Chapter 5
Design for Sustainability: An Introduction

Historically, the reaction of humankind to environmental degradation, especially since the second half of the last century, has moved from an end-of-pipe approach to actions increasingly aimed at prevention. Essentially this has meant that actions and research focused exclusively on the de-pollution of systems have shifted towards research and innovation efforts aimed to reduce the cause of pollution at source.

In other words, the changes have been from: (a) intervention after process-caused damages (e.g. clean up a polluted lake), to (b) intervention in processes (e.g. use clean technologies to avoid polluting the lake), to (c) intervention in products and services (e.g. design product and services that do not necessitate processes that could pollute a lake), to (d) intervention in consumption patterns (e.g. understand which consumption patterns do not (or less) require products with processes that could pollute that lake).

Due to the characteristics of this progress, it is evident that the role of design in this context has expanded over time. This increasing role is due to the fact that: the emphasis shifts from end-of-pipe controls and remedial actions to prevention; the emphasis expands from isolated parts of the product life cycle (i.e. only production) to a holistic life cycle perspective; the emphasis passes further into the sociocultural dimension, into territory where the designer becomes a 'hinge' or link between the world of production and that of the user and the social/societal surroundings in which these processes take place; and the emphasis widens towards enabling users' alternative and more sustainable lifestyles.

Within this framework, the discipline of **Design for Sustainability** has emerged, which in its broadest and most inclusive meaning could be defined as:

a design practice, education and research that, in one way or another, contributes to sustainable development[1]

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[1]Some authors adopt a more stringent definition of Design for Sustainability: e.g. Tischner [113] argues that Design for Sustainability requires generating solutions that are equally beneficial to the society and communities around us (especially unprivileged and disadvantaged populations), to the natural environment, and to economic systems (globally but especially locally).

5.1 Evolution of Design for Sustainability

Design for Sustainability has enlarged its scope and field of action over time, as observed by various authors [23, 56, 93, 98]; Vezzoli and Manzini [20, 120]. The focus has expanded from the *selection of resources with low environmental impact* to the *Life Cycle Design* or *Eco-design* of products, to *designing for eco-efficient Product-Service Systems* and to *designing for social equity and cohesion*.

5.2 Product Life Cycle Design or Eco-Design

Since the 90s, attention has partially moved to the product level, i.e. to the design of products with low environmental impact. This attention was initially focused on redesigning individual qualities of individual products (e.g. reducing amount of material used in a product, facilitate disassembly, etc.). These early attempts to integrate environmental sustainability in product design go under the label of *green design* e.g. see [11]. It was only later, especially in the second half of the 90s, that this design approach broadened to systematically address the entire product life cycle, from the extraction of resources to the product end-of-life. This is usually referred as *product Life Cycle Design*, *Eco-design* or *product Design for Environmental Sustainability* [58]; [10, 75]; [112]; Hemel [44, 45]; ISO 14062 [50]; [99, 110]; Nes and Cramer [87]. In those years, the environmental effects attributable to the production, use and disposal of a product and how to assess them became clearer. New methods of assessing the environmental impact of products (the input and output between the technosphere, the geosphere and the biosphere) were developed; from among them, the most accepted is Life Cycle Assessment (LCA). In particular, two main approaches were introduced.

First, the concept of *life cycle approach*—from designing a product to designing the product life cycle stages, i.e. all the activities needed to produce the materials and then the product, to distribute it, to use it and finally to dispose of it—are considered in a holistic approach.

Second, the *functional approach* was reconceptualized from an environmental point of view, i.e. to design and evaluate a product's environmental sustainability, beginning from its function rather than from the physical embodiment of the product itself. It has been understood that environmental assessment, and therefore also design, must have as its reference the function provided by a given product. The design must thus consider the product less than the 'service/result' procured by the product.

