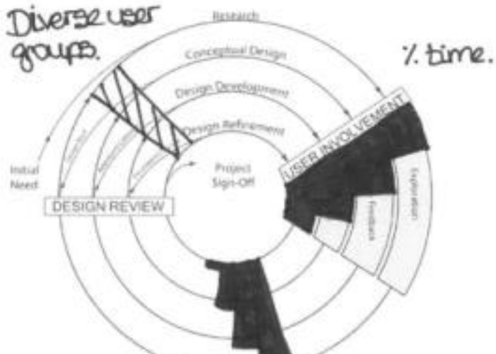


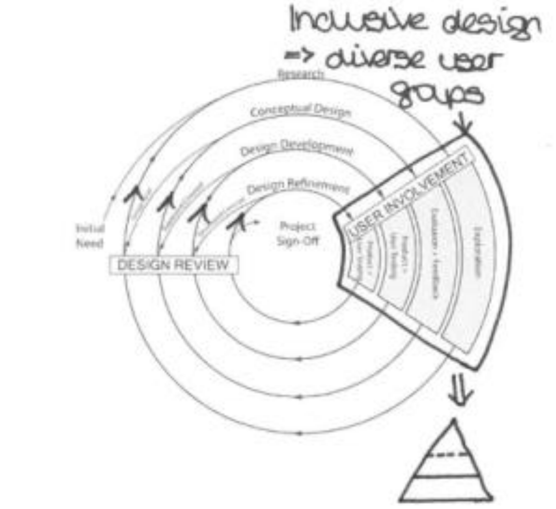


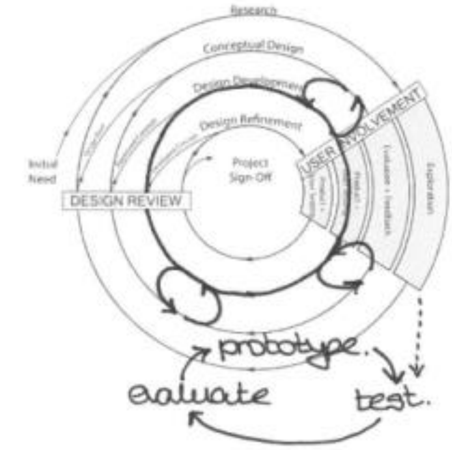
FUNDING ALLOCATION:

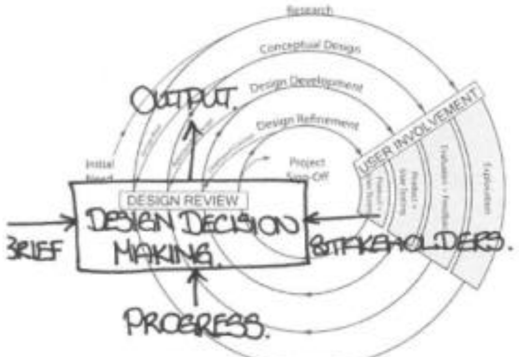


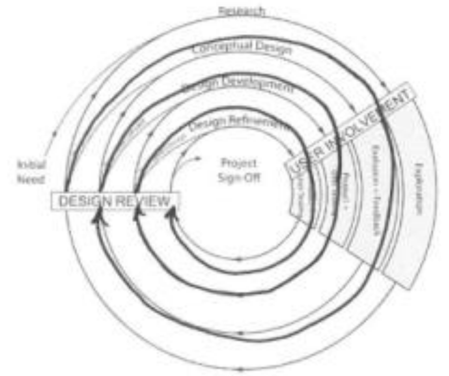
Resource requirement:
- user recruitment.
- environment of use.
- observation.
- designer/user allocation.

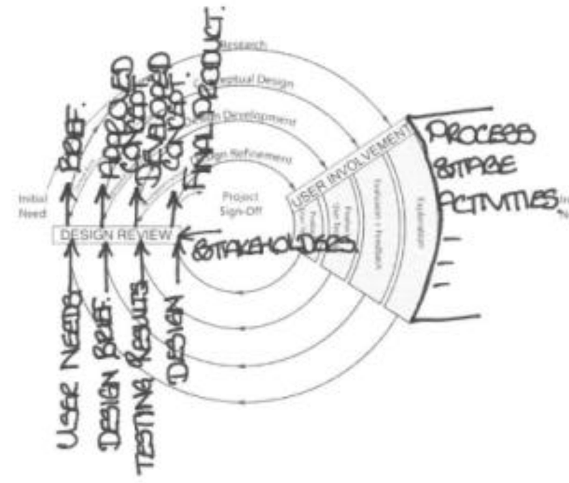


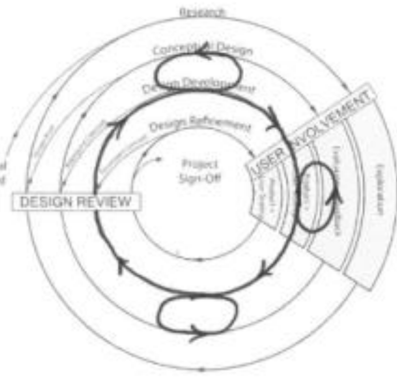

Inclusive design
=> diverse user groups
Research
Conceptual Design
Design Development
Design Refinement
Initial Need
Project Sign-Off
DESIGN REVIEW
USER INVOLVEMENT


Research
Conceptual Design
Design Refinement
Initial Need
Project Sign-Off
DESIGN REVIEW
USER INVOLVEMENT
prototype.
evaluate
test.

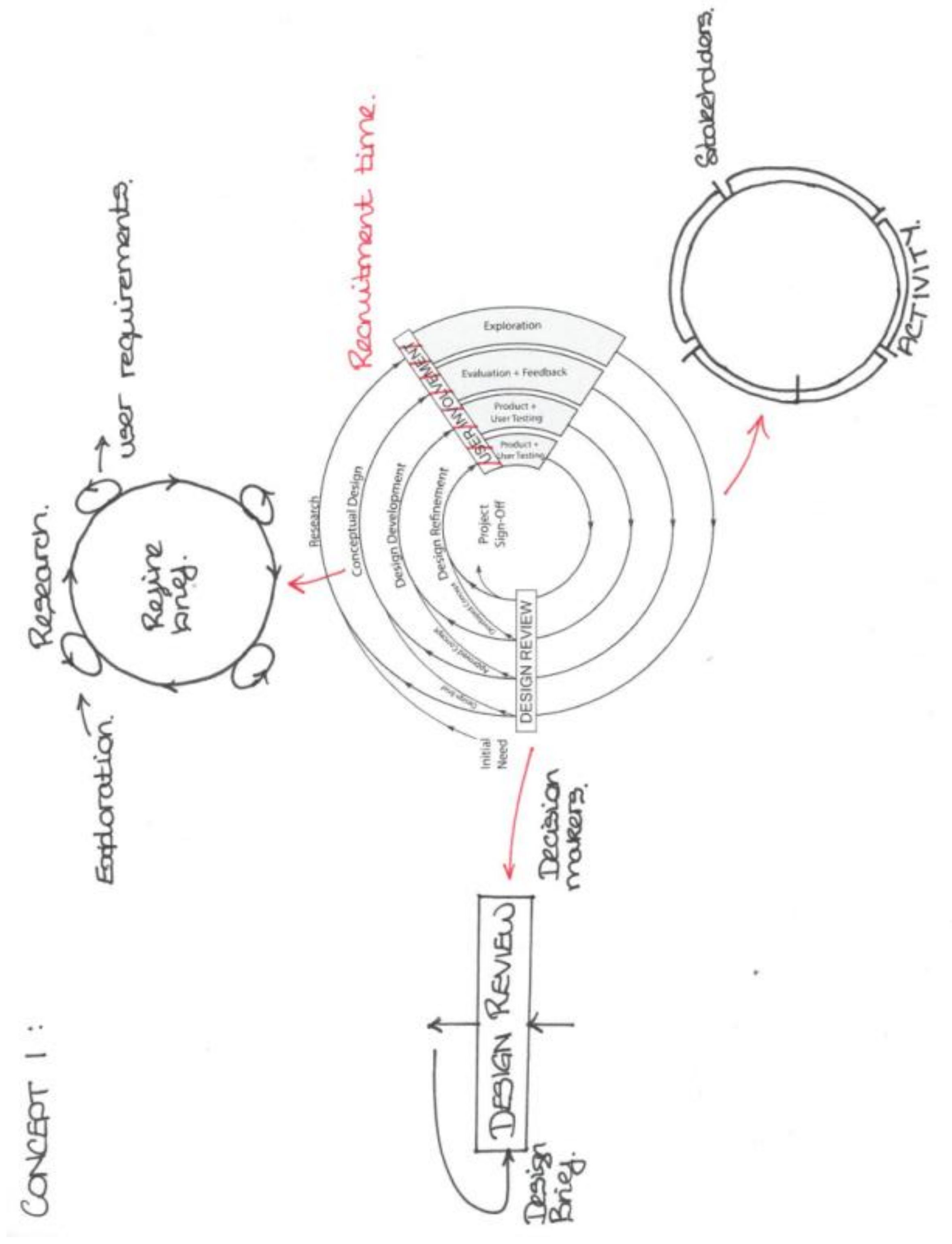

Research
Conceptual Design
Design Development
Design Refinement
OUTPUT.
DESIGN REVIEW
DESIGN DECISION MAKING.
BRIEF
STAKEHOLDERS.
PROGRESS.
USER INVOLVEMENT


Research
Conceptual Design
Design Development
Design Refinement
Initial Need
Project Sign-Off
DESIGN REVIEW
USER INVOLVEMENT

