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SUSTAINABLE DESIGN CONSIDERATIONS FOR PRODUCT PERSONALISATION ADOPTING HALF-WAY DESIGN APPROACH (1)

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INTRODUCTION

Extending product lifetimes is a key goal of the circular economy, helping to reduce waste and resource consumption (Ellen MacArthur Foundation, 2015). Design strategies to support this goal are typically grouped as product-oriented, system-oriented, or user-oriented (Doğan and Bakırlıoğlu, 2020; Özçelik et al., 2022). Product-oriented strategies aim to prolong products' technical lifetime through strategies such as durability, repairability, and modularity, typically driven by manufacturers (Haines-Gadd et al., 2018). System-oriented strategies include product-service systems, which rethink product ownership and/or offer post-use services (Lofthouse and Prendeville, 2018), and Integrated Scales of Design and Production for Sustainability, which empowers local skills, addresses diverse user needs, and enables local post-use services (Doğan and Walker, 2008). User-oriented strategies focus on extending psychological product lifetimes, besides technical aspects. Key concepts include emotional durability (Chapman, 2005) and design for product attachment (Mugge et al., 2005; van den Berge et al., 2021), which aim to strengthen users' relationships with products.

This study examines product personalisation, a user-oriented strategy that delays product replacement by fostering product attachment (Haines-Gadd et al., 2018; Haug, 2019; Mugge et al., 2005; van Nes, 2010). Blom (2000) defines personalisation as changing a system's aesthetic or functional attributes to increase personal relevance. In product personalisation, a product is adapted to its owner's preferences and becomes unique and a medium of self-expression. Research suggests the self-expressiveness of personalised products and the effort put into the process enhance product attachment (Mugge et al., 2009b) promoting maintenance and repair (Ackermann et al., 2021; Keulemans et al., 2023; Schifferstein and Zwartkruis-Pelgrim, 2008) that help reduce waste and mitigate consumption. However, product personalisation can take many forms,

such as Do-It-Yourself (DIY) or mass-customisation, and not all necessarily contribute to product longevity, as the way a product is personalised and how many times this can happen may influence its lifespan. Accordingly, this study focuses on a specific form of personalisation: half-way design (Fuad-Luke, 2009), where products are partially produced and/or designed, allowing users to personalise and finalise them. This allows the use of local materials, skills, and production methods in the personalisation process, a key consideration across all sustainability dimensions (Doğan and Walker, 2008). Moreover, half-way design can allow continuous adaptation of products to meet changing or diverse user needs, which can positively affect product lifetime. Thus, its real value is beyond forming product attachment and rather creating evolving products adaptable to changing needs.

Half-way design has been explored across various product categories including lighting and decorative accessories (Bernabei and Power, 2017), furniture (Fuad-Luke, 2009), toys (Ozan Avcı, 2025), and bicycles (Doğan and Bakırlıoğlu, 2020). Open design initiatives like OpenStructures also demonstrate its application to small appliances, using locally sourced and 3D-printed parts based on a shared grid (Doğan and Bakırlıoğlu, 2020). Despite these examples, their implications for sustainability have not been thoroughly investigated in terms of how people design and interact with half-way designs, with a focus on developing sustainable design considerations for personalisation. Existing research examined whether product personalisation fosters product attachment and longevity for environmental sustainability through exploring mass-produced objects personalised by users (Mugge et al., 2009b) or self- or custom-made objects which are not designed considering sustainability (Maldini et al., 2019). While Bernabei and Power (2017) provide valuable insights into the potential of half-way design for sustainability through co-designed half-way products, they did not deeply examine users' personalisation experiences. This study investigates how half-way products can be designed considering not only environmental but also social sustainability by the development of half-way lighting design explorations as generative toolkits adopting generative design research approach. Thus, the toolkits already reflect the researcher's intervention and integrate sustainability considerations such as local production and adaptation, use of local skills, re-use and upgrading of product parts upfront rather than leaving this to completely individual personalisation experiences such as DIY or custom-made products. Employing *Research through Co-design* (RTC) approach (Bakırlıoğlu and Doğan, 2020; Busciantella-Ricci and Scataglini, 2024) along with generative research methods and tools including toolkits, diaries, workshops, and individual sessions, this study explores how people with diverse skills personalise half-way products to develop sustainability considerations. The paper presents sustainability considerations in product personalisation as the main findings of a doctoral study, while a detailed methodological discussion of the RTC process lies beyond its scope.

THEORETICAL BACKGROUND

Many practices support product personalisation to varying degrees. Mass-customisation enables customers to select from predefined parts or parameters using digital toolkits (Hermans, 2012). In contrast, everyday design and product hacking involve non-designers adapting finished products with local resources to meet their needs (De Couvreur, 2016; Kim and Lee, 2014). DIY, similarly user-initiated, includes the creation,

repair, or modification of artefacts using locally available materials (Mota, 2011; Singh, 2022). The maker movement, rooted in DIY and enhanced by digital fabrication tools, fosters user-led innovation through hands-on making, hacking, and open sharing of knowledge (Anderson, 2012). Open design complements this by enabling anyone to design, replicate, modify, and redistribute products through open-source design data and digital fabrication (Gershenfeld, 2005; Kohtala et al., 2020; Boisseau et al., 2017), and facilitates innovative solutions such as Fairphone (Micklethwaite, 2017).

