

A User Centered Design Strategy to Enhance Sustainable Behavior

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Abstract

This paper proposes a strategic framework that integrates User-Centred Design (UCD) with Design for Sustainable Behaviour (DfSB) to develop products that effectively encourage sustainable user practices. While UCD focuses on optimizing usability and user satisfaction, and DfSB focuses on influencing behaviour, their combination is essential for creating interventions that are both effective and adopted by users. The proposed framework consists of five stages: (1) Identifying Sustainable Goals, (2) User Research, (3) Strategy Selection, (4) Design and Prototyping, and (5) Usability Testing. This framework was explored through a methodology involving focus groups of product design students, resulting in two product case studies: an energy-efficient kettle and a smart lighting system. The findings suggest that a user-centred approach is critical for diagnosing the root causes of unsustainable behaviours and for selecting and implementing behavioural strategies that users find intuitive and acceptable. The paper argues that this integrated approach can bridge the gap between behavioural intention and action, leading to more successful and human-centred sustainable design outcomes.

Keywords

user-centered design, design for sustainable behavior, behavior change.

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Introduction:

The aim of user-centered design is to create products, services, and systems that are not only functional and efficient but also intuitive, accessible, and satisfying to users (Chammas et al., 2015). This can be achieved by placing the needs, wants, and limitations of the end-user at the forefront of every stage of the design process. This involves iterative cycles of research, prototyping, testing, and refinement to deeply understand the user's context, tasks, and goals, ultimately ensuring that the final design solves real problems and provides a positive user experience.

The environmental impact of consumer products is usually in the usage phase, where they consume energy, water, or other resources over their lifetime. This is a fundamental principle of sustainable design, which seeks to minimize a product's overall ecological footprint (Keitsch, 2015). Therefore, instead of focusing solely on recyclable materials, sustainable design prioritizes energy efficiency, durability, and resource conservation during the critical usage stage. For example, designing an appliance that uses minimal electricity, a showerhead that reduces water flow without sacrificing performance, or a vehicle with lower emissions directly addresses the most significant portion of its life-cycle impact, leading to far greater environmental benefits than end-of-life considerations alone.

With more understanding of user behavior in the

usage phase, designers can move beyond merely creating efficient products and begin to actively design for sustainable behavior (Coskun et al., 2015). This approach involves applying insights from psychology and behavioral economics to subtly guide, encourage, and empower users to make more environmentally sound choices. For instance, by understanding routines and motivations, a design can provide feedback on energy consumption, make sustainable actions the default option, or even gamify conservation. This shifts the focus from the product's inherent efficiency to the entire system of human-product interaction, leveraging user-centered techniques to achieve the larger goal of reducing environmental impact.

In this paper, we argue that the connection between user-centered design and design for sustainable behavior can enhance the behavior change of the user. While traditional sustainable design focuses on a product's technical efficiency, it often overlooks how real people actually interact with technology, leading to a "performance gap" where optimal efficiency is not achieved in practice. By integrating user-centered methods, designers can identify the specific motivations, barriers, and contextual triggers that influence a user's actions. This deep understanding allows for the strategic application of behavioral design principles that are not generic but are precisely tailored to the user's reality. Therefore, this fusion ensures that

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interventions for sustainability are not only effective but also desirable, intuitive, and ultimately more successful in fostering lasting behavioral shifts.

User-centered Design

In traditional design process, designers tend to focus on product development. Form and function are central to the designer's concerns in the design process. This approach of design eliminates the user from the design process. Therefore, Norman and Drapper (Norman & Drapper, 1986) introduced the user-centered design (UCD) to argue the importance of embedding the user in the center of the design process. Products should be designed based on user's abilities and limitations. According to this approach, design is an iterative process that should take in consideration the needs, wants, and limitations of users. The process of user-centered design involves several stages that include understanding the user and context of use, identifying the user requirements, ideation and design solutions, and evaluating design according to requirements (ISO 9241-210, 2010).

The aim of user-centered design is to develop usable systems and products through involvement of prospective users in the design process (Karat, 1996). ISO 9241-11 defined usability as the 'the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use' (Szopa & Karwowski, 2021). According to this definition, usability can be measured based on three factors: effectiveness, efficiency, and satisfaction (Buurman, 1997). These factors can differ in its proportion in measuring usability according to the product. For example, in some products, consumers pay more attention to pleasure in use rather than effectiveness and efficiency (De Vet, 1993). There are four main steps in the process of user-centered design (Gould & Lewis, 1995). These steps begin with knowing users, embed user's knowledge in the process, feedback through prototyping and evaluation, and if it is necessary, redesign can be done.