In the late 90s design researchers also started to look at nature as a source of inspiration to address sustainability. One of these approaches is known as Cradle to Cradle (C2C) design [78], whose main principle 'waste equals food' focuses on creating open loops for 'biological nutrients' (i.e. organic materials) and closed loops for 'technical nutrients' (i.e. inorganic or synthetic materials). Different from

product Life Cycle Design, C2C is mainly focused on the products' flow of material resources, and this might result in overlooking some other (and potentially more important) environmental aspects (e.g. energy consumption in the use phase).

As highlighted by Ceschin and Gaziulusoy [20], although product Life Cycle design focuses on the whole life cycle, this is mainly done from a technical perspective, with limited attention to the human-related aspects. Starting from the late 90s, design researchers started to address this issue by exploring design approaches that could complement product Life Cycle design. In particular, *emotionally durable design* [21, 22, 85, 117] focuses on the user-product emotional connection and proposes design strategies to strengthen that connection in order to extend product lifetime. On the other hand, *design for sustainable behaviour,* e.g. Lilley [64], [5], Lockton et al. [66] focus on the effects that users behaviour can have on the overall impact of a product, and on how design can influence users to adopt a desired sustainable behaviour and abandon an undesired unsustainable behaviour.

5.3 Design for Eco-Efficient Product-Service Systems

Even if it is true that the design approaches mentioned in the above section are fundamental to reduce the environmental impacts of products, from the end of the 90s we started to realise that a more stringent interpretation of sustainability requires radical changes in production and consumption models. For this reason, attention has partially moved to *design for eco-efficient Product-Service Systems*, a wider dimension than designing individual products alone [6, 9, 23, 25, 65, 74, 125]. From among several converging definitions, the one given by the United Nations Environment Programme [114] states that a Product-Service System (PSS) is 'the result of an innovative strategy that shifts the centre of business from the design and sale of (physical) products alone, to the offer of product and service systems that are together able to satisfy a particular demand'. In this context, it has therefore been argued [122] that the design conceptualization process needs to expand from a purely *functional approach* to a *satisfaction approach*, in order to emphasise and to be more coherent with the enlargement of the design scope from a single product to a wider system fulfilling a given demand related to needs and desires, i.e. a *unit of satisfaction.*[2]

Some design researchers have also proposed to adopt a territorial approach, looking at local socio-economic actors, assets and resources with the goal of creating synergistic linkages among natural and productive processes [2]. This approach has been labelled as *systemic design* [7, 8], and seeks to create not only

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[2]This approach is further elaborated and declinated to the design of S.PSS applied to DRE as discussed in the first part of the book.

industrial products or S.PSSs but complex industrial systems, where material and energy flows are designed so that output from a socio-economic actor becomes input for another actor.

5.4 Design for Social Equity and Cohesion

Finally, design research has opened discussion on the possible role of *design for social equity and cohesion* [28, 76, 92], Mance [70], [13, 43, 73, 93, 121]; Carniatto and Chiara [14]; [33, 63]; Maase and Dorst [67]; [89]; Tischner and Verkuijl [111]; [27, 124]; dos Santos (2008); [122]. This potential role for design directly addresses various aspects of a 'just society with respect for fundamental rights and cultural diversity that creates equal opportunities and combats discrimination in all its forms' [35, 36]. Moreover, several writers and researchers urge a movement (and a key role for design) towards harmonising society such that it is not only just and fair but also that people are encouraged to be empathic, kind and compassionate for the benefit of others [38]; Rifkin (2010). We can indeed observe new, although sporadic, interest on the part of design research to move into this territory, to trace its boundaries and understand the possible implications.

Some researchers have adopted a bottom-up approach and investigated how people and communities innovate to address their own daily problems. 'Creative communities' [80] is an often used term to highlight the inventiveness of these ordinary people and communities (sometimes in collaboration with other local institutions, organisations and entrepreneurs) in designing, implementing and managing social innovations [53]. Typical examples include new forms of exchange and mutual help, community car-pooling systems, food networks linking consumers directly with producers, etc. Researchers in the field of *design for social innovation* have been exploring the characteristics of these innovations and the role of professional designers can play in supporting, promoting and scaling-up these community-based innovations, e.g. see [71].

