Practitioner Perspectives: Usability Needs for Digital Sustainable Product Development Tools

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Keywords: Usability Heuristics, Sustainable Product Development, Design Guidelines, Participatory Design.

Abstract: This study investigates the application of Nielsen's 10 usability heuristics in the design of digital Sustainable Product Development (SPD) tools using a participatory design approach. Participants included representatives from three companies and SPD experts from academia. During the workshops, the ten usability criteria were presented, after which participants engaged in a brainstorming session to generate practical recommendations for SPD tool design based on their professional experience. The results suggest that SPD practitioners consider these heuristics relevant for SPD tool development. Future research will evaluate the effectiveness of integrating these guidelines into the design process and ongoing improvements to SPD tools.

1 INTRODUCTION

The integration of digital solutions into industrial product development processes represents one of the most significant shifts in today's economy. Industries that used to depend on manual and analog procedures are now embracing the use of digital tools that allows for the collection of large amounts of data.

Sustainable product development (SPD) involves integrating sustainability considerations into the product development process (Kaebernick et al., 2003; Ahmad et al., 2018). Product development itself involves designing, improving and managing a product or service throughout its development cycle (Press, 2011). Incorporating sustainability into this process is crucial for advancing societal sustainability objectives, as the impacts associated with product life cycles are among the primary contributors to the ongoing sustainability crisis (Kaebernick et al., 2003; Pujari, 2006; Tukker and Jansen, 2006; Sutherland et al., 2020). This crisis not only threatens society's capacity to sustain itself, posing direct risks to human life and social systems (United Nations Department of Economic and Social Affairs, 2025; Richardson et al., 2023; Planetary Boundaries Science, 2025; UNEP, 2025), but also drives seven of the ten most significant global economic risks projected for the next decade, according to the World Economic Forum (World Economic Forum, 2026).

Several Sustainable Product Development (SPD) tools are utilized across various industries, including LEASA and the Sustainability Fingerprint (SF). LEASA (Watz and Hallstedt, 2024) employs structured workshops and focus groups that integrate backcasting, life cycle assessment, gap analysis, and prototyping within requirements engineering to identify key sustainability criteria for assessment in the early stages of product development. The SF (Hallstedt et al., 2023) tool elaborates on different levels of compliance for each criterion. SF supports the definition of the sustainability design space and the desired sustainability profile for new solutions by facilitating user assessment of the sustainability criteria identified through LEASA. Another SPD tool, the Sustainability Impact Assessment (Hallstedt and Pigosso, 2017), provides a step-by-step approach tailored to the Technology Readiness Level. This tool aims to increase awareness of sustainability impacts during the design and development of new products and technologies.

The digitalization of SPD tools has a potential to promote a wider adoption of the tools in companies. In particular, these tools are designed to be used by groups consisting of stakeholders with different backgrounds and competences. Although group decision making is common in business organizations, sustain-

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Hu, Y., Gould, R. K., Garro, V. and Wang, P.
Practitioner Perspectives: Usability Needs for Digital Sustainable Product Development Tools.
DOI: 10.5220/0014914400004018

In *Proceedings of the 28th International Conference on Enterprise Information Systems (ICEIS 2026) - Volume 3*, pages 1952-1958
ISBN: 978-989-758-834-1; ISSN: 2184-4992

ability is considered a complex topic for collective decision making (Brambila-Macias and Sakao, 2021). Moreover, to be effective, digital tools should be designed considering the companies' context and should pursue high levels of usability. **Usability** assesses how easy the users interact with a digital tool, including five quality aspects: learnability, efficiency, memorability, errors, and satisfaction (Nielsen et al., 2012).

Despite there being numerous and varied approaches, tools, methods, and frameworks for sustainable product development (Faludi et al., 2020), their actual **adoption remains limited** (Bovea and Pérez-Belis, 2012; Lee-Mortimer et al., 2009; Deutz et al., 2013). Furthermore, the sustainability performance of products still does not meet the ambition level of product development companies. For instance, a 2023 study of seven Danish manufacturing firms revealed that these companies were not achieving their stated sustainability performance targets (Vilochani et al., 2025).

A barrier to the adoption of sustainable design tools is that users experience many of the tools as **time-consuming** (Bovea and Pérez-Belis, 2012) and **overly complex** (Bovea and Pérez-Belis, 2012; Prendeville et al., 2013; Schöggl et al., 2024). Mallalieu et al. (Mallalieu et al., 2024) found that knowing how to appropriately use the design methods proposed by SPD experts is a category of factors that influence the adoption of sustainable design practices and ultimately sustainability performance. Specifically, a **lack of understanding of how to use** SPD tools had a negative impact on (1) design method outcomes, (2) practitioner engagement and ultimately (3) sustainability outcomes (Mallalieu et al., 2024). Indeed, improved 'user friendliness' of tools and methods has been requested by both product developers (Hallstedt et al., 2022) and academics (Faludi et al., 2020).