The challenge in user-centered design process is how to gather knowledge about users (Karat, 1997). To overcome this challenge, designers use several techniques such as observation (Auernhammer & Roth, 2021), questionnaires (Lietz, 2010), storyboard, scenario (Muck & Palkovits-Rauter, 2021), and focus groups (McDonagh-Philp & Bruseberg, 2000). But the real challenge was in lack of defined principles that can be used in a systematic way.

In the light of International Standard "Human centered design processes for interactive systems" (ISO DIS 13407) Bevan & Curson (Bevan &

Curson, 1998) presented a tutorial that contained a plan to be used within the usual design process. This plan includes methods that can improve the effectiveness of usability design in early and late stages of the design process such as prototyping and usability inspection methods (Hollingsed & Novick, 2007) in the early stages and performance measurement (Macleod et al., 1997) in late stages.

Gulliksen et al. (Gulliksen et al., 2003) identified 12 key principles that can be used in the design process to insure the effectiveness of the resulted design. These 12 principles are engaging user's needs and wants in the heart of the design process. It allows designers more understanding of the context of use which improve usability of the product.

Design for Sustainable Behavior

Sustainable design aims to enhance people's lives by enabling them to perform daily tasks in ways that reduce negative environmental and social impacts (Lockton et al., 2008; De Medeiros et al., 2018). Since most environmental consequences occur during a product's usage phase, researchers have shifted focus toward user behavior and its ecological effects. To address this, various methods have been developed to influence behavior in ways that lessen environmental harm (Lilley, 2005; Lidman & Renström, 2011; Chiu et al., 2020). Among these, design for sustainable behavior has emerged as a key approach, seeking sustainable solutions to everyday challenges.

This field examines how behavioral shifts can minimize environmental damage. Strategies in this domain explore how products can shape user actions (Zachrisson & Boks, 2010), incorporating behavioral theories to understand how habits form and how they might be altered. Behavior change can stem from multiple factors—some individuals respond to increased awareness of their actions' consequences, while others require incentives like rewards or deterrents like penalties (Webb et al., 2010; Davis et al., 2015). Researchers have translated these insights into actionable strategies for designers, enabling the creation of products that encourage more sustainable behaviors.

Human behavior in product design can be viewed as a dynamic communication process between users and products, beginning the moment a consumer decides to make a purchase. From this perspective, researchers have developed various strategies to influence behavior, which can be categorized into three key approaches: learning and motivation (Lidman & Renström, 2011), technology (Kuo et al., 2018; Chiu, 2020), and innovation.

User-centered design and design for sustainable behavior are inherently interconnected, both rooted in a deep understanding of user needs, motivations, and contexts. While user-centered design prioritizes

creating products and services that align with users' goals and capabilities, design for sustainable behavior extends this approach by intentionally shaping behaviors toward specific outcomes, such as sustainability or health. By leveraging user-centered design methods, designers gain insights into the cognitive, emotional, and situational factors driving user actions. These insights then inform design for sustainable behavior strategies to guide users toward desired behaviors without compromising usability or satisfaction. Together, this integration ensures that behavior-focused interventions remain empathetic, practical, and embedded seamlessly into users' lives, bridging the gap between what people do and what they need or aspire to do.

The Strategy Framework:

While The user-centered design (UCD) process concentrates on understanding user needs and context and identifying user and business requirements, the process of design for sustainable behavior pay more attention to the way that can change user behavior into more sustainable form. Therefore, the UCD process uses methods to collect data about the user and his needs such as questionnaire, observations, and focus groups. It attempts to adapt the design with the way the user can understand and practice.

On the other hand, the process of design for sustainable behavior interests in understanding the patterns of user behavior and the methods that can make change in this behavior to be more sustainable. It uses methods such as learning and motivation (Lidman & Renström, 2011), technology (Kuo et al., 2018; Chiu, 2020) and innovation (Gharib, 2024). These methods used by designers to encourage users to behave in a sustainable way or to prevent them from doing the opposite.

The traditional framework for human-product interaction, proposed by Shackel in 1984 (Shachel, 1984) includes four basic factors: the product, the user, the user's goal, and the context of interaction. In this paper, we extended this framework to account for modern complexities of the product usage and environmental issues. The need for a more effective framework to design user centered products that can enhance the sustainable behavior of people is being crucial in the modern life.