Some authors have also focused on understanding how design can address social and environmental issues faced by people in low-income context, i.e. *design for the Base of the Pyramid* (*BoP*). The initial emphasis has been on product design for BoP, e.g. UNEP [26, 115]; dos Santos et al. (2009). More recently, the design research focus on BoP has moved to S.PSS, e.g. see [84]; Schafer et al. [102]; Jagtap and Larsson [51]; dos Santos [101], and social entrepreneurship and innovation, e.g. see [81]; Cipolla et al. [24].

Other authors [103, 122] have argued that a promising approach would be that of Sustainable Product-Service Systems (S.PSS) design for social equity and cohesion, or more shortly, System Design for Sustainability. This issue of Sustainable Product-Service System design for social equity and cohesion is described in the following chapter as in relation to the design of sustainable energy system accessible to all.

Nowadays, design for SE4A necessarily includes the issue of access to affordable, reliable, sustainable and modern energy for all, which UN has described in the

Sustainable Development Goals. In accordance with what was said before, design of S.PSS applied to DRE is called SD4SEA and it will be described in following sections.

5.5   Design for Socio-Technical Transitions

More recently, we understood that the challenge is not only to design sustainable solutions but also to identify which strategies and pathways are the most appropriate to favour and speed up their introduction and scaling-up [18, 20]. It has become in fact clear that some sustainable innovations (e.g. sustainable Product-Service Systems or sustainable social innovations) involve fundamental changes in culture, practice, institutional structures and economic structures, and thus they may cope with the current and dominant socio-technical systems [95]. For these reasons, a handful of design researchers have started to build upon system innovation and transition theories, e.g. see [41]; Kemp et al. [57, 94], to explore how design can address this issue. This resulted in an initial body of work exploring [20]: the development of a theory of design for system innovations and transitions [40]; how to design socio-technical experiments and transition paths [16, 18]; the connections between S.PSS design and system innovation theories [17, 19, 54, 55]; the importance of designing a multiplicity of interconnected and diverse experiments to generate changes in large and complex systems [52, 72, 79, 97]; the development of a curriculum on transition design for the first time Irwin et al. [49].

5.6   State of the Art of Design for Sustainability

Looking at the evolution of Design for Sustainability, it clearly emerges that there has been a widening in the scope of action. In particular, a number of considerations can be made [20].

First, DfS has broadened its theoretical and practical scope progressively expanding from single products to combinations of products and services to complex systems.

Second, this has been accompanied by an increased focus on the 'people-centred' aspects of sustainability. In fact, the first DfS approaches (e.g. see green design, eco-design, Cradle to Cradle) have predominantly focused on the technical aspects of sustainability. On the other hand, more recent approaches have recognised the crucial importance of the role of users (e.g. see emotionally durable design, design for sustainable behaviour), communities (e.g. see design for social innovation) and social dynamics in socio-technical systems (e.g. see design for system innovation and transition).

Third, a consideration can be made on the importance of each DfS approach. Even if it is true that sustainability must be addressed at a socio-technical system

level, this does not mean that the approaches focusing at the product innovation level are less useful than systemic approaches. New socio-technical systems are anyhow characterised by a material dimension that needs to be appropriately designed using product innovation DfS approaches. Thus, each DfS approach is equally important because 'addressing sustainability challenges requires an integrated set of DfS approaches spanning various innovation levels, from products to socio-technical systems' [20].

5.7   Human-Centred and Universal Design

Introduction

This section discusses the importance of universal design and human-centred design approach in designing products, services, systems and environments. The aim is to design products, services, systems and environments that are usable, useful and desirable to a broad spectrum of people without the need for specialised designs for disabled users. The two approaches advocate for the concept of designing with diverse users with diverse characteristics rather than designing for users. That is, users are placed at the centre or core of all design activities. When universal design and human-centred design principles are applied, products, services, systems and environments meet the needs of potential users with a wide variety of characteristics. This can only happen when users are made active participants in the design process, and the possibility of their needs, interests and wants to be encoded in the final design are high and this may lead to the design to be accepted by many users without the need for adaptation or specialised design. The goal of universal design and human-centred design is to place a high value on diversity, equality, and inclusiveness of users when designing products, services, systems and environments.