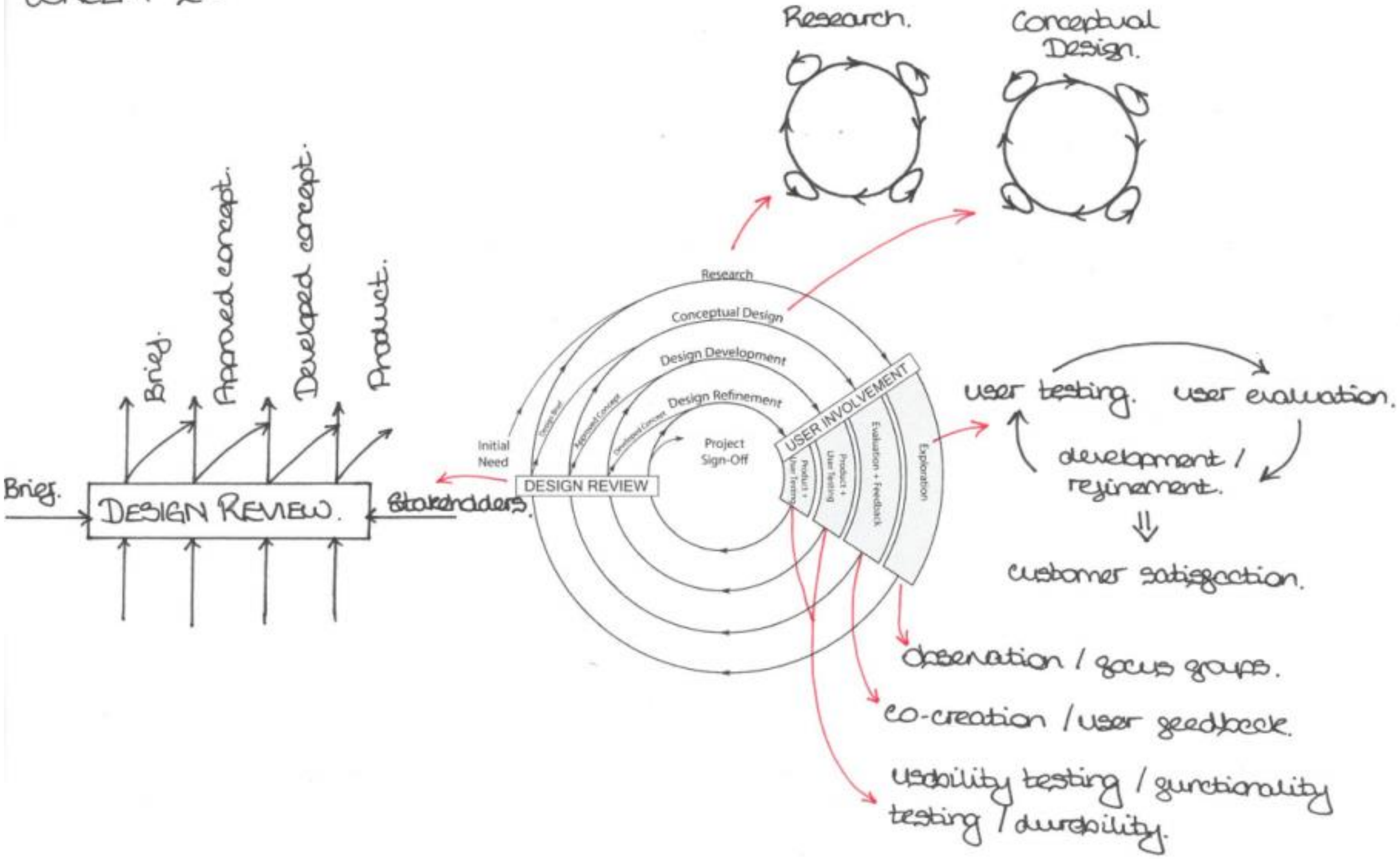

BRIEF.
APPROVED CONCEPT.
DEVELOPED CONCEPT.
FINAL PRODUCT.
USER NEEDS
DESIGN BRIEF.
TESTING RESULTS
DESIGN
STAKEHOLDERS
PROCESS STAGE ACTIVITIES
DESIGN REVIEW
USER INVOLVEMENT
Initial Need
Project Sign-Off


Research
Conceptual Design
Design Refinement
Project Sign-Off
DESIGN REVIEW
USER INVOLVEMENT

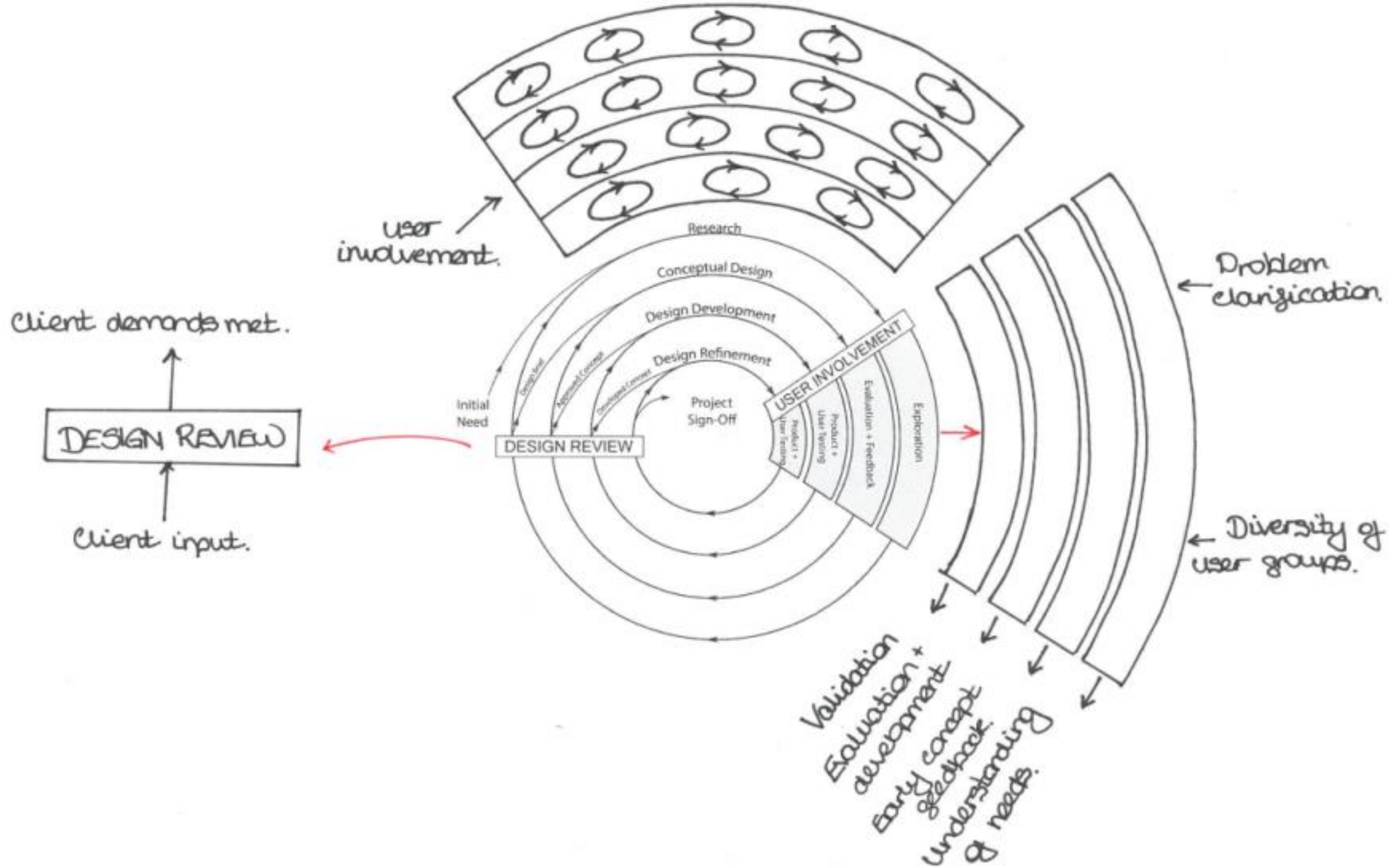
A 4.2. Early development of concepts (Chapter 7)



CONCEPT 2 :

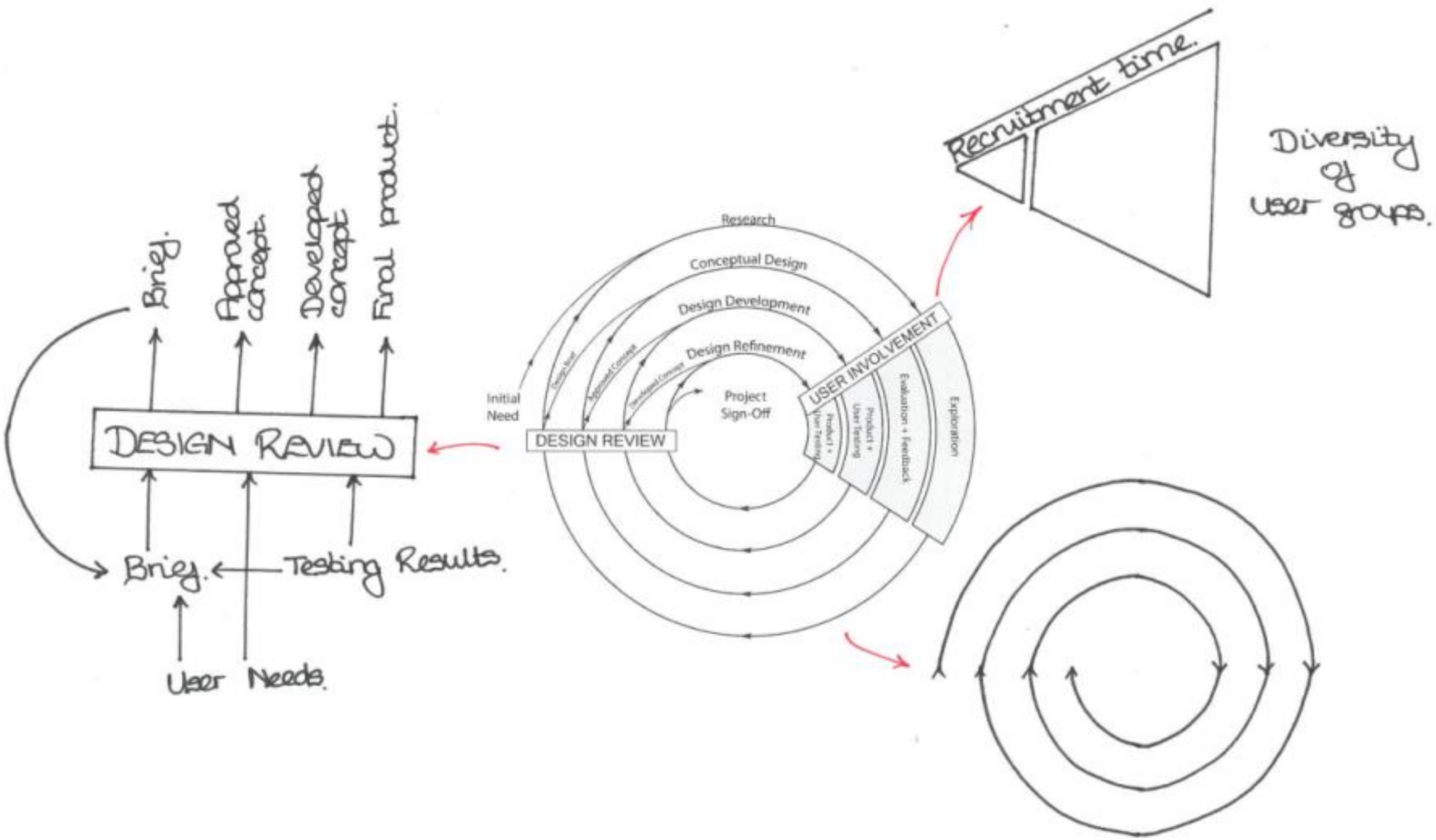

Research.
Conceptual Design.
Brief.
Approved concept.
Developed concept.
Product.
Brief.
DESIGN REVIEW.
Stakeholders.
Initial Need
DESIGN REVIEW
Research
Conceptual Design
Design Development
Design Refinement
Project Sign-Off
USER INVOLVEMENT
Product + User Testing
Product + User Testing
Evaluation + Feedback
Exploration
user testing.
user evaluation.
development / refinement.
⇓
customer satisfaction.
observation / focus groups.
co-creation / user feedback.
usability testing / functionality testing / durability.