The suggested framework involves five stages that encounter the design process. Designers can follow these steps to design user-centered products which can change users' behavior into sustainable way in the same time. These five stages are as the following:

1- Identify sustainable goals:

In this stage, designers conduct a life cycle assessment to pinpoint the product's biggest environmental impacts which usually the usage phase in consumer products. In this step, the key stakeholders, from engineers to end-users, are engaged to understand practical constraints and opportunities. This combined analysis allows us to define specific, measurable, and achievable goals that address the highest-priority impacts without compromising the product's core function or user needs.

2- User research:

Designers conduct user research through a mixed-methods approach to build deep empathy and uncover actionable insights. This typically begins with qualitative methods like user interviews and contextual inquiries to observe behaviors and understand underlying needs, motivations, and pain points in a real-world context. These findings are often supplemented with quantitative data from surveys or analytics to validate patterns at a larger scale. Techniques like creating user personas and journey maps then synthesize this research into digestible formats that align the entire team, ensuring design decisions are not based on assumptions but are firmly grounded in a rich, evidence-based understanding of the user.

3- Strategy selection:

A designer selects a strategy for sustainable behavior within a user-centered design framework by integrating empirical user insights with evidence-based behavioral interventions. This process begins with qualitative research, such as contextual inquiry (Privitera & Culverhouse, 2019) and diary studies (Olorunfemi, 2024), to identify existing user practices, motivations, and barriers to sustainable action. These insights are analyzed to locate specific behavioral bottlenecks, such as a lack of feedback, situational constraints, or ingrained habits. The designer then maps these barriers to appropriate behavioral strategies drawn from established models like the Behavior Change Wheel (Michie et al., 2014) or 4DB framework (Chatterton & Wilson, 2014). The selected strategy, whether it involves simplifying information, enabling feedback, incentivizing action, or reshaping social norms, is rigorously prototyped and tested with users to ensure it is both effective and acceptable. Thus, the approach remains fundamentally user-centered: the intervention is grounded in real-world behaviors and co-developed to reduce environmental impact without compromising usability, accessibility, or user autonomy.

4- Design and prototype:

Following the selection of a behavioral strategy, the designer translates these insights into tangible product features and interactions. This phase involves iterative prototyping, where low-fidelity models such as sketches, 3D modelling, or physical mock-ups are developed to embody the chosen sustainability strategy. These prototypes are used to test and refine how the product cues, guides, or enables the desired sustainable behavior in real-use contexts. For example, a prototype might make energy consumption visible through an ambient display, or simplify recycling through intuitive material-separation mechanisms. Through repeated user testing and feedback loops, the product's form, interface, and functionality are refined to ensure the behavioral intervention feels intuitive, valuable, and seamlessly integrated into the user's experience. This evidence-based approach ensures the final design effectively promotes sustainable outcomes while maintaining core usability and engagement.

5- Usability testing:

Usability testing evaluates if the sustainability features work without making the product harder to use. Researchers observe people interacting with the prototype to spot points of confusion, frustration, or misunderstanding especially around the new sustainable behaviors. This feedback is used to immediately refine the design, ensuring the product remains user-friendly while effectively promoting its environmental goals.

Methodology:

Two focus groups of five final-year product design students were selected. Participation was based on the students' interest and their prior experience in research, project work, or studies related to sustainable design. The session began with an oral presentation by the author introducing the concept of design for sustainable behavior, including relevant strategies and frameworks with an introduction to user-centered design principles and practice. The author clarified that the goal was to develop a product aligned with the proposed framework, focusing on promoting sustainable behaviors according to user-centered design principles.

Each focus group met for three days, five hours per day, to allow sufficient time for in-depth investigation and concept development. On the first day, each group began with a one-hour brainstorming session to identify daily behaviors that could be changed to improve sustainability. Over the next two hours, participants conducted field research around the campus using observations, interviews, and surveys to gather data. The final two hours were dedicated to analyzing their findings and defining a direction for the

following days.

The second and third days were focused on the ideation and development of a product concept designed to change a harmful behavior, in accordance with the presented framework. Each group refined their ideas, developed their concepts, and prepared a final presentation. At the end of the third day, each group delivered an oral presentation of their product concept, followed by a group discussion to reflect on the process and outcomes from their perspectives.

The activity resulted in two product case studies. The first addressed the environmental impacts of kettle usage during in homes and offices and proposed a new concept for a kettle that can improve energy usage. The second focused on the lighting systems in homes. This group developed a smart lighting concept aimed at effective lighting and in the same time control the energy waste.