Universal design

Universal design refers to a design approach that strives to ensure that products, services, systems and environments are usable by the broadest possible spectrum of people, without the need for adaptation or specialised design. When universal design principles are applied, products, services, systems and environments meet the needs of potential users with a wide variety of characteristics such as disabled or non-disabled, age, gender, capabilities or cultural background [12]. Universal design increases the potential for developing a better quality of life for a wide spectrum of users. Steinfeld and Maisel [106]; Petrie et al. [90] argue that it creates products, places and systems that reduce the need for special accommodation and many expensive hard to find assistive devices. The authors also advance that it reduces the stigma by putting users with disabilities on an equal playing field with non-disabled population. It also supports users in being self-reliant and socially engaged.

Universal design process

Burgstahler [12] proposed the following universal design process:

1. *Identify the application*—specify the product or environment to which you wish to apply universal design.
2. *Define the universe*—describe the overall population (e.g. users of service, product and system) and the diverse characteristics of the potential users of the design.
3. *Involve consumers*—involve users with diverse characteristics in all stages of the development, implementation and evaluation of the design.
4. *Adopt and apply guidelines or standards*—select existing universal design guidelines/standards and integrate them with other best practices in a given field.
5. *Plan for accommodation*—develop processes to address accommodation requests from users for whom the design does not automatically provide access.
6. *Train and support*—tailor and deliver constant training and support to stakeholders with respect to diversity, inclusion and practices that ensures accessibility, and inclusive of all users.
7. *Evaluate*—include universal design measures in periodic evaluations of the design, with a diverse group of users, and make modifications based on users' feedback.

Principles of universal design

According to the Centre of Universal Design [15], Ron Mace, Jim Mueller, Abir Mullick, Bettye Rose Connell, Mike Jones, Jon Sanford, Elaine Ostroff, Molly Story, Ed Steinfeld and Gregg Van der heiden collaborated to establish the principles of universal design to guide a wide range of design disciplines including environments, products and communications. This working group of architects, product designers, engineers and environmental design researchers proposed seven principles of universal design that can be applied to evaluate existing designs, guide the design process, and educate both designers and consumers about the characteristics of more usable, useful and desirable products, services and environments. The Centre of Universal Design [15] outlined the seven principles and guidelines of universal design, which are as follows:

1. **Equitable use**—the design is useful and marketable to people with diverse abilities.

   Guidelines:

   - *Provide the same means of use for all users: identical whenever possible; equivalent when not;*
   - *Avoid segregating or stigmatising any users;*
   - *Make the design appealing to all users.*

2. **Flexibility in use**—the design that accommodates a wide range of individual preferences and abilities.

Guidelines:

- *Provide choice in methods of use;*
- *Provide adaptability to the user's pace.*

3. **Simple and intuitive use**—use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.

Guidelines:

- *Eliminate unnecessary complexity;*
- *Be consistent with user expectations and intuition;*
- *Arrange information consistent with its importance;*
- *Provide effective prompting and feedback during and after task completion.*

4. **Perceptible information**—the design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.

Guidelines:

- *Use different modes (pictorial, verbal, tactile) for redundant presentation of essential information;*
- *Provide adequate contrast between essential information and its surroundings;*
- *Differentiate elements in ways that can be described (i.e., make it easy to give instructions or directions).*

5. **Tolerance for error**—the design minimises hazards and the adverse consequences of accidental or unintended actions.

Guidelines:

- *Provide fail safe features;*
- *Discourage unconscious action in tasks that require vigilance.*

6. **Low physical effort**—the design can be used efficiently, comfortably and with minimum fatigue.