CONCEPT 3:



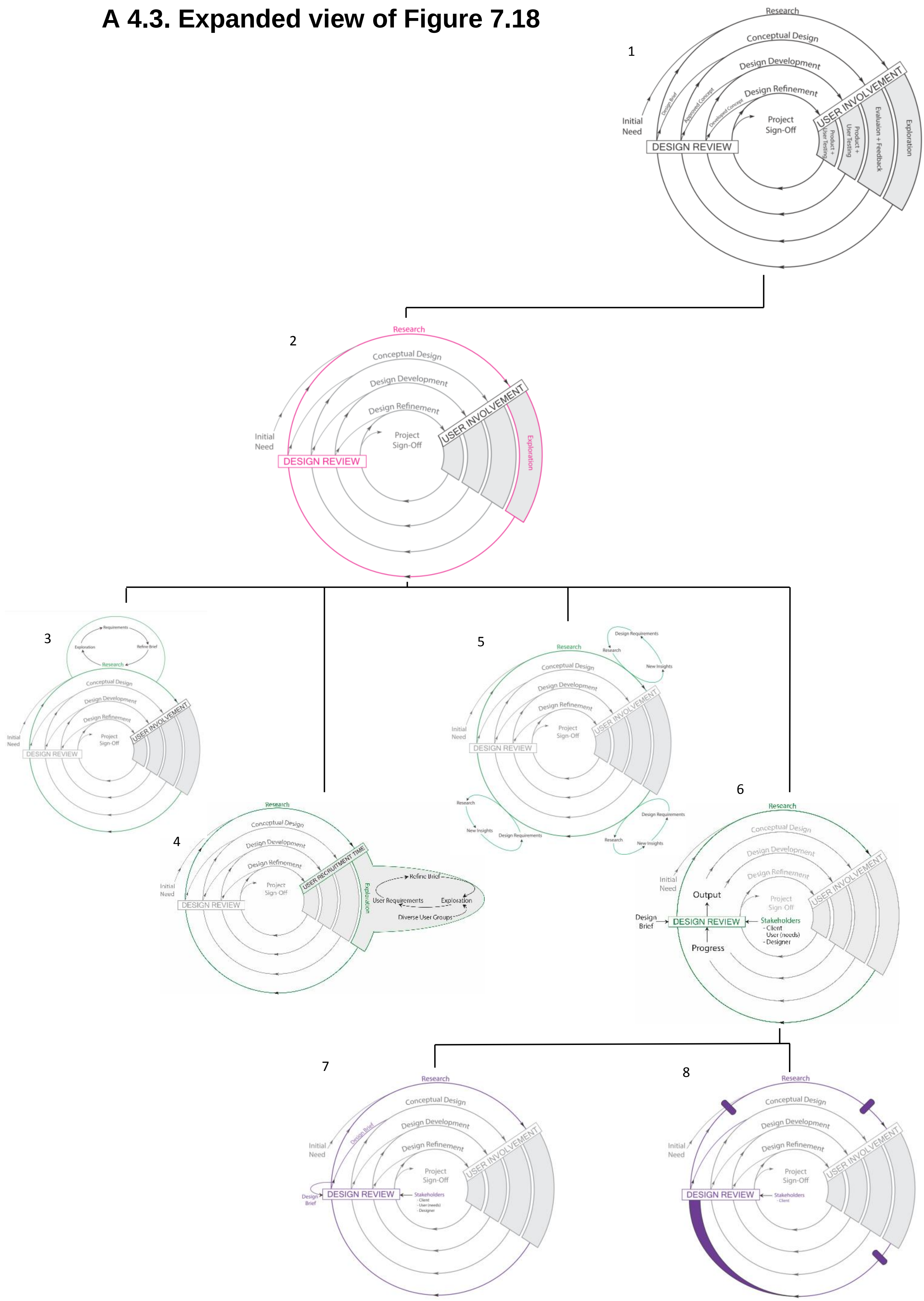
user involvement.
Client demands met.
DESIGN REVIEW
Client input.
Research
Conceptual Design
Design Development
Design Refinement
Project Sign-Off
Initial Need
DESIGN REVIEW
USER INVOLVEMENT
Exploration
Evaluation + Feedback
Product + User Testing
Product + User Testing
Problem clarification.
Diversity of user groups.
Validation
Evaluation + development.
Early concept feedback.
Understanding of needs.

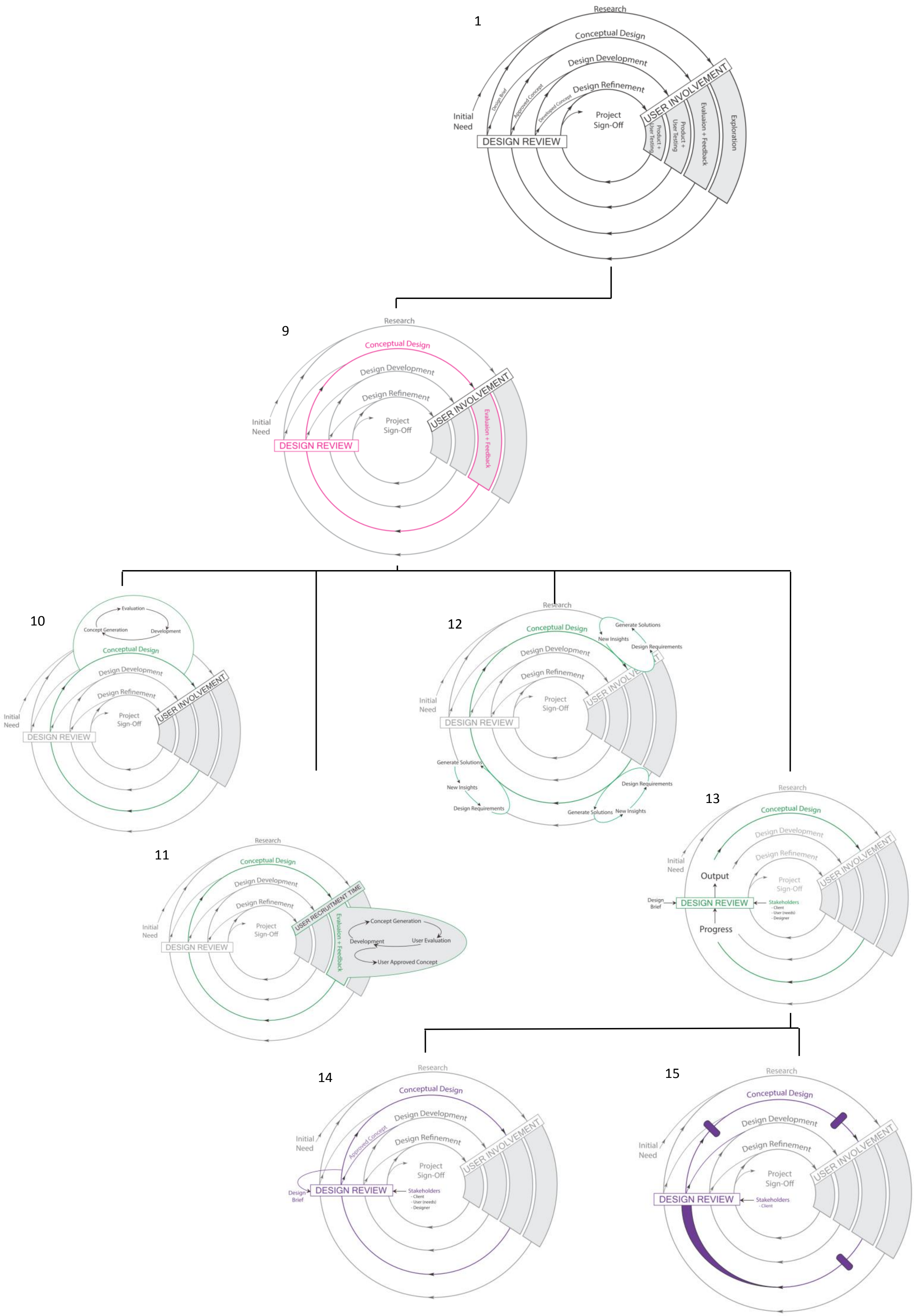
CONCEPT 4:

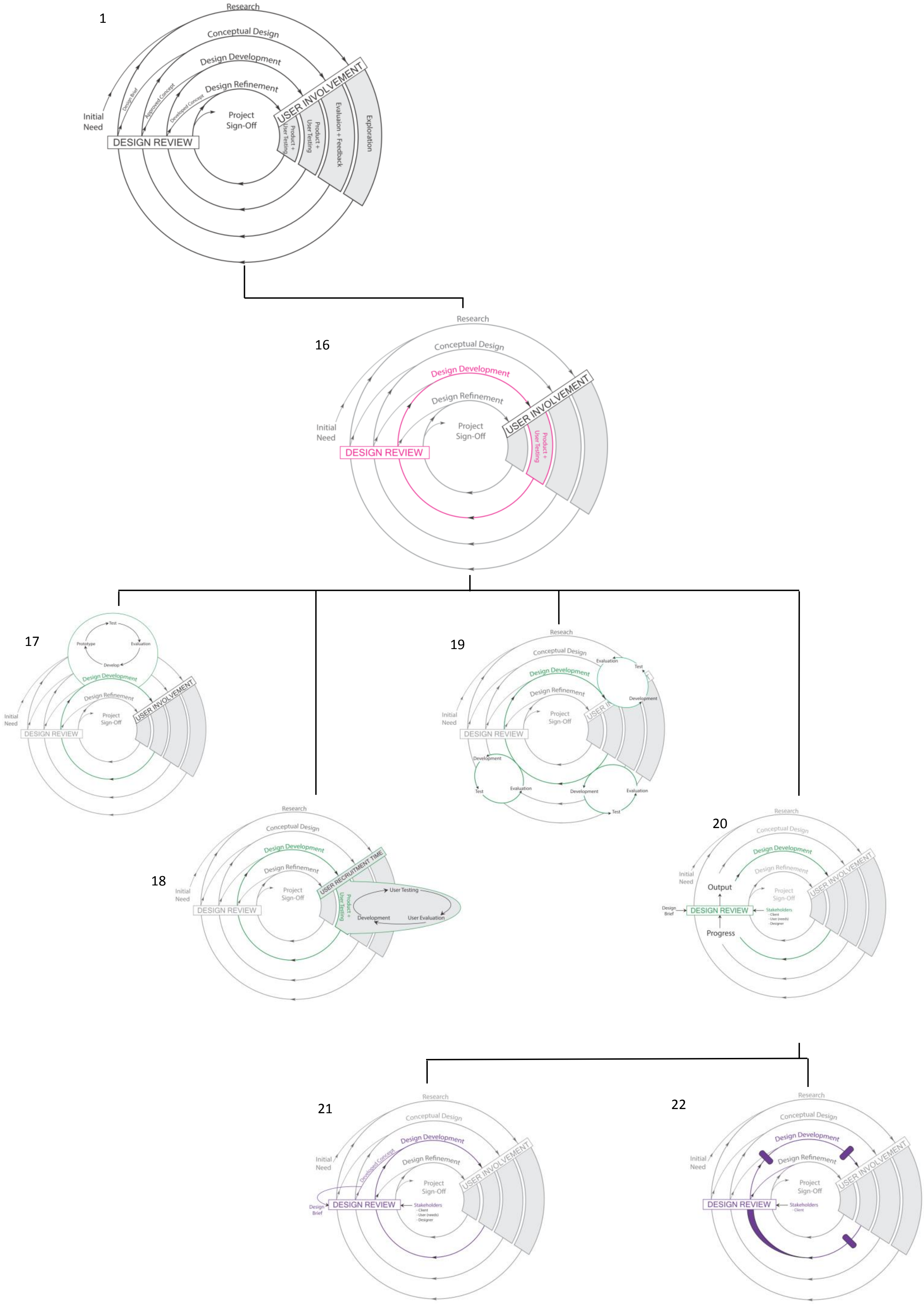


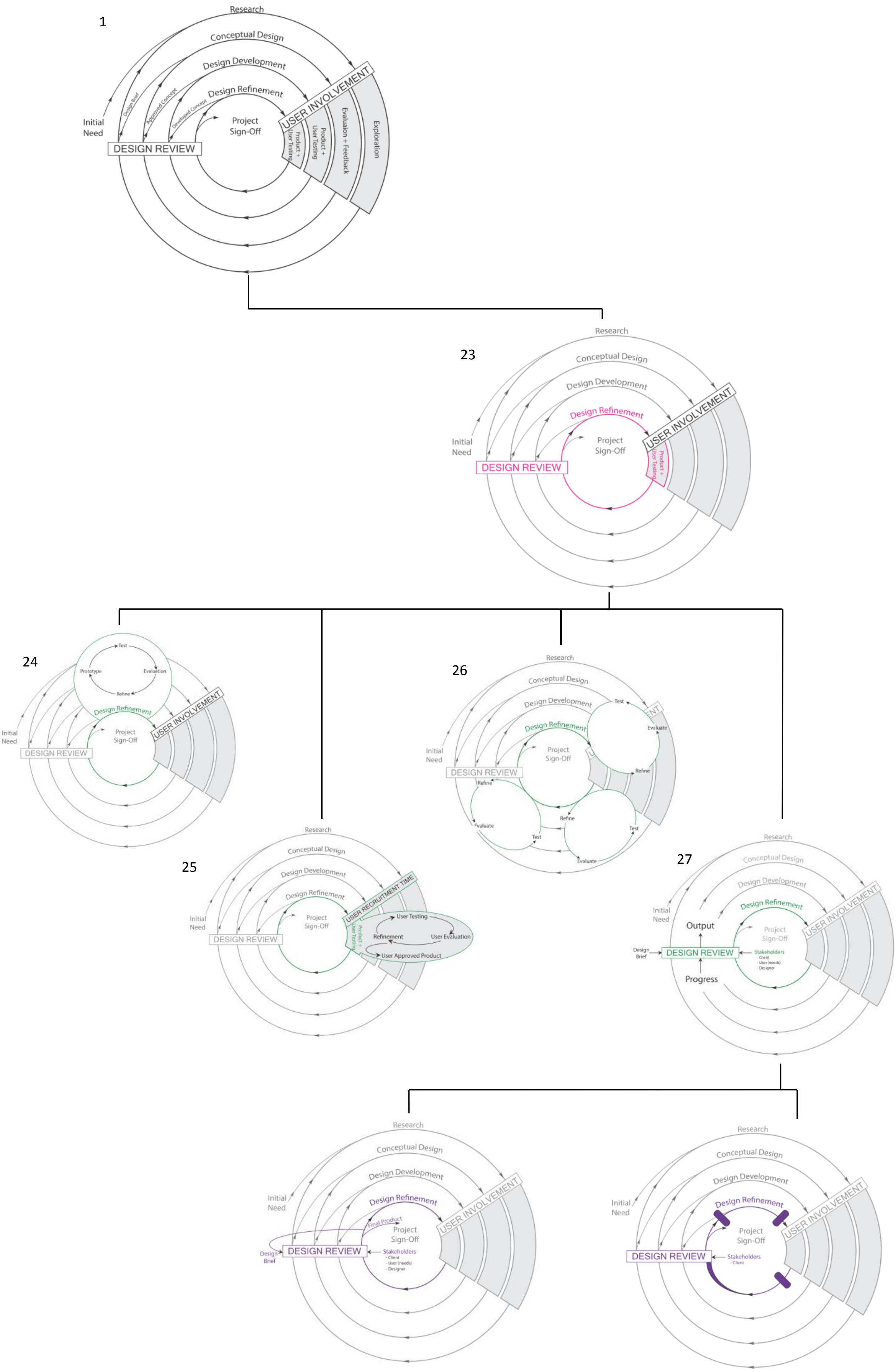
Brief.
Approved concept.
Developed concept
Final product.
DESIGN REVIEW
Brief.
Testing Results.
User Needs.
Research
Conceptual Design
Design Development
Design Refinement
Project Sign-Off
Initial Need
DESIGN REVIEW
USER INVOLVEMENT
Product + User Testing
Product + User Testing
Evaluation + Feedback
Exploration
Recruitment time.
Diversity of user groups.

A 4.3. Expanded view of Figure 7.18




1
Research
Conceptual Design
Design Development
Design Refinement
Initial Need
Project Sign-Off
DESIGN REVIEW
USER INVOLVEMENT
Product + User Testing
Product + User Testing
Evaluation + Feedback
Exploration
9
Research
Conceptual Design
Design Development
Design Refinement
Initial Need
Project Sign-Off
DESIGN REVIEW
USER INVOLVEMENT
Evaluation + Feedback
10
Evaluation
Concept Generation
Development
Conceptual Design
Design Development
Design Refinement
Initial Need
Project Sign-Off
DESIGN REVIEW
USER INVOLVEMENT
11
Research
Conceptual Design
Design Development
Design Refinement
Initial Need
Project Sign-Off
DESIGN REVIEW
USER RECRUITMENT TIME
Evaluation + Feedback
Concept Generation
Development
User Evaluation
User Approved Concept
12
Research
Conceptual Design
Design Development
Design Refinement
Initial Need
Project Sign-Off
DESIGN REVIEW
Generate Solutions
New Insights
Design Requirements
13
Research
Conceptual Design
Design Development
Design Refinement
Initial Need
Project Sign-Off
Output
Progress
Design Brief
DESIGN REVIEW
Stakeholders
USER INVOLVEMENT
14
Research
Conceptual Design
Design Development
Design Refinement
Initial Need
Approved Concept
Project Sign-Off
Design Brief
DESIGN REVIEW
Stakeholders
- Client
- User (needs)
- Designer
USER INVOLVEMENT
15
Research
Conceptual Design
Design Development
Design Refinement
Initial Need
Project Sign-Off
DESIGN REVIEW
Stakeholders
- Client
USER INVOLVEMENT


1
Research
Conceptual Design
Design Development
Design Refinement
Project
Sign-Off
Initial
Need
Design Brief
Approved Concept
Developed Concept
DESIGN REVIEW
USER INVOLVEMENT
Product +
User Testing
Evaluation + Feedback
Exploration
16
17
Test
Prototype
Evaluation
Develop
18
USER RECRUITMENT TIME
User Testing
Development
User Evaluation
19
Reseach
Development
Test
Evaluation
20
Output
Progress
Design
Brief
Stakeholders
21
22


1
Research
Conceptual Design
Design Development
Design Refinement
Project
Sign-Off
Initial
Need
DESIGN REVIEW
USER INVOLVEMENT
Product +
User Testing
Evaluation + Feedback
Exploration
23
24
Test
Prototype
Evaluation
Refine
25
USER RECRUITMENT TIME
User Testing
Refinement
User Evaluation
User Approved Product
26
Evaluate
27
Output
Progress
Design
Brief
Stakeholders
Final Product

Appendix 5

A 5.1. Designer/client interview consent forms (Chapter 8)

Participant Information Sheet for Client Interviews

Name of department: Department for Design, Manufacture and Engineering Management

Title of the study: Evaluation and development of a communication framework to aid inclusive design practice.

Introduction

This workshop has been organised by Nicky Wilson (nicky.wilson.2013@uni.strath.ac.uk), a postgraduate research student at the University of Strathclyde. The workshop forms part of a 3 year PhD research project.

What is the purpose of this investigation?

This workshop aims to gain feedback on a framework intended to aid client and designer communication of the inclusive design process.

Do you have to take part?

Participants will be asked to take part in discussions regarding the framework, potential room for improvement and content of the framework. Participants will also be asked to fill out a questionnaire.

Participation in this workshop is the participant's decision and is entirely voluntary. Participants have the right to refuse to participate or withdraw from participation without reason at any time.

What will you do in the project?

Participants will be asked to take part in discussions regarding existing design processes and discussion/brainstorming exercises to develop an existing model further. Participants will also be asked to fill out a questionnaire.

The workshop will be conducted at a location of the participant's choice.

Why have you been invited to take part?

Participants should be representative of a typical client involved in the design process. Clients have been invited to take part based on their involvement as clients in the Strathclyde University DMEM Industrial Projects.

What happens to the information in the project?

This workshop will be recorded with the participants permission. Information gained will be used to aid further development of the researchers PhD.

All information will be stored securely and will not be disclosed to any third parties. All interview recordings will be solely for the researchers benefit. Where papers/thesis have been written based on the research, all participants will remain anonymous and no sensitive/confidential information will be released.

The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998.

Thank you for reading this information – please ask any questions if you are unsure about what is written here.

What happens next?

Explain that if the participant is happy to be involved in the project, please sign the consent form to confirm this.

Following the interview, participants can receive research updates if requested. Results will be published as part of the researchers PhD thesis and potentially in additional publications. As stated, all participants will remain anonymous.

Researcher contact details:

Nicky Wilson

DMEM, 75 Montrose Street, Glasgow, G1 1XJ

nicky.wilson.2013@uni.strath.ac.uk

0755736678

Consent Form for Interviews with Clients

Name of department: Department for Design, Manufacture and Engineering Management

Title of the study: Evaluation and development of a communication framework to aid inclusive design practice.

- I confirm that I have read and understood the information sheet for the above project and the researcher has answered any queries to my satisfaction.
- I understand that my participation is voluntary and that I am free to withdraw from the project at any time, up to the point of completion, without having to give a reason and without any consequences. If I exercise my right to withdraw and I don't want my data to be used, any data which have been collected from me will be destroyed.
- I understand that I can withdraw from the study any personal data (i.e. data which identify me personally) at any time.
- I understand that anonymised data (i.e. .data which do not identify me personally) cannot be withdrawn once they have been included in the study.
- I understand that any information recorded in the investigation will remain confidential and no information that identifies me will be made publicly available.
- I consent to being a participant in the project
- I consent to being audio recorded as part of the project

(PRINT NAME)	
Signature of Participant:	Date:

A 5.2. Description of the inclusive design framework

The first slide shows the full design process model, more for context than to gain an initial understanding.

Clicking anywhere on the first slide takes you to the second, where you have the option to access any of the four core stages of the inclusive design process – research, conceptual design, design development or design refinement. Clicking on any of these four stage names will lead you to a slide highlighting the four key aspects of each of these stages.

Research – the introduction slide to research highlights the four main areas that are important to research within inclusive design – the core stages of research, the iterations, user involvement and the design review.

- The research phase is made up of initial exploration to understand the problem (often including user focused design methods such as observations and focus group interviews). This exploration leads to the identification of design requirements that allows the designer to refine the design brief further. The design process is continuous until a full brief is gained.
- The exploration process discussed above is continuous throughout the research stage of researching, gaining new insights and refining the brief. This understanding of the user and gaining new insights is continuous throughout the inclusive design process.
- User involvement during research involves an initial recruitment time to source the correct user groups. There is then time spent identifying user requirements and using these to refine the brief. User involvement here is key to ensure that the brief reflects the needs of the user – user groups should reflect diversity.
- The design review at the end of the process stage involves all stakeholders to discuss project progress.
    - At the end of research, there should be a developed design brief that the designers understand and meets the needs of the stakeholders. If all is ok, then progress to conceptual design. If not all requirements are met, continue on the research phase.
    - Client involvement is throughout the research phase – particularly to highlight any areas the designer is unsure of. The client should be phased

into the design review phase and kept up to speed on the progress of the project to ensure they do not come into the design review unaware of what has led to that point.

Conceptual design – the introduction slide to research highlights the four main areas that are important to conceptual design – the core stages of conceptual, the iterations, user involvement and the design review.