Case study 1:

Kettle usage impacts the environment primarily through the energy-intensive process of boiling water, which contributes to greenhouse gas emissions, especially when the electricity is generated from fossil fuels. Other impacts include the depletion of raw materials during manufacturing, particularly for metal kettles, and the end-of-life issue of plastic kettles ending up as persistent plastic pollution. Reducing environmental impact can be achieved by boiling only the necessary amount of water, choosing energy-efficient models, using renewable energy sources, and ensuring kettles are properly disposed of to prevent pollution.

A life cycle assessment of a standard electric kettle showed its most significant environmental impact was energy consumption during the usage phase, exacerbated by users repeatedly boiling full kettles for a single cup. The sustainable goal was defined as: Reduce energy consumption by 30% per use by designing a kettle that discourages overfilling and minimizes standby power draw.

Contextual inquiries in homes revealed a common pattern: users filled the kettle by habit, often to its maximum capacity, regardless of need. Interviews uncovered the root causes: a lack of clear measurement, the speed of the filling process, and a desire to avoid having to refill it later for a second cup.

Research pointed to two key barriers: a lack of immediate feedback and an ingrained habit. The selected strategy combined Enablement (making precise measurement effortless) and Feedback (providing clear, immediate data on consumption). The concept was a kettle with incremental water measurement and an energy-display strip, moving away from a simple on/off interaction.

Case study 2:

A life cycle assessment for home lighting identifies the usage phase as the dominant source of environmental impact, specifically electricity consumption from prolonged and often inefficient use. The primary sustainable goal is to reduce energy consumption from residential lighting by at least 40% compared to standard LED bulb usage. A secondary goal is to mitigate light pollution by reducing unnecessary outdoor spillage and blue-light emission at night.

Researchers employed contextual inquiries, observing how families use light throughout the day and evening. Diary studies revealed key patterns: lights were often left on in empty rooms out of forgetfulness or for a sense of security. Interviews uncovered that users found most "smart" lighting systems complex and were unaware of the health and energy impacts of cool-toned light in the evening.

Analysis of the research pinpointed the main barriers: habit (forgetting to turn lights off), lack of awareness (of energy use and health impacts), and perceived complexity. The chosen strategy is a combination of Facilitation and Feedback.

- **Facilitation:** Making energy-saving automation the default, effortless option.
- **Feedback:** Providing subtle, ambient data on energy consumption to build awareness without creating a burdensome interface.

The system would use presence sensing and automated scheduling aligned with natural sleep-wake cycles, rather than relying on user-initiated commands.

Discussion:

The findings of this study emphasize the key role of understanding user behavior in the successful implementation of sustainable design strategies. Our proposed five-stage framework, which integrates user-centered design principles with behavioral change methodologies, provides a structured approach for designers to create products that not only meet user needs but also actively promote environmentally conscious actions. The case studies on the energy-saving kettle and the smart lighting system serve as concrete examples of this framework in practice, highlighting the effectiveness of addressing specific behavioral barriers.

A key insight from our research is that effective design for sustainable behavior must move beyond simple awareness campaigns. As evidenced by the kettle study, users often fill kettles to capacity due to ingrained habit and a lack of clear feedback on energy consumption. The solution, therefore, was not merely to inform users of their energy waste but

to make precise measurement and real-time energy display an effortless part of the product's use. This aligns with the principles of nudging and facilitation, where the sustainable choice becomes the path of least resistance. Similarly, the smart lighting system's success hinged on making energy-saving automation the default, thereby overcoming user forgetfulness and the perceived complexity of "smart" technology.

This research reinforces the connection of usability and sustainability. A product, no matter how environmentally friendly in its design intent, will not achieve its sustainable goals if it is inconvenient or frustrating to use. The iterative process of prototyping and usability testing, as outlined in our framework, is essential for ensuring that behavioral interventions do not compromise the user experience. The feedback from the focus groups confirmed that for a sustainable behavior to be adopted, it must be integrated and feel intuitive, valuable, and even satisfying. This echoes the sentiment that while effectiveness and efficiency are crucial, factors like user satisfaction and pleasure in use can be equally, if not more, important for consumer products.

Conclusion:

This research demonstrates that effective sustainable design must be rooted in a deep understanding of user behavior. The proposed framework merges user-centered design with behavioral strategies to create products that make sustainable action the easiest path. The case studies show that solutions succeed when they address specific user barriers like habit or lack of feedback. Ultimately, for sustainability to work, it must be seamlessly integrated into a product's usability and experience.

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