Faludi et al. (Faludi et al., 2020) recently presented a comprehensive overview of digitalization solutions and digital supports for sustainable design. Their work offers a roadmap that documents hundreds of methods, tools, and other supports for sustainable design, as well as a thorough discussion of existing literature reviews. Research and practice in the Nordics and Baltics have developed taxonomies and toolboxes to guide the selection of eco-design tools for various design tasks (CIR, ; Sus,), and have also introduced digital solutions to support sustainability reporting (Willskytt et al., 2020). However, these studies have not considered usability in any significant way. Therefore, this paper focuses on the usability of SPD tools.

This paper investigates the integration of usability design guidelines into the development of digital SPD tools. A participatory design approach is employed, involving sustainability representatives from companies and SPD experts from academia, through workshops. Nielsen's 10 usability heuristics provide the foundational guidelines for the workshops. Drawing on the workshop outcomes, this paper provides design guidelines for digital SPD tools.

2 10 USABILITY HEURISTICS

Jakob Nielsen proposed the 10 usability heuristics over three decades ago (Nielsen, 1994). These heuristics are widely recognized as the most frequently used guidelines in user interaction design. The 10 usability heuristics were formulated to maximize explanatory power across diverse usability issues. Factor analysis produced heuristics based on fundamental mismatches between humans and machines, rather than specific screen designs or user interface technologies (Nielsen, 2024). They are called "heuristics" because they are broad rules of thumb and not specific usability guidelines. The heuristics are as follows:

1. **Visibility of System Status:** The system must consistently inform users of ongoing processes by providing timely and appropriate feedback. Users should be able to check the current system status at any time.
2. **Match Between System and Real World:** The system must use terminology, phrases, and concepts familiar to users. Information should be presented in a logical and intuitive sequence, following real-world conventions.
3. **User Control and Freedom:** Users may inadvertently perform unintended actions; therefore, the interface should provide clearly marked options to exit unwanted states efficiently. Additionally, support for undo and redo functions is essential.
4. **Consistency and Standards:** Terminology, actions, and interface elements must be used consistently to prevent ambiguity. Adherence to platform and industry standards reduces user confusion.
5. **Error Prevention:** Proactive design should prioritize preventing errors over relying on error messages. Eliminate error-prone conditions or implement checks that prompt users for confirmation before proceeding.
6. **Recognition Rather Than Recall:** Reduce users' cognitive load by keeping objects, actions, and options visible. Users should not be required to

recall information across different interface sections. Instructions must be readily accessible.

7. **Flexibility and Efficiency of Use:** Incorporate accelerators that enhance efficiency for experienced users while remaining unobtrusive to novices. The system should enable users to customize frequently performed actions.
8. **Aesthetic and Minimalist Design:** Interfaces must exclude irrelevant or infrequently needed information. Superfluous content competes with essential information, reducing its prominence.
9. **Help Users Recognize, Diagnose, and Recover from Errors:** Error messages must use clear, non-technical language, precisely identify the issue, and provide constructive guidance for resolution.
10. **Help and Documentation:** Although optimal systems require minimal documentation, help resources may still be necessary. Documentation should remain easily searchable, task-oriented, concise, and provide clear, actionable steps.

3 RESEARCH DESIGN

This study employs a participatory design approach to investigate usability design guidelines for digital SPD tools, as part of a larger participatory design project to improve and develop SPD tools. Participatory design is a collaborative methodology that involves end users, stakeholders, and other relevant parties throughout the design process. Originating in Scandinavia in the 1970s as part of democratic workplace movements, this approach challenges the traditional top-down model in which designers develop solutions independently (Ehn and Badham, 2002). Participatory design acknowledges that prospective users of a product, service, or system possess critical knowledge and insights that contribute to more effective and contextually appropriate outcomes (Ehn and Badham, 2002). Through the use of workshops, co-design sessions, prototyping activities, and iterative feedback loops, participants act as co-creators rather than passive research subjects. This methodology produces designs that better address user needs and preferences, enhance participants' sense of ownership and empowerment, and contribute to higher adoption rates and more sustainable results (Bødker et al., 2022). Although participatory design needs a greater initial investment of time and resources, it reduces the risks of developing solutions that do not address real-world problems or are ultimately rejected by users (Wacnik et al., 2025).