- The conceptual design phase is made up concept generation to create solutions to the problem (often including design methods such brainstorming). These concepts are evaluated against the design brief (which is continually developing) and developed further to meet the design requirements.
- The process discussed above is continuous throughout the conceptual design stage of creating design solutions, evaluating them to gain new insights, which in turn lead to developments of the design requirements.
- User involvement during conceptual design may also involve initial recruitment time to source the correct user groups. These users can be involved in the evaluation of potential concepts to ensure their needs are met. This evaluation and development process is continuous until a user approved concept is selected. User groups should reflect diversity to ensure the outcome is inclusively designed.
- The design review at the end of the stage involves all stakeholders to discuss project progress.
    - At the end of conceptual design, there should be an approved concept in rough form that meets the needs of the stakeholders. If all is ok, then progress to design development. If the concept does not meet all requirements in the design brief, continue on the conceptual design phase. The design brief is constantly updated with new insights gained through the inclusive design process.
    - Client involvement is throughout conceptual. The client should be phased into the design review phase and kept up to speed on the progress of the project to ensure they do not come into the design review unaware of what has led to that point.

Design development – the introduction slide to research highlights the four main areas that are important to design development – the core stages of design development, the iterations, user involvement and the design review.

- The design development phase is made up development of the concept, prototyping, testing and evaluation. The design is constantly evaluated against the design brief (which is continually developing) and developed further to meet the design requirements.
- The process discussed above is continuous throughout the design development stage of evaluating the design, physical product testing and evaluation.
- User involvement during design development may also involve initial recruitment time to source the correct user groups although testing is more focused at this point. Users are involved in the evaluation of prototypes to ensure their needs are met. This evaluation and development process is continuous as the product is further developed. The product should be tested against those user groups from where ideas originated to ensure the product meets the needs of those user groups.
- The design review at the end of the stage involves all stakeholders to discuss project progress.
    - At the end of design development, there should be a developed concept that meets the needs of the stakeholders. If all is ok, then progress to design refinement. If the concept does not meet all requirements in the design brief, continue on the design development phase. The design brief is constantly updated with new insights gained through the process.
    - Client involvement is throughout design development. The client should be phased into the design review phase and kept up to speed on the progress of the project to ensure they do not come into the design review unaware of what has led to that point.

Design refinement – the introduction slide to research highlights the four main areas that are important to design refinement – the core stages of design refinement, the iterations, user involvement and the design review.

- The design refinement phase is made up refinement of the concept, prototyping, testing and evaluation. The design is constantly evaluated against the design brief (which is continually developing) and final refinements are made to meet the design requirements.

- The process discussed above is continuous throughout the design refinement stage of evaluating the design, physical product testing and evaluation.
- User involvement during design refinement may also involve initial recruitment time to source the correct user groups although testing is more focused at this point. Users are involved in the evaluation of prototypes to ensure their needs are met. This evaluation and development process is continuous as the product is further developed. Testing is more focused on small tweaks and aesthetic details rather that detailed design work. The product should be tested against those user groups from where ideas originated to ensure the product meets the needs of those user groups.
- The design review at the end of the stage involves all stakeholders to discuss project progress.
    - At the end of design refinement, there should be a final product that meets the needs of the stakeholders. If all is ok, then the product progresses to the production stage. If the concept does not meet all requirements in the design brief, continue on the design refinement phase. The design brief is constantly updated with new insights gained through the process.
    - Client involvement is throughout design refinement. The client should be phased into the design review phase and kept up to speed on the progress of the project to ensure they do not come into the design review unaware of what has led to that point.

A 5.3. Product designer validation process (Chapter 8)

Interview Structure

Aim of the study: to assess the applicability of the framework to improve the uptake of inclusive design through aiding designers communicate their design process and requirements to the client.

This study focuses on discussions with designers to ensure key areas of the design process (important to them) are communicated within the framework – timescales, funding, etc. The framework should be used as a tool to enable to the designer to improve communications with the client to remove some of the client driven barriers to inclusive design.

- Overview of the framework:
  - Introduction to the research
  - Aims of the framework
  - Overview and demonstration of the framework
- Feedback on the framework:
  - Interview questions
  - Feedback form
  - Concluding questions from the designer

A 5.3.1. Designer interview questions

Interview questions are highlighted in bold. As interviews were semi-structured, additional prompts are included to ensure relevant points are covered.

1. **Was the framework effective in communicating the inclusive design process?**
    a. Are there any areas you don't understand?
    b. Was the framework useful for breaking down the process?
    c. Was the framework useful for emphasising importance of user involvement?
2. **Does the process highlight areas of the process that are important to you as a designer?**
    a. What are they?
3. **Are there any areas you had difficulty in understanding?**
    a. Is the interface easy to use/understand?
    b. Are the graphics clear?
    c. Are the images communicated clearly?
    d. Navigation through the framework?
4. **Would the framework be a method you would choose when communicating with a client?**
    a. If other techniques would be preferred what are they?
5. **Does the framework communicate the importance of:**
    a. Early research.
    b. User involvement throughout.
6. **Is the framework in a format that is useful and usable to you as a designer?**
    a. Would you want an accompanying hard copy?
    b. Would supplementary text be needed (in slides or as help guide)?
    c. Would you like to be able to adapt the framework for individual projects?
    d. Would you improve the visual representation of the framework?

A 5.3.2. Designer feedback questionnaire

Please answer YES or NO:	
Is the framework useful to you as a designer?	YES / NO
Will the framework improve communication between designer and client?	YES / NO
Would you use a software version of the framework?	YES / NO
Is there enough detail in the model?	YES / NO
Please leave detail of what could be removed/added to improve the framework:	
Would you use a hard copy of the framework?	YES / NO

Please rate (1 bad – 5 good) the usefulness of the framework:
Representing the inclusive design process.
Representing the iterative nature of the inclusive design process.
Representing areas for user involvement throughout the inclusive design process.
Highlighting benefits of user involvement (to the design project).

Will the framework improve client awareness of the importance of:	
User involvement throughout the inclusive design process.	Yes / No / Maybe
The need to complete thorough research early in the inclusive design process	Yes / No / Maybe
The need to iterate within the inclusive design process.	Yes / No / Maybe

A 5.4. Client validation process (Chapter 8)

Interview Structure

Aim of the study: to assess the applicability of the framework to improve the uptake of inclusive design through aiding designers communicate their design process and requirements to the client.

This study focuses on discussions with clients to ensure they are able to understand the inclusive design process as a result of the framework. The framework should be used by the designer to improve communications with the client to remove some of the client driven barriers to inclusive design.

- Overview of the framework:
    - Introduction to the research
    - Aims of the framework
    - Overview and demonstration of the framework
- Feedback on the framework:
    - Interview questions
    - Feedback form
    - Concluding questions from the client

A 5.4.1. Client interview questions

Interview questions are highlighted in bold. As interviews were semi-structured, additional prompts are included to ensure relevant points are covered.

1. **Was the framework effective in communicating the inclusive design process?**
    a. Are there any areas you don't understand?
    b. Was the framework useful for breaking down the process?
    c. Was the framework useful for emphasising importance of user involvement?
2. **Does the process highlight areas of the process you had not previously given much thought to?**
3. **Do you want to know the inclusive design process and the different levels of detail shown here?**
4. **Are there any areas you had difficulty in understanding?**
    a. Is the interface easy to use/understand?
    b. Are the graphics clear?
    c. Are the images communicated clearly?
5. **Would the framework be a method you would choose when communicating with a designer?**
    a. If other techniques would be preferred what are they?
6. **Does the framework convince you of the value in investing in:**
    a. Early research.
    b. User involvement throughout.
7. **What areas of the framework do you feel could be improved?**
    a. Graphics
    b. Illustrations
    c. User interface
    d. Additional text