Guidelines:

- *Allow user to maintain a neutral body position;*
- *Minimise sustained physical effort.*

7. **Size and space for approach and use**—appropriate size and space is provided for approach, reach, manipulation, and use, regardless of user's body size, posture, or mobility.

Guidelines:

- *Provide a clear line of sight to important elements for any seated or standing user;*
- *Make reach to all components comfortable for any seated or standing user.*

The application of universal design in education is apparent in the following areas: Human-centred design, universal design for learning, universal design for instruction and universal design for education. In this chapter, the focus will be on human-centred design as it is more relevant to the overall objectives of Sustainable Energy for All by design.

Human-centred design

When we dream alone, it is a dream. When we dream together, it is no longer a dream, but the beginning of reality [29].
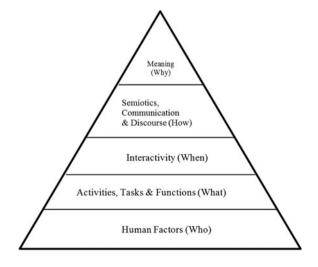
This section discusses the concept of human-centred design as the process puts the user at the pinnacle of all design activities. This process is referred to as human-centred because it starts and end with the people one is designing for. The human-centred design process encourages the concept of designing with users rather than designing for users. The process commences by probing the needs, interests and behaviours of the users affected by the problem by listening and understanding their real needs. Human-centred approach contribute to innovation in design, increase productivity, improve quality, reduce errors, improve acceptance of new products and reduce development costs. This approach to design and development aims to make products, services and systems more useful, usable, pleasurable and cherisable. Some designers in new emerging economies have not yet embraced this approach in their practice, resulting in products, services or systems that do not respond to user's social, physical, emotional and cultural needs. Despite the advantages offered by this approach, it also has some limitations that need to be taken into consideration at the conceptual design stages. In this chapter, the authors opted to use the term human-centred design instead of user-centred design because the former suggests a concern for people, while the latter suggests a limited focus on people's roles as users.

Human-centred design is a methodology that puts users at the centre of the design process. It is an approach based on the needs and interests of users with special attention to making products, services or systems usable and understandable. Human-centred design is based on the premise that design is meaningful only when the focus of its activities and outcomes accommodate the largest possible number of people inclusive of their diversity [83]. It focuses on how people actually interact with specific products, services and systems, and designed environments, rather than prioritising the product form and appearance. IDEO [47] define human-centred design as a process and technique that create new solutions (products, services, systems, organisations, environments and modes of interaction) for the world. Human-centred design is an approach for designing products, services and systems, which are physically, perceptually, cognitively and emotionally intuitive [42]. Furthermore, the authors argues that the approach goes beyond the design's traditional focus on the physical, emotional and cognitive needs of users, and encompasses social and cultural factors. From these varied definitions, it is proposed that human-centred design is a multidisciplinary approach which is driven

by users' needs and expectations, and at the same time involves users at every stage of the product development process in pursuit of creating useful, usable, engaging, pleasurable and desirable experiences. It has been noted that the above definitions emphasise the quality of the relationship between the person who uses the product to achieve some result and the product or service itself. The fundamental features of this relationship are effectiveness, efficiency, satisfaction and pleasure. The user-focused design concept, according to Stoll [107], has two characteristics: it satisfies people's needs in the most optimal way and it is superior to all competitive products, services and systems with respect to the design's characteristics.

The primary objectives of human-centred design, as argued by Rouse [96], are that: (a) the design should enhance a human ability, that is, user interests should be identified, understood and cultivated; (b) it should help overcome human limitations, for example, errors need to be identified and appropriate compensatory mechanisms devised and (c) it should foster user acceptance, that is, user preferences and concerns should be explicitly considered in the design process.