Half-way design supports ongoing product adaptation across design and use phases by offering templates that users assemble, personalise, complete, and make. Design solutions may include offering a main structure, connection parts, or modular kits that can be assembled and adapted locally. In this process, users become both co-designers and co-makers, with roles including defining the product's form and function through surface finishing, integrating local materials, arranging functional components, and even producing half-way parts in open-source contexts. The outcome is personal, unique, and reflects the individual's needs, tastes, creativity, memories, and mistakes in the personalisation process (Bernabei and Power, 2017; Fuad-Luke, 2009), which may foster product attachment. Unlike the limited engagement in mass-customisation, half-way design invites active mental and physical user involvement. While DIY, maker, and hacking practices are typically user-initiated, half-way design involves deliberately incomplete components that invite further development, whether initiated by designers or by makers. The key distinction lies in the intentional design of openness: in half-way design, products are purposefully left unfinished to support co-creation and local adaptation. When half-way solutions are digitally and openly shared, personalisation potential increases through digital fabrication, enabling adjustments in size, material, and form (Bernabei and Power, 2017; Ozan Avcı, 2019).

From a sustainability perspective, half-way design aligns with DIY, maker, and open design practices by promoting user participation, local production and post-use adaptation. While not always explicitly aimed at sustainability (Doğan and Walker, 2008; Ozan Avcı, 2019), DIY and maker practices can promote re-use, repair, and refurbishing; reduce environmental impact through localised production; support fostering environmental awareness and social inclusion; and enable adaptation of products tailored to local needs (Coşkun et al., 2022; Niinimaki et al., 2021). Open sharing of design outcomes and processes supports sustainability by enabling local production and efficient resource use, empowering local skills and knowledge, and enhancing the comprehensibility of product structure, maintenance, and repair through active user participation in design, manufacturing, and post-use stages and accessibility of technical information and product components. Furthermore, this fosters social and economic benefits by enabling individuals to apply their skills and creativity in the design and making processes and reducing technological independence (Bakırlıoğlu and Doğan, 2020; Bakırlıoğlu and Kohtala, 2019). Together, these principles position half-way design as a promising pathway toward participatory and sustainable product solutions.

Relevant sustainability approaches for personalisation including Integrated Scales of Design and Production for Sustainability (ISDPS) (Doğan, 2007) and locally tailored design explorations (Walker, 2011; 2006) propose combining mass-produced and locally sourced parts to support local

adaptation and upgrade of products. Similarly, encouraging product re-appropriation via repair, re-use, and upgrades (Coşkun, 2010; Terzioğlu, 2021), and combining old and new product parts (Marchand, 2008) can facilitate personalisation in the post-use phase. Design considerations for sustainability addressed in DIY, maker practices, open design, and sustainable design approaches can be summarised as:

- understandability and accessibility of product parts for maintenance and repair,
- modular, evolving, upgradable, and adaptable products for changing and diverse user needs,
- empowering people to use their skills in design, production, maintenance, and repair,
- use of locally available materials, production techniques, post-use services,
- integrating various design and production scales.

In this research, sustainable product personalisation is defined as defining, adapting, or modifying a product's aesthetic and functional attributes during design, use, and/or post-use stages of product lifespan to increase its personal relevance (Ozan Avcı, 2019). In this process, designers or makers leave space for user adaptation, encouraging mental and physical engagement for continual adaptation and personalisation of design solutions.

METHODS AND PROCEDURES

This qualitative study employs Research through Co-design (RTC) approach (Bakırlıoğlu and Doğan, 2020; Busciantella-Ricci and Scataglini, 2024), integrating generative design research with non-designers into a Research through Design (RTD) process, through which half-way design explorations as generative toolkits were iteratively developed by involving participants actively and creatively. RTD is characterised by iterative theory development and design practice (Walker, 2006). Scholars (Jonas, 2015; Walker, 2011) define RTD as a designerly method of knowledge generation for addressing wicked problems (Rittel and Weber, 1973). It emphasises envisioning potential futures rather than exploring present realities (Godin and Zahedi, 2014). As traditional methods often fail to tackle the complexities of sustainability (Walker, 2011), RTD offers valuable insights through exploratory designs grounded in theoretical understanding (Doğan, 2007; Marchand, 2008; Terzioğlu, 2021; Walker, 2011; 2006).