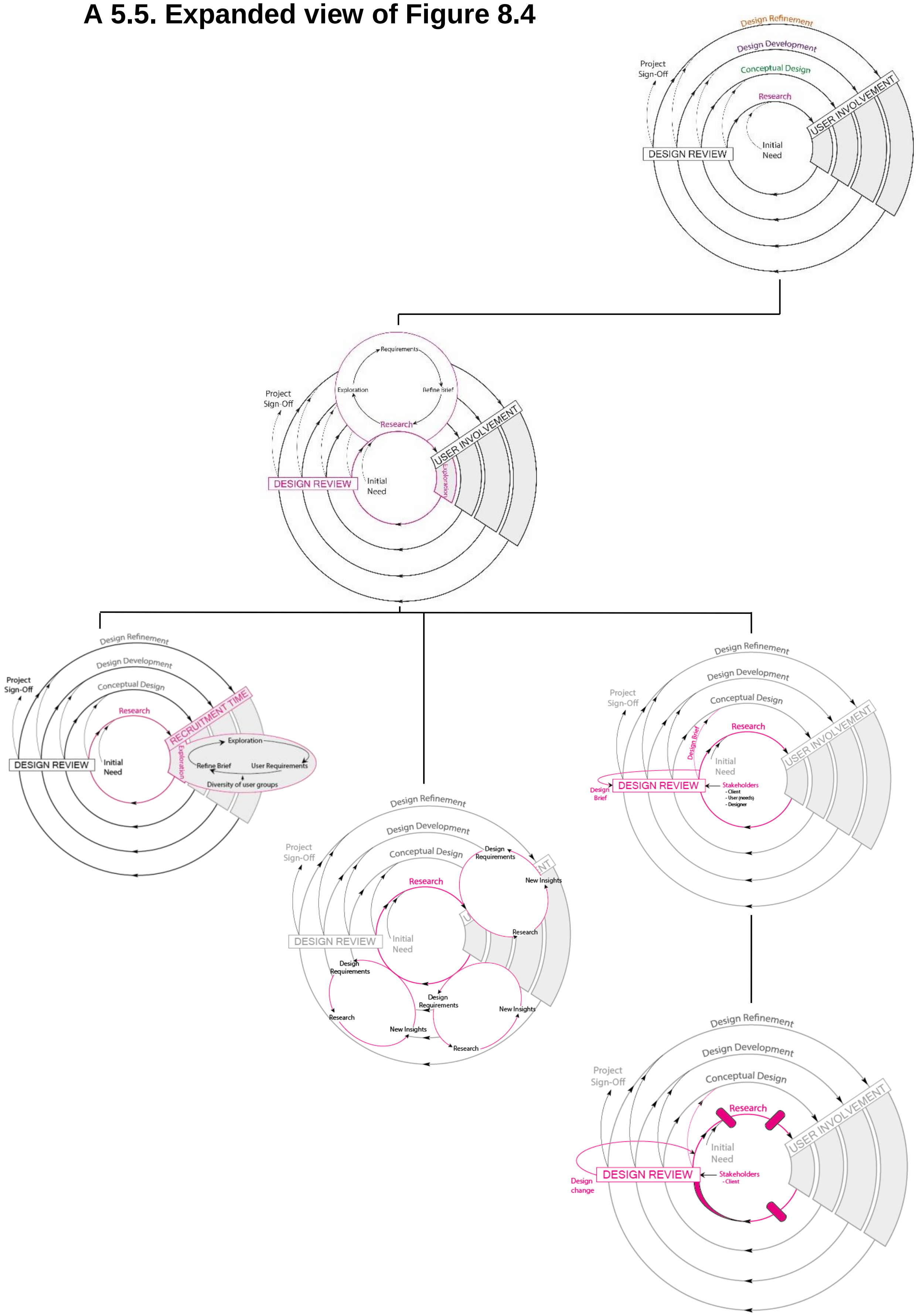
A 5.4.2. Client feedback questionnaire

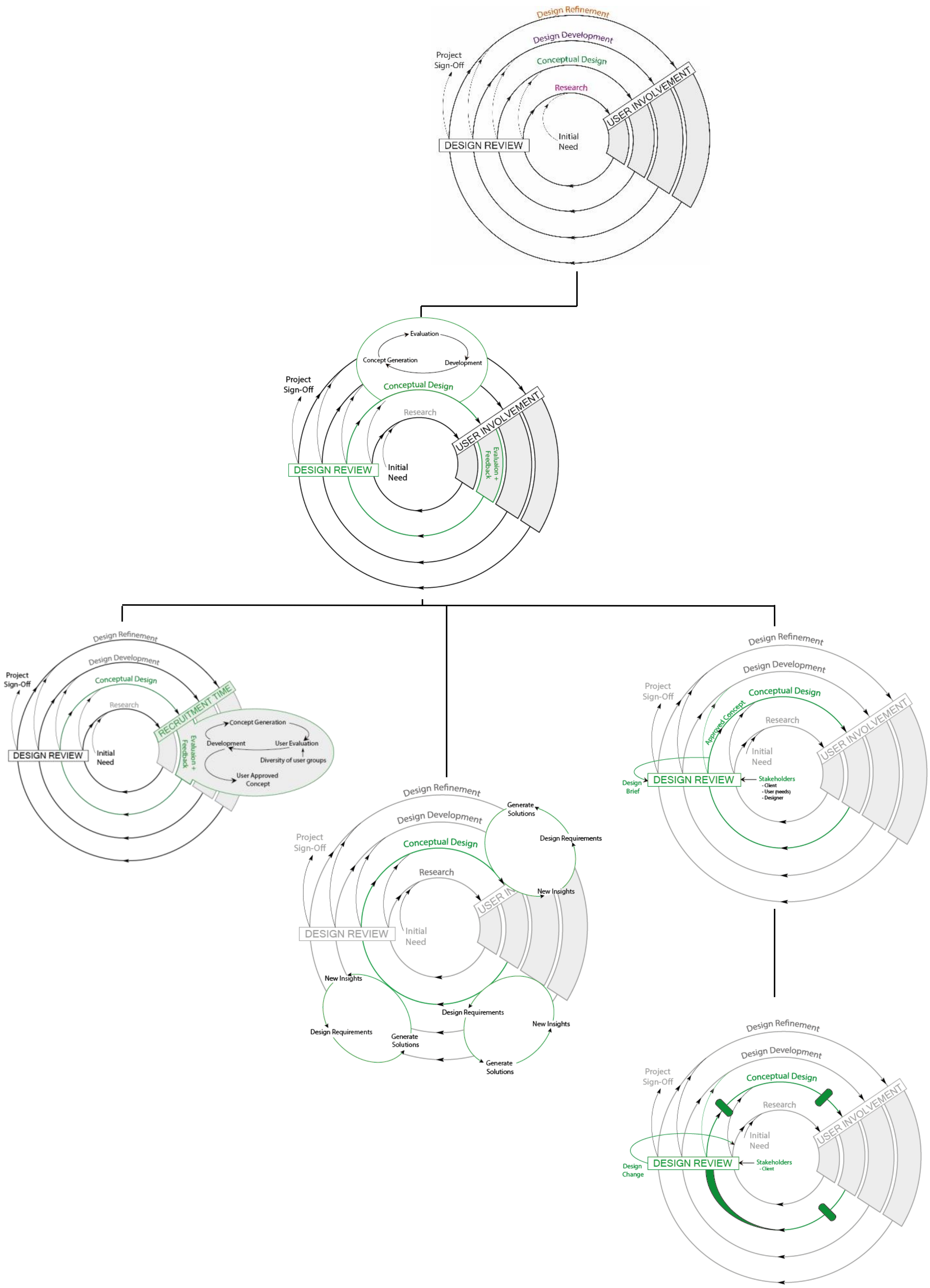
Please answer YES or NO:	
Has the framework improved your knowledge of the inclusive design process?	YES / NO
Would you use the process when communicating with a designer?	YES / NO
Would you use a software version of the framework	YES / NO
Is there enough detail in the model?	YES / NO
Please leave detail of what could be removed/added to improve the framework:	
Would you use a hard copy of the framework?	YES / NO

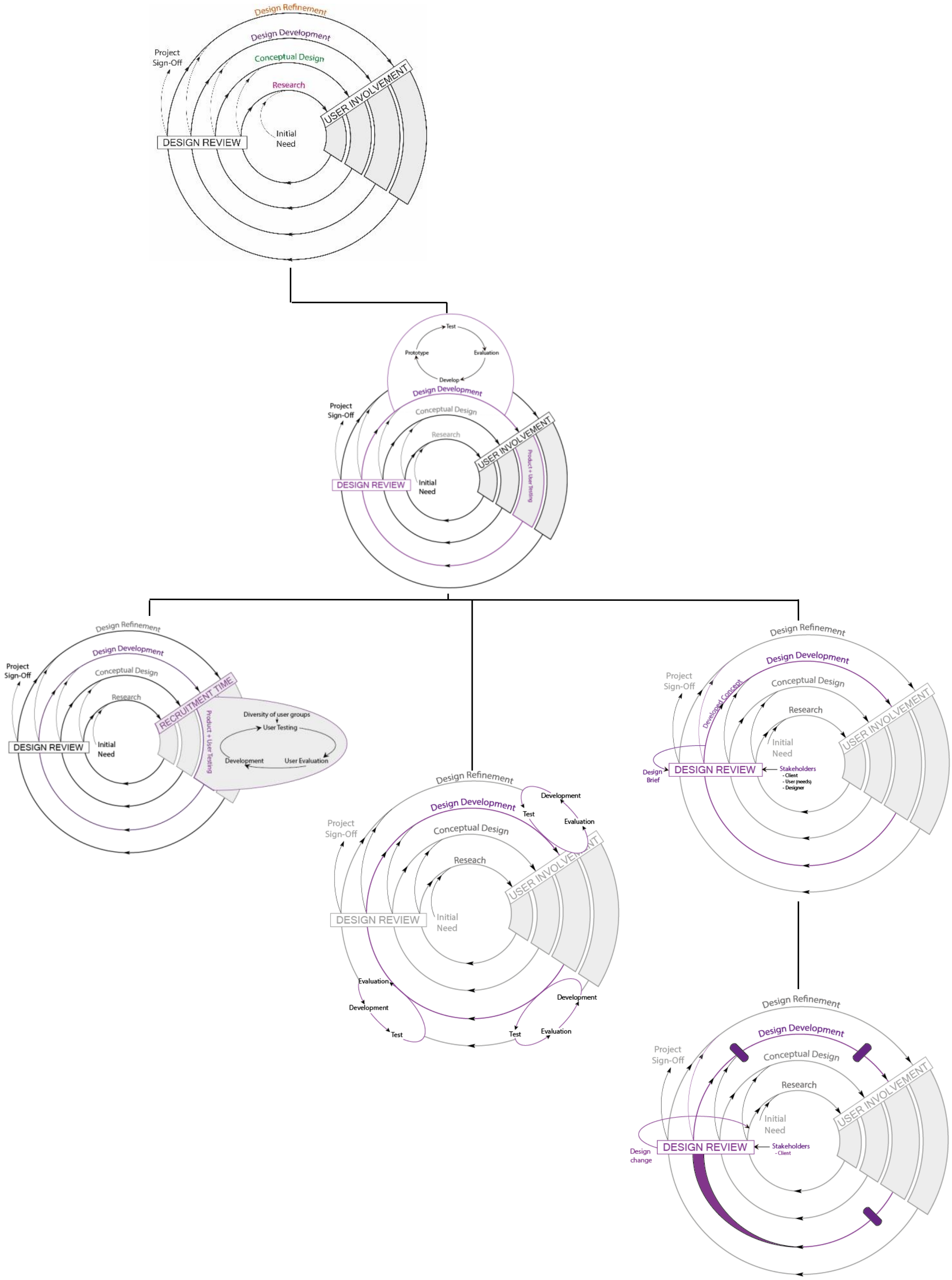
Please rate (1 bad – 5 good) the usefulness of the framework:
Representing the inclusive design process.
Representing the iterative nature of the inclusive design process.
Representing areas for user involvement throughout the inclusive design process.
Highlighting benefits of user involvement (to the design project).
Highlighting the benefits of user involvement to you (the client).

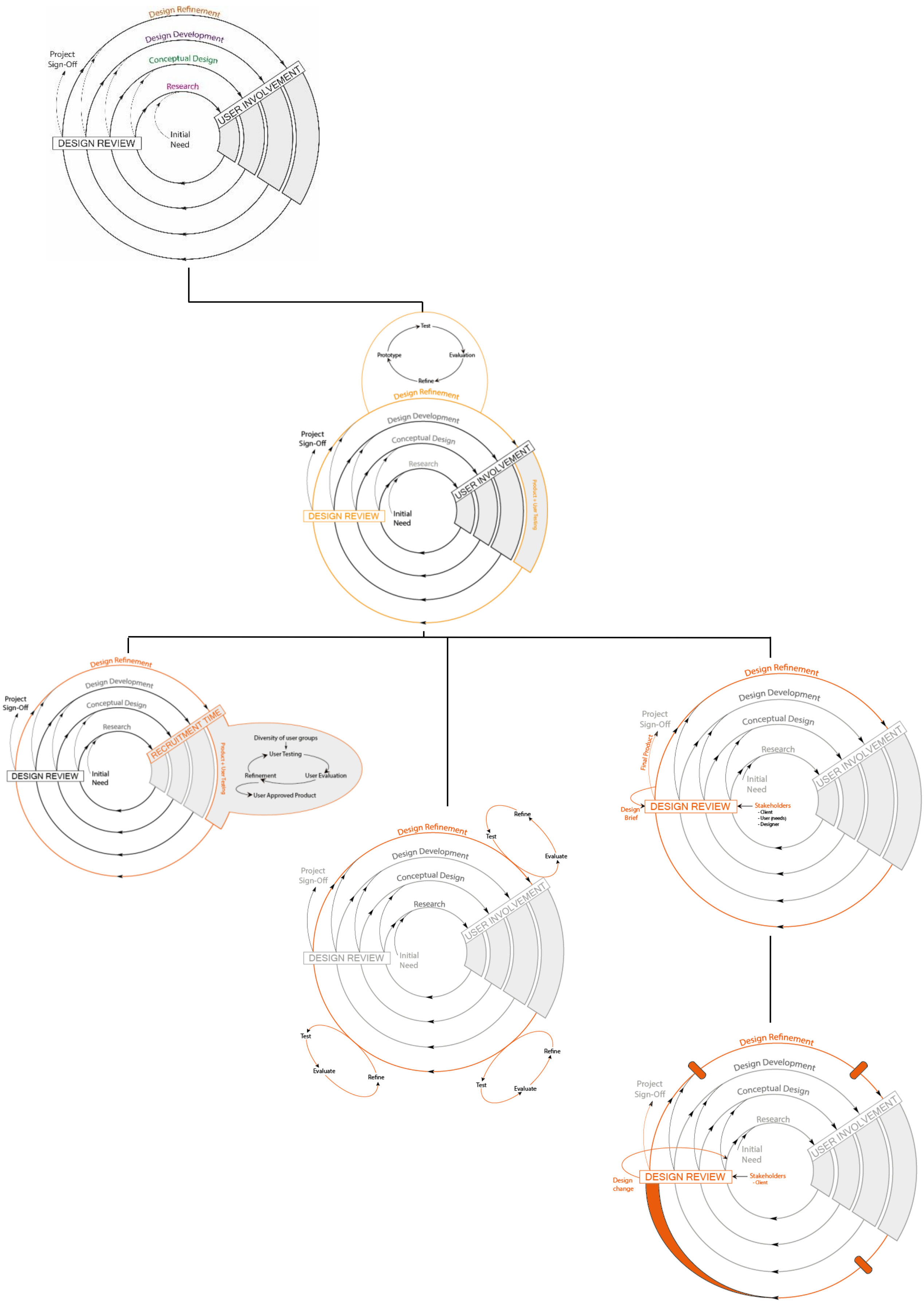
Please indicate whether you understand the following:	
That iteration is a necessary part of the inclusive design process.	Yes / No / Maybe
That user involvement will help to minimise design errors.	Yes / No / Maybe
That user involvement is needed to prevent design errors later in the design process.	Yes / No / Maybe