Figure 5.1. shows a human-centred design pyramid model proposed by Giacomin [42] which illustrates a journey from the more physical and physiological questions to the metaphysical questions. The model shows a hierarchy of human physical, perceptual, cognitive and emotional characteristics, followed gradually by more multifaceted, interactive and sociological considerations [42]. The model is made up of factors ranging from the physical nature of a user's interaction with the product, system and service to the metaphysical. The metaphysical meaning involves users forming their interpretation of the system, product and service based on its interaction with users. The metaphysical meaning is of paramount importance to social acceptance and commercial success. Giacomin [42] further argues that the designs whose characteristics answer questions which are high in the pyramid would be expected to offer a wider range of affordances to people and to embed themselves deeper within the user's culture.

Fig. 5.1 Human-centred design pyramid. *Source* Giacomin [42]

Human-centred design process

This study has adopted to use the human-centred design process in tackling complex energy challenges in new emerging economies. This approach was adopted because it can assist entities to connect better with the local people affected or dealing with energy issues. It can transform field data into actionable ideas, assist the team to find new opportunities and help to increase the speed and effectiveness of creating new solutions [47].

There are many models that represent the human-centred design process such as participatory design, ethnography, lead user approach, contextual design, co-design, co-creation and empathic design [62, 109, 119]; Beyer and Holzblatt [4]; Bennette [1, 3, 100]; EPICS [34, 47]; Steen et al. [105]. 'All the human-centred approaches have human beings in the process, involve users throughout the design process and seek to understand them holistically' [126]. Zoltowski et al. [127] state that it includes multidisciplinary collaboration to make products, services and systems useful, usable and desirable. In addition to the aforementioned, Krippendoff [61] identified the following features: (a) human-centred design employs both divergent and convergent thinking, (b) the process is concerned with how stakeholders attribute meaning through the use of the proposed design and (c) it includes the development of prototypes for the stakeholders to test their design ideas. According to the *International Organisation for Standardisation* 9241–210 [48], the human-centred design has six characteristics:

- The adoption of multidisciplinary skills and perspectives;
- Explicit understanding of users, tasks and environments;
- User-centred, evaluation-driven/refined design;
- Consideration of the whole user experience;
- Involvement of users throughout the design and development process and it is an iterative process.

This activity comprises the evaluation plan, data collection and analysis, reporting the results and making recommendations for change. One should iterate this activity until the usability and cherishability objectives are met.

One of the most widely used human-centred design models in tackling complex, wicked challenges, was developed by IDEO. IDEO's human-centred design process commences with a specific design challenge within a given context. The continuum of user involvement ranges from informative, through consultative and to participative Zoltowski et al. [127]. The process then goes through three main phases: Discover, Ideate, and Prototype.

  i. **Discover**—*I have a challenge. How do I approach it? Who do I talk to?* This phase involves getting out into the world and learning from local people. The design team conducts field observational research by collecting stories and inspirations from the people.
 ii. **Ideate**—*I learned something. How do I interpret it?* The design team conducts workshops and narrows down what has been learnt during the fieldwork, and translating those into themes, patterns and opportunities. During this phase, the

       design team moves from concrete to more abstract thinking in identifying themes and opportunities, and then back to the concrete with solutions.

iii. **Prototype**—*I have an Idea. How do I build and refine it?* This phase involves rapidly evolving the design team's ideas into tangible designs based on real feedback. It also involves launching or implementing the proposed solution in the context it was designed to solve.

    The participation of users is the main strength of human-centred design as they provide insight into the problem and this enhances the acceptance of the end product [69]. The approach requires that users should be actively involved throughout the design and development life cycle. Above all, this calls for designers to conduct immersive user research by watching users carrying out tasks in their own environment and asking open-ended questions about their actions, thoughts and feelings. This process is often accompanied by interviewing and video-recording users in their social context for later analysis and presentation to the design team.

    The design team should be multidisciplinary, thus taking into account all knowledge and expertise required to produce a usable and pleasurable product or service. The cross-functional team might include all the relevant stakeholders who are directly or indirectly affected by the identified problem. The purpose of the team approach is to ensure that all needed information is readily available, as design decisions are made throughout the course of the project. Cross-functional teams are viewed as enhancing design creativity due to cross-fertilisation of thought processes, behaviour and functional skills. This team approach allows the development process to occur in non-linear iterations that bounce back and forth between disciplines, so that design decisions are fully informed. Such an approach provides a unifying framework and at the same time reduces the wastage of conflicting initiatives.