Four workshops were conducted with representatives from three companies and experts from SPD academia, providing diverse industry perspectives on digital SPD tool development. Two of the companies operate in the traditional mechanical manufacturing industry, while the third is in the food industry, allowing for cross-sector insights into sustainability challenges and practices. Company representatives primarily included sustainability managers or product managers responsible for sustainability, with one company also involving engineers to provide technical perspectives on implementation feasibility. Each of the three companies has utilized their current SPD tools across various design phases. Each workshop included between 5 and 7 participants, with a total of 13 participants across all workshops. The main SPD tools addressed during the workshop were LEASA (Watz and Hallstedt, 2024) and SF (Hallstedt et al., 2023). Furthermore, one company discussed the SPD tool Sustainability Impact Assessment (Hallstedt and Pigosso, 2017), which was identified as their primary tool.

Each workshop followed a standardized process, beginning with participant introductions and an explanation of the workshop's objectives to establish a common understanding. The researcher then presented the ten usability heuristics to the participants, providing a framework for evaluating digital tool design. Following this presentation, participants engaged in a brainstorming session focused on the design of digital SDP tools in relation to the ten heuristics, generating practical recommendations grounded in their professional experience. Each workshop concluded with a summary and an outline of next steps.

4 USABILITY HEURISTICS IN SPD

In this section, we present the results of our analysis of the workshops.

Visibility of System Status: Participants underscored the need for progress indicators in digital SPD tools, recommending features such as step numbers, visual cues for the current stage, marking completed steps in green, and previews of upcoming steps to clarify the workflow position. Several participants also emphasized the importance of time estimation, suggesting that the system should display estimated durations for both the entire process (e.g., "this will take one hour") and individual tasks. This information would enable users to make informed decisions about whether to wait or return later. Collectively, these findings indicate that transparent system status enables users to distinguish between slow but functional processes and system failures, supports decisions about waiting or multitasking, and reduces frustration by establishing clear expectations throughout the multi-step sustainability assessment process in the digital SPD tools.

Match Between System and the Real World: Participants discussed the challenge of balancing accessibility with technical credibility in language use. Several participants noted that some users experienced confusion when faced with highly professional, academic, or complex terminology with some current SPD tools. It suggests that the system should employ a more general language that does not require specialized knowledge. However, other participants, especially engineers, emphasized the need to maintain scientific and technical rigor to preserve trust and credibility with technical audiences. One suggestion could be that the tool educates users so that they learn the specialized terms. Language localization emerged as a significant theme, with participants indicating that explaining complex sustainability topics would be more effective in local language for non-English-speaking audiences or for individuals outside the sustainability field. They recommended implementing a language-switching function for SPD tools.

User Control and Freedom: The discussion emphasized the necessity of flexibility and recovery mechanisms in SPD system design. Participants indicated that users should be able to navigate between steps, revise previous actions, and tailor the setup to their specific contexts. For example, one participant suggested that users should have a "quick pass" to return from step C to step A if required. The concept of "emergency exits" implies that digital SPD tools should similarly offer clear escape options when errors occur. Participants noted the need for robust undo and redo functions to prevent users from having to restart their work. Although one participant observed that the priority of these features may depend on the amount of user investment, there was broad consensus that input controls are necessary to prevent the entry of incorrect or invalid data, thereby balancing user freedom with appropriate constraints.

Consistency and Standards: Participants considered multiple dimensions of consistency important for the digital SPD tools. Participants emphasized internal consistency within the tool itself, such as ensuring that components are consistent with each other and maintaining a uniform professional appearance throughout the system to build trust. Currently, some participants stressed consistency between integrated SPD tools, noting that when integrating two SPD tools in the future, they must use consistent terms and concepts to represent the same things rather than using different words for identical concepts. They also highlighted the importance of consistency with external standards, suggesting that the system could reference and align with other sustainability frameworks or regulatory frameworks, potentially through visual triggers or nudges that help users understand how their criteria satisfy various external requirements.

Error Prevention: Participants highlighted the importance of guiding users through the correct workflow order, such as preventing them from jumping from step A to step C or developing sustainability criteria before completing all required boxes in earlier phases. Input validation was identified as crucial, with participants noting that when users enter values, the system should validate them against acceptable ranges and directly inform users when inputs fall outside those ranges or are incorrect. Additionally, participants emphasized that error prevention is closely related to intuitive design, which means that design should reduce confusion and errors by making the system naturally understandable rather than requiring users to guess or learn arbitrary interfaces.

Recognition Rather Than Recall: Participants emphasized that users should not need deep sustainability expertise or recall multiple details to use the SPD tools effectively. They noted that artificial intelligence (AI) could potentially guide users through tasks. One example involved the sustainability criteria process, which requires users to move between workshop findings, prioritization, and documentation, a workflow that demands considerable manual effort and frequent cross-referencing. The group agreed that features that enable iteration to be streamlined within digital SPD tools would facilitate smoother workflows.