A 5.5. Expanded view of Figure 8.4




Design Refinement
Design Development
Conceptual Design
Research
Project Sign-Off
USER INVOLVEMENT
DESIGN REVIEW
Initial Need
Evaluation
Concept Generation
Development
Conceptual Design
Research
Project Sign-Off
USER INVOLVEMENT
Evaluation + Feedback
DESIGN REVIEW
Initial Need
Design Refinement
Design Development
Conceptual Design
Research
Project Sign-Off
RECRUITMENT TIME
Concept Generation
Development
User Evaluation
Diversity of user groups
User Approved Concept
Evaluation + Feedback
DESIGN REVIEW
Initial Need
Design Refinement
Design Development
Conceptual Design
Research
Project Sign-Off
Approved Concept
USER INVOLVEMENT
Initial Need
Design Brief
DESIGN REVIEW
Stakeholders
- Client
- User (needs)
- Designer
Design Refinement
Design Development
Conceptual Design
Research
Project Sign-Off
Generate Solutions
Design Requirements
New Insights
DESIGN REVIEW
Initial Need
New Insights
Design Requirements
Generate Solutions
Design Requirements
New Insights
Generate Solutions
Design Refinement
Design Development
Conceptual Design
Research
Project Sign-Off
USER INVOLVEMENT
Initial Need
Design Change
DESIGN REVIEW
Stakeholders
- Client


Design Refinement
Design Development
Conceptual Design
Research
Project Sign-Off
DESIGN REVIEW
Initial Need
USER INVOLVEMENT
Test
Prototype
Evaluation
Develop
Product + User Testing
RECRUITMENT TIME
Diversity of user groups
User Testing
Development
User Evaluation
Reseach
Developed Concept
Design Brief
Stakeholders
- Client
- User (needs)
- Designer
Design change



Design Refinement
Design Development
Conceptual Design
Research
Project Sign-Off
USER INVOLVEMENT
DESIGN REVIEW
Initial Need
Test
Prototype
Evaluation
Refine
Design Refinement
Design Development
Conceptual Design
Research
Project Sign-Off
USER INVOLVEMENT
Product + User Testing
DESIGN REVIEW
Initial Need
Design Refinement
Design Development
Conceptual Design
Research
Project Sign-Off
RECRUITMENT TIME
Product + User Testing
DESIGN REVIEW
Initial Need
Diversity of user groups
User Testing
Refinement
User Evaluation
User Approved Product
Refine
Test
Evaluate
Design Refinement
Design Development
Conceptual Design
Research
Project Sign-Off
USER INVOLVEMENT
DESIGN REVIEW
Initial Need
Test
Evaluate
Refine
Refine
Test
Evaluate
Design Refinement
Design Development
Conceptual Design
Research
Project Sign-Off
Final Product
USER INVOLVEMENT
Initial Need
Design Brief
DESIGN REVIEW
Stakeholders
- Client
- User (needs)
- Designer
Design Refinement
Design Development
Conceptual Design
Research
Project Sign-Off
USER INVOLVEMENT
Initial Need
Design change
DESIGN REVIEW
Stakeholders
- Client

Appendix 6

A 6.1. Interview transcript example (Chapters 4-8)

The following interview transcript is taken from the sports designer interviews undertaken as part of Chapter 4. The interviews carried out in Chapters 4, 5, 6 and 6 all followed a similar structure. The names of the interviewee, company and professional athletes the company work with have been removed.

The researcher (Ni) questions are in bold. Interviewee (Ma) responses are in standard text.

Large sports company A transcript:

Ni: Where does your design brief normally come from?

Ma: Basically I'm working in the development team so within product development of any business unit, whether it's football, running, whatever, you've got three kind of core functions within that team. You've got a marketing team, a design team and a development team. So I'm part of the development team. Generally the design brief will come from the marketing team, so they've done a lot of research into, it could be anything from what different colours are trendy right now, what is trending the market, they do a lot of focus groups with kids. I mean our kind of target consumer group is 14-19 year olds so that's what we're always trying to go towards. So they'll do a lot of focus groups, a lot of market research to put together, it can be anything, so price, retail, technologies which are right now, storylines, is carbon popular, is neon popular, anything. So they basically gather all this information up. A big thing for us is obviously cost and of course we're a company that wants to make money but you've also got to put the products in the right price range. If you create a product and you say you're going to sell this for £150 and all the people that you're aiming it at are only willing to spend £80 then this needs to change. So this is also a big factor of it. In a very general term, the design brief comes from the marketing team.

Ni: And is that then given to you as a designer in a written document or is it a more verbal communication?

Ma: There's a calendar set up and we work on an 18 month calendar. And there's a period at the start of the season before you start the creation phase where marketing speak to the regions, countries and gather all the information, all the information from trend research and create briefs based on the needs of each individual runner. You build your range from low priced lines all the way up to very high price points, depending on where you're going to sell the product, what distribution channel you're in. So they create a brief and within that brief, you've got everything from the type of consumer that you're wanting to sell it to, you've got all the types in inspirational imagery that you would use to inspire the creation of the design, you've got your target price, you've got a whole list of requirements that we need to check off to make sure that the product will remain profitable even when it is created.

Ni: And do you all this yourself, it's all primary data that you collect? Or do you contract anyone else in to collect it?

Ma: Yes, it's all done by the marketing guys. I mean there's different types of marketing teams, so you've got marketing teams who are in the countries and they will give feedback to the global team and say this doesn't work well in Brazil or this works great in Germany so they're gathering all that information and then they have a design brief. Normally the design brief is quite detailed to the cost it will be sold at, how much money they want to spend on the product, the type of materials they want to use for a certain product and then at other times they leave it very open and they say we just want something new, something fresh, something cool and give us something. But in theory the starting point is coming from marketing.

Ni: In terms of information, user needs that the marketing team collect, do they collect it themselves, so it's the company that goes out and collects the data or do you get a third party in to collect it for you?

Ma: It's quite complex, there's a couple of different ways you could use. One you could just base it purely on what articles, what models are selling really well. So you can see in a season what's trending very well, what's not, so you do the analytics on that. The other approach is you're collaborating with trend and design agencies who are doing all the research predictions on what the future colours, trends, materials are going to be. And you use this to build your colour pallets for the new season. So the only external input you have is from that early stage of the creation process, from the colour and trend agencies. They kind of define throughout the whole industry what the key colour and trends are going to be. So all the big brands would use them, from fashion to sport. Anybody that is going to be doing fast consumer goods.

Ni: You're involved in designing footwear. Do you ever get users in to try out your product or assess how someone should move in them?

Ma: Sure, we go through a full analysis of the product during the creation process. I'm not a designer, I'm a developer, so the designer will create a 2D sketch of what we believe is a fresh concept along the marketing brief. And then from that, they'll sit down and work closely with me and my understanding of biomechanics, understanding of what the requirements are, the functional needs of each athlete and I then assess what they're handing over in terms of design. Through my experience I can then guide them on how to do things better to make sure you're not getting pressure points, etc. So then throughout the creation process you've got a few review stages. So when the shoe arrives at the first review stage, you do a full fit testing and wear testing program. You do a full quality program to make sure that the materials are ok. You bring in different types of athletes, so marketing might say this is fore foot focus, mid-foot focus, heel focus, and we want to make sure that the people testing this shoe is the desired consumer that we're trying to sell this product to. We can't put every single pair of shoes onto the high speed filming, onto the Vicon system, you can't put every single pair of shoes through the lab testing program, and you can't put every pair of shoes through the DET – Dynamic Evaluation Testing, where you are assessing our product and the competitors product, who you're competing against in the market. There's far too many shoes in the range so you choose a selection of really important shoes, brand statement shoes and you do the full program, the fit, the wear, the high speed filming, the lab testing, the DET testing to ensure that what you're communicating and you're standing for is going to be achieved.

Ni: Competitor products – do you evaluate them at the start?

Ma: Yeah, all the time. I mean with us there's not really a start and end point, you always work from season to season, meaning you've got a spring/summer season where all the products are launched in January and then you've got a fall/winter season where all the products are launched in June. So you're always working on season to season, but because there's only 6 months between them, there's always an overlap. So for example, we're finalising right now the spring/summer 2015 range, so we're putting all the final details on that but at the same time we're starting the fall/winter 2015 range. So before the products are on the market, we've already got a lot of market feedback based on that range, but it needs to be continued, it can't be stopped, it's a big wheel you know, you need to continue releasing products. So some of the spring/summer 2015 products will be on the market in January coming and they're already been evaluated with focus groups, with retailers, our key retail partners, with different marketing teams in other countries and they've already given the feedback. But the products will be released and then we use that feedback to influence the next season. And that's what we're really doing right now. So for example, maybe (I'm just making up an example here) we release a material for the upper of the boot and we already know that player's love it or player's hate it, then this is already influencing what we do in the next season.

Ni: Do you launch your products with the players first? Or is does it go to the players and come to market around the same time?

Ma: Players are very much involved in the development process but at different levels. So at the very early stages of a product, at the kind of product creation process, if it's aimed at a specific player, so take for instance XXX, then we'll take feedback at a very early stage. So what he likes, what he doesn't like, what he liked about the previous model, what he maybe didn't like about the previous model. We'll give him some ideas of where the range is going to go, maybe the graphics that are going to be applied, does he like that, does he not like it.

Ni: So he needs to like it and if he doesn't wear it then the kids aren't going to wear it.

Ma: Yeah, I mean contractually he needs to wear it, you know if he doesn't wear it then he's in big trouble, but one of the things so take for instance his XXX logo, which is built out of the three stripes. So on some of the very first products the "XXX" was only on the inside of the shoe, but he then specifically said, no I want it on the outside of the shoe so then people know it's definitely his product. So little things like that, I know this is a small detail but he might say he likes a particular stud shape or he doesn't like a particular type of stud shape, or he maybe likes a particular type of upper material or he maybe didn't like a previous upper material. He's one of those guys, he really goes into the details of how he likes the inside of the boot to feel and how he likes the stitching over the top of the boot. So he's got a specific requirement that he likes. And then for his particular range, we try and build that into the product.

Ni: It all feeds into the brief.