Consideration of sociocultural needs in human-centred design
Most designers tend to ignore the users' sociocultural needs when applying the human-centred design process in new emerging economies context. The evolution of design practice beyond ergonomics and human factors has been highlighted by Maguire [69], who argued for the need to identify stakeholders and contexts of use, and to apply creative processes. Gasson [39] highlights that 'user-centred system development methods fail to promote human interests because of a goal-directed focus on the closure of predetermined, technical problems'. The development of recognising the context and its people facilitated the probing, classification and description of the interactions, which occur between users and their environments and which has resulted in using personas and scenarios to provide a basis for describing users and contexts [86].

    Users' culture is fundamental to the development of any new product or service as it plays a role in the acceptance of the product, service or system. Moalosi et al. [83] also argue that designs conceived from a sociocultural perspective may provide users with cultural meaning which facilitates their acceptance. Response to products often produces a mixture of intrinsic and extrinsic meaning. Products, services or

systems are no longer seen only as functional objects, but they are seen for what they symbolise: their meaning, association and involvement in building a user's self-image. Therefore, the user's sociocultural needs should be considered in the early stages when the design is still relatively fluid and this provides a deeper insight and analysis of users' culture. It is envisaged that this type of design will lead to the creation of quality user cool experiences that add symbolic value to products, services or systems and to users' lives. This can also assist designers on how to create or design value, and to think of culture as a design resource. Krippendorff [60] sums it by saying, any design activity should identify the meaning which the product, service or system should offer to people.

Therefore, the field of human factors should extend beyond the usual physical and cognitive fit between products, services or systems and users, to embrace social and cultural considerations, personal needs, desires and aesthetic responses [104]. It is observed that human-centred design invites users to the design table, where they have traditionally been excluded. It seeks to bring the user closer to the designer, often reducing the step function of market research, which has tended to act as a barrier between the designer and the user [108]. In view of all these, the designing activity has been reshaped because it implies that ordinary people can contribute to the design process from the start. This methodology involves users in data gathering instead of relying on the designer's assumptions and experiences. The designer's perception has not been discredited, but only relocated to a more appropriate position. It can now be used to develop tools for understanding and facilitating creativity.

Human-centred design tools

The human-centred design toolbox techniques at times borrows from the fields such as psychology or sociology and sometimes those that emerge from design and engineering practice [30, 31, 42, 46, 116]. Human-centred design tools can be classified based on their intended use. The basic tools consist of facts about people such as anthropometric, biomechanical, cognitive, emotional, psychophysical, psychological and sociological data and models [42]. Such data often include materials on ergonomics or human factors which provide information about the abilities and limitations of users. Other tools consist of techniques for interacting with users to facilitate the discovery of meanings, desires and needs, either by verbal or non-verbal means. These techniques include ethnographic interviews, questionnaires, focus groups, participant observation and body language analysis. Table 5.1 summarises the human-centred design tools and the design phases that can be used.

Benefits and limitations of human-centred design

The benefits of usable and pleasurable products, services or systems include some of the following as identified by Wang [123] and Maguire [69]: Human-centred design (a) leads to increased productivity, that is, users concentrate on the task rather than the tool which could be causing a lot of problems, (b) reduces errors, (c) leads to reduced training and support, and yields products, services or systems that are easier to use and require less training, less user support (less documentation

Table 5.1 Human-centred design tools

Discover	Define	Ideation	Prototype	Testing
User observation, Cultural probes, Context mapping, Interviews, Questionnaires, Customer journey Mind mapping, Focus groups, Co-creation/co-design In-context immersion	Product collage, Personas Moodboards, Storyboards, Business model canvas Written scenario, Problem definition SWOT analysis	Analogies and metaphors, Synectics, SCAMPER, Bisociative technique, Brainstorming, Brainwriting, Who-what-where-when-why-how	Sketch modelling, Rapid prototyping, mock-ups, Empathy tools, Paper prototyping, Appearance models Quick-and-dirty prototypes, Experience prototyping	Scenario testing, User trials, Material testing, Safety testing

Source designed by the Authors

cost) and less maintenance, (d) enhances learning and user experience. Ultimately, all these lead to an improved acceptance through the trial and evolution of new products, services or systems before a full-scale launch. The approach enables an increased accessibility of products, services or systems to a range of users (for example, from an able-bodied to a disabled community).