Flexibility and Efficiency of Use: When discussing this aspect, participants emphasized the importance of providing detailed guidance for first-time users while offering shortcuts for experienced users who regularly use the system. One example is providing a function to export and reuse previous work from similar products without recreating steps; instead, just review and revise, rather than blindly copying last year's data. The group discussed whether different user roles (product managers vs. sustainability experts) should have customized views, ultimately agreeing that all collaborators should work with the same information to avoid miscommunication and ensure everyone interprets data consistently, especially when working remotely. However, it would be great if the SPD tools could provide experienced users who have used the system many times with a fast-track option that skips repetitive explanations. The system should still alert them if they have missed something critical to maintain accuracy and completeness.

Aesthetic and Minimalist Design: The discussion on “Aesthetic and Minimalist Design” focused on developing a professional interface that omits irrelevant information and unnecessary elements, such as gamification, which participants agreed would not be suitable for a professional SPD tool. Participants reached a consensus that the system should achieve a balance by maintaining a professional appearance while remaining inspirational and user-friendly, emphasizing relevant content and avoiding features that do not support the tool’s primary professional function.

Help Users Recognize, Diagnose, and Recover from Errors: Participants recommended that the system should notify users when they attempt to proceed with incomplete work, such as leaving multiple boxes empty, and should explain the potential issues associated with this action. They emphasized that, in the event of errors, whether due to incorrect numbers or other mistakes, users should be able to correct only the erroneous data without re-entering all information. The group expressed uncertainty regarding the potential sophistication of the system’s error detection capabilities, but agreed that error messages should use plain language to indicate where to look and what might be incorrect, for example, “This criteria doesn’t look right, you should check this”, rather than technical error codes such as “E67”.

Help and Documentation: Participants noted that most current SPD tools lack self-explanatory features and depend significantly on facilitators to provide verbal explanations. The group proposed that AI assistance could offer step-by-step guidance, highlight relevant sections, and clarify concepts as users advance through the process. Multiple documentation needs were identified, including in-tool help features such as information icons, comprehensive process description documents, and the potential integration of an AI chatbot for interactive support. Additionally, the group underscored the need to document the discussion process when using SPD tools, noting that users often fail to do so adequately. Such documentation was considered essential for research reporting and for individuals seeking to understand or enhance the SPD tool.

5 DISCUSSION

The workshop results highlight the necessity of user-centered design principles in digital SPD tools, indicating that participants prioritize clarity, accessibility, and flexibility throughout the user experience. Although the 10 heuristics for user interface design were developed more than 30 years ago, they remain applicable to contemporary digital SPD tool design. The findings emphasize the significance of transparent progress indicators, consistent terminology, and mechanisms for error recovery, reflecting a strong demand for tools that support both novice users and experts. Additionally, the focus on localized language options, integrated help features, and minimalistic design reflects an awareness of diverse user backgrounds and the complexities of collaborative, multi-step sustainability processes.

Collectively, these insights provide a framework for developing digital SPD tools that enable users to conduct accurate, effective sustainability assessments. A future digital SPD tool is expected to be cooperative and interactive, allowing multiple user types to collaborate within the same system while addressing diverse user requirements and preferences. Recent advances in artificial intelligence have led several participants to recommend the integration of AI assistant features into future digital SPD tools. For example, an AI assistant could clarify specialized terminology related to sustainability, as not all stakeholders might be familiar with sustainability jargon and theoretical concepts. However, the integration of AI into SPD tools must address concerns regarding data security and privacy, reliability, dependence, and ethical and regulatory uncertainty (McLean et al., 2023).

One limitation of our study is that participants may not have fully understood the possibilities related to all concepts discussed. For example, participants said that gamification was not suitable in a professional tool, yet this may have been due to not having extensive knowledge about gamification and its application areas. Supporting users to progress at a rate that suits them and giving them feedback to show that they have taken action, and the right action, is also part of gamification (Werbach and Hunter, 2020) - and they asked for these features in other parts of the workshops. A further limitation of this study is the relatively small number of workshop participants, which may result in certain aspects of usability remaining unaddressed.

6 CONCLUSION AND FUTURE WORK

This study examined the application of Nielsen’s 10 usability heuristics in the design of digital SPD tools. The findings indicate that SPD practitioners consider these heuristics as relevant for SPD tool development.

Design guidelines for digital SPD tools were established based on discussions from participatory design workshops. Future research will evaluate the implementation of these guidelines in the design and further development of SPD tools.

ACKNOWLEDGMENTS

This work was funded in part by the Knowledge Foundation, Sweden, through the Sustainable Product Innovation for Rewarding Transformation (SPIRIT) Synergy Project (contract 20240015). The authors would like to thank all workshop participants for their valuable contributions.

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