Ma: Yes, exactly. Or at least we get that feedback in the early stages. But in other cases, so just recently, we launched the first ever knitted boot, so the whole boot was made of knitted material and because it was such a new concept, we went the professional players at a later stage, because the idea initially came from the running shoe. So we've got our prime knit running shoe, which is a kind of technology using knitting machines. The idea came because the knitted upper feels amazing, I mean you don't feel any seams. And basically the idea was how do you get that on a football shoe. So we actually spent three months just looking at the knit structures and looking in the lab, building up different prototypes and the main goal was to try and control the stretch of the material because that was our big concern. With the running shoe, it's got a little bit of stretch to it, I think it's about 70% stretch. And we wanted to go below 30% stretch because football's a multi directional sport, whereas running is more a linear sport. So we did a lot of work inside the lab to try and control this stretch. Once we had something that we thought worked, we made it into a shoe and then we did player testing. But again, the player testing was only local players. So the thing about Germany is, it's really a unique place where you've got a lot of semi-professional teams within 100km of the company. So the way they set up their league structures, basically if you're playing in 4th, 5th or 6th league in Germany, you're semi-professional, you get paid. And there's a lot of those teams around the company, so we take it to them first to get their feedback because A. we know they're going to wear it and B. we're going to get a lot of hours on the shoe, meaning a lot of testing time. And then once we're happy with the performance of the product, then we took it to XXX at that time. He was the guy who actually wore it and he wore it against XXX a couple of weeks ago. But on something completely brand new in that case, then we would tend to take it to the professional players later because you don't want to give them a bad impression of the product. You want to take it to them that you're actually confident that the product works. Not taking them something that doesn't work and them be like I don't want to wear this ever. So there's a different approach to it. But something that we know, like the XXX example, we'll try and get his feedback as early as possible.

Ni: So what would you say are the core stages to your typical design process?

Ma: I'll draw it for you…

So there's really only 10 months development and then the product goes into the commercialisation phase. So key stages would be colour and trend research, marketing brief, design phase, concept finalisation. And it starts, if I take this year for example, it starts in January and the first review (and when we say the first review, I mean with senior management) is April. So we've literally got 2.5 months and again within the core team, so the marketing guy, the design guy and the development guy, we're working together. So designers creating designs, we're creating mock-ups, prototypes, marketing will take the early samples to maybe some young kids and ask what do you think, we'll make refinements, etc. And then at the first review stage, it's literally sketching, it's basically a strategy – this is something like the product's going to look like, these are the type of materials we're going to do, this is the type of construction and this is how it could look to the outside world. Next would then be tech pack creation you call it, so once you've finalised the concept between marketing, design and development, design the go back and start detailing everything out so they can do a proper handover to ensure that we can get the products created in China. The next stage is then China travel, where the whole team travel over to China to revise and really hone in on the final details and let the factories know exactly how we want this created. So you've got a technical pack handover, which include information on the way that the upper part of the shoe, the lower part of the shoe is going to be created, what materials would be used and what details are necessary for us to hand over to our development team in China. So that's the technical pack creation. And then after that it would be concept review 1. So concept review 1 is when all of the range arrives from China and we do a full evaluation of the product in terms of quality, costing, design, function, everything, testing. After that is concept refinement, after that would be China travel – after the concept refinement you go back to China again and really get closer to the finished product. After that we have CR2 – concept review 2. You might be better there where I said concept finalisation – change that to CR0, concept review 0, which means the actual concept finalisation where the concept is confirmed, because you don't actually have any shoes on hand at this point, this is all from sketches and renders from the design team. So you've got CR0, CR1 and CR2, I'm just trying to make it clear for you with what happens at each stage. So for concept finalisation, put in brackets CR0 (*edits made on* *mapping of the design process*). So now we're up to China travel after CR1. So concept review 2 again you go through the whole evaluation of costing, quality, testing, design, stylisation, function, etc. and then one final concept refinement. The next stage would then be sales sample, this is where we send out shoes to the various markets around the world and sales give us an opportunity to show to the key retailers to get their buy into the product and we can then start promoting what we're doing. After that we have an initial evaluation stage – call it confirmation stage 1 – where you're really starting to hand over to the factory. So they take full responsibility. So before confirmation stage 1 – actually change that to commercialisation stage 1 – at that point there that is where the factory start taking the lead on the product and they start trying to figure out how they can manufacture this across multiple sizes, because with shoes, you do all your initial development in size 8.5 for men or size 5.5 for women and at that stage, CS1, the factory have to start figuring out how to roll this out for the full size run, about mould openings, about size relationship with suppliers to make sure they can deliver the right materials in the right colours on time. You go through all the final quality checks to make sure it's ready for production. So that's what happens at CS1. After commercialisation stage 1 is commercialisation stage 2. Again it's a factory refinement process, getting costs for final production and after commercialisation stage 2 you've then got opening your full size run, and what I mean by that is opening your full set of moulds needed for your full range of pairs from size 3.5 through to size 14.5, so multiple moulds need to start being opened. And after that it's production start and then after production start, you've got retail introduction. And that's a full 18 month program.

Ni: So going back to the start, you went through colour and trend research, market brief, the initial design phase – is that all designers sitting down, sketching ideas out, brainstorming and coming up with the general appearance of the product?

Ma: The design phase is kind of like a 8-10 week phase after they've been given the marketing brief. Even before they've been given the marketing brief because not everything's designed around the brief because sometimes you might be inspired from elsewhere, marketing haven't seen an opportunity and maybe you sometimes overlook what the marketing brief is and you start going after a new concept because you feel very strongly about it. I think that kind of creative freedom is important because you can't always be bound by the rules. But in general that design creation phase is about a 8-10 week opportunity to sketch multiple ideas and then sit as a team, they call it a tri-am team, which is marketing, design and development and we discuss the sketches and again you go through this refinement process up until CR0. And then at CR0, we make a final call on what sketch or idea will move forward based on all of the feedback from the team. So development from my side, I've got to ensure that the shoe can be made on cost, that the actual athlete is going to be able to get the experience that is required, ensure the shoe is actually manufacturable in the timeline that we've been given, so I basically look at project management, making sure that everything is in place to get the shoe on the shelf for retail introduction.

Ni: So that takes you through from concept generation, detailed design through to launch. What sort of methods, iterations, prototyping, testing feeds into the detailed design phase?

Ma: It can be anything, so first of all from the development side, we're always looking at new materials, so we're trying to find new materials, new processes and we, from our side might also create a prototype based on an idea of a material and we might then give it to design and marketing and say guys what do you think of this? But at these early stages, the products are never fully refined. So it's more how it looks, how high is it, what does the shell pattern look like, how does it feel in terms of on the foot. But you've always got to remember it's not a refined prototype so it's quite a rough mock up. We still do them in Asia. In theory you can play in them, but they're not the finished article. And it's only once we've got this feedback from senior management or the market or focus groups, that's when we really start refining and we start testing.

Ni: Whereabouts does your biomechanics testing come in? You obviously need a product at that point.

Ma: Exactly, so as I said you go to China and then after the shoe's arrived at CR1, CR1 is when you start doing your biomechanical analysis because that's the first real shoes that arrive.

Ni: And is there then design refinement after that if you need to refine things or optimise things slightly?

Yeah, so you go through CR1, then refinement, then you go back to China and finalise things again and then the shoes come back to CR2, you go through the whole biomechanics testing again, through quality testing again you've got another refinement process and then yeah that's it.

Ni: It's obviously quite an iterative process between testing, refining, taking it back to China, testing it again. You've got in 2 full iterations. Is that normal or do you sometimes only need the one or do you go as many as 3 or 4, does it change much?

Ma: It can do. It's a flexible process at the end of the day, you've still got to ensure that the shoe arrives on the shelf on time, because you've got commitments to all of your markets, you've got commitments to how you're going to communicate your product, what you've created in terms of advertising, so there's deadlines to be met. On some occasions, yes you can finalise the product after one round of design and testing and validation, sometimes it takes three runs because it's a really important brand statement product, so there's a lot of people getting involved, so you've got the politics of it as well, where people say they don't like that, you've got to change that. Or maybe the biomechanics team point blank refuse to allow it to move forward because it's just not fulfilling the needs so they overhaul the third stage because it's just too risky for the brand to release a product that's not biomechanically correct. But traditionally its two iterations in terms of biomechanics testing. Sometimes you're lucky and you only need one, sometimes you're unlucky and you need to do it three times.

Ni: In terms of the athletes that you get in, do you target the professional or recreational athlete with a normal style or do you design for the abnormal or less experienced users as well?

Ma: In general you design for the everyday athlete because 80% of the people buying our products are the everyday athlete. It's not like professional. Bu we do have range segmentation where we do have a particular range of shoes that is more focused at the elite athlete. So we test it with everyone from XXX, XXX, XXX, whoever we sponsor, we work very closely with them to ensure we hear their needs. And we also work with national level athletes and club level athletes because we're not making custom shoes for our top athletes. Whatever you buy, and that's one of our policies that we're quite proud of and like to stand by, is that the shoes that you see elite athletes wearing, you can buy the exact same product. Of course, there are some elite athletes where we have to do some custom programs in terms of footfall or certain efficiencies that they have, but in general we cater towards your average runner when making shoes.

Ni: How do you eventually decide – you've done your multiple design refinements, your trips to China, you then get to the sales and commercialisation phase, do you have a set criteria or benchmarking that the product has to meet and you then say that you're going ahead with the product? How do you decide that that is the product that you are going to run with?

Ma: We have a retail introduction.

Ni: And if they like it then that's it?

Ma: Well if they don't like it you pull it off the market or if there's a massive problem, you pull it off the market and you push out retail introduction to deal with the issues. But in general with an 18 month calendar, you have the time needed to make the product as close to perfect as you can. There's no such thing as a perfect running shoe because you've got so many different gait characteristics – you've got different foot types, leg lengths, there's so many different variations, how people land, strike, move. There's no such thing as the perfect running shoe – everyone is different. You get 75% heel strikers, you get whatever % midfoot strikers, some fore foot strikers – all do very different thing, so it's a very complex part of the anatomy the foot. So you need to respect that and do what you think is right. So biomechanically we always get as close as we can to what is right and at the same time if it's a stylistic issue then that's something that can be modified a lot more easily than something that's going to affect biomechanically at a later stage of the creation process.

Ni: So what's your main emphasis on in terms of time and effort?

Ma: I would say from the starting point up until the first review. But I would say that from January to June we want the product finished, we want the product to be almost signed off. From June to October, it's really just aesthetic development. Of course there might be some performance updates like we might have some problems with a material and we might need to switch it, but in theory this early development stage is where everything happens and this later stage is more minor updates. This is the stage where XXX will come in and say I want my logo on the outside rather than the inside, but earlier is where he's giving us more performance feedback and later is the commercialisation phase and mass production.

Ni: So all the testing that happens earlier in the process, is that all durability, etc.

Ma: Yeah, wear testing. We've actually got three testing phases. We test during design refinement, at stage 2 and at product sign-off. But testing during design refinement is the critical one where we actually look at the performance of the product, it's got to work. So during design development, this is where all the prototypes, all the analysis happens. It might be that later on we find a slight problem and we have to change it. This is a very general process.

Ni: It will vary between products.

Ma: Everyone always asks what's the starting point of an idea or what's the starting point of a product. It might be market feedback, it might be a design or it might be a material that development have come up with. It depends. We've got an innovation team, so if we're starting in January then the innovation team are starting even earlier. Sometimes they're just delivering concept ideas for a certain product, sometimes it's a specific technology that you can put in three or four different shoes. It might be a new material, but at the moment these guys are spread across footwear, apparel and balls. So sometimes they're working on a ball concept, the next time on an apparel concept and the next time a footwear concept, so it really depends. A big thing as well is costing in the design refinement stage. That's a big thing. You want to make sure that you're going to sell it.