In addition to the above benefits, human-centred design products, services or systems are viewed as having an improved quality, which makes them more competitive in a market that is demanding usable and pleasurable systems. Furthermore, other benefits include savings in developmental costs and time; increased trust in the product, service or system, as users are retained and new users are attracted; and increased job satisfaction for both the employer and employee, resulting in increased motivation and reduced stress. Human-centred design means relieving users of their frustration, confusion and a sense of helplessness [88], and helping them to feel in control and empowered. Moreover, IDEO [47] advance that some of the benefits of the human-centred design include: deep understanding of users' needs, development of customised solutions, facilitates bottom-up innovation, creates impact design, that is, desirable, feasible and viable, and user involvement is clearly useful and it has positive effects on both system success and in improving user satisfaction.

Despite the aforementioned benefits, human-centred design has limitations. Most scholars, for example, Rouse [96], Stanton [104] and Maguire [69], pay insufficient attention to the fact that this methodology has some restrictions. There is a problem in involving users in new innovative technologies: users of these technologies are not yet known, and therefore cannot be involved in the development process [59]. In support of previous point of view, Van Kleef et al. [118] and Marc [77] also argue that people may be unaware of their needs, unable to articulate their needs or unwilling to speak about their needs with an interviewer. In this case, innovative technologies refer to technologies that are either not yet realised at all or technologies that may be realised in a technical sense, but which are not part of the established social structure. Examples include interactive television and e-commerce software. These kind of products, services or systems are realised through the technology-centred approach, whereby the designer's expression of creativity is at the centre of the process.

The idea of user involvement is to engage people who are representatives of the assumed future users. However, if user requirements are fairly vague, it is difficult to determine who could be a representative of the future user. This creates a dilemma. If the scenario is still uncertain and it does matter which groups are going to be involved, the identity of the groups would remain uncertain. This condition is prone to outcomes which may not prove to be very reliable.

Potential users would not be willing to make an effort to participate in projects with uncertain outcomes and to cope with not yet fully determined technologies. Moreover, potential users rely on their previous work experience to contribute to the innovation process. If the new product is an invention, it becomes difficult for users to contribute fully because this is outside their experiences. This point of view is shared by Norman [88], who states that one cannot evaluate an innovation by

asking potential users their views. This requires people to imagine something with which they have no experience. People find it difficult to articulate their real problems. Even if they are aware of the problem, they do not often think of it as a design issue. It is not possible to accurately predict user performance in future situations [91]. People do not react until the situation occurs; it is the context and environmental conditions that trigger their actions.

However, even if all the design problems are addressed, success is not guaranteed. In spite of this danger, even if the best-laid plans are suspect, by having put everything in place, the risk of failure has been reduced and there are better prospects of success [82]. In design, as in any other problem-solving process, it pays to analyse the problem before creating the solution. It is better to use 10% of the resources to find out how to use the remaining 90% properly than to use 100% of the resources the wrong way [37].

Summary

In this chapter, the importance of universal design and human-centred design with a bias towards the consideration of user sociocultural context have been emphasised, to enable designers to better understand and design for their intended users. Regardless of the research method used, the primary objective is to develop products, services, systems and environments for human diversity, social inclusion and equality. It also requires developing an understanding of users' values, attitudes and behaviour that can be translated into viable, powerful design concepts. In conclusion, universal design and human-centred design should not only include usability aspects but also it should go beyond and incorporate the cultural background and social situation of the user at the point of using the product, service, system or environment.

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