In co-design, designers and non-designers collaborate, with the latter regarded as having expertise in their own experiences and involved in developing knowledge, ideas, and concepts. The researcher, who can be the designer or collaborate with them, provides tools for ideation and expression (Örnekoğlu Selçuk et al., 2024), whereas the designer materialises these ideas. Generative research approach is adopted in co-designing to investigate what people say, do, and make through various tools, which complement each other (Sanders and Stappers, 2013).

As individuals become co-designers and co-makers in half-way design, exploring how people personalise such products required collaboration between the designer/researcher and non-designers. Thus, a co-design process involving design workshops and individual generative studies was incorporated into the RTC methodology. The designer/researcher

developed half-way lighting design explorations as generative toolkits that were then personalised by two participant groups during co-design sessions. The iterative process between the researcher and participants in co-design, happened through the participants' involvement in iteration and adaptation of the toolkits. This prompted the researcher to revisit design details enabling personalisation in later generative sessions, allowing the toolkits to evolve based on participant feedback and enriching the theoretical understanding. The focus was not on the final products but on how the participants personalised the toolkits regarding their adaptability to various skills in the design phase. Generative research tools (Sanders and Stappers, 2013; 2014), including the toolkits and user diaries, helped identify participant needs regarding the personalisation process, which were then evaluated from the sustainability perspective. The diaries enabled participants to document their process, while interviews and think-aloud methods complemented these tools, supporting triangulation and enhancing credibility.

Lighting was selected as the product category due to its suitability for exploring local skills, materials, and production techniques. The research process is illustrated in **Figure 1** and further detailed in the following sections due to its iterative nature.

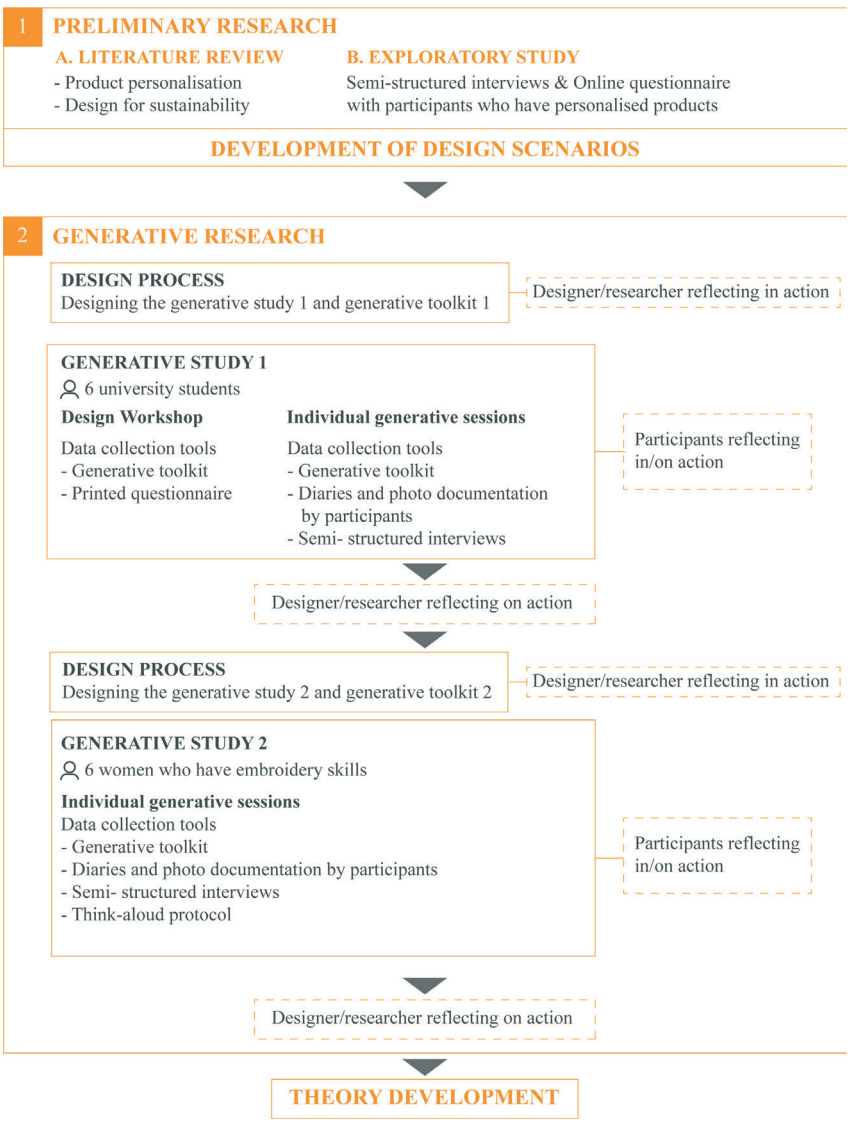

Figure 1. Research process.

Initial Model for Product Personalisation

An initial model of product personalisation was developed (**Figure 2**), drawing from prior research (Mugge et al., 2009a) and an exploratory study with individuals who personalise their products (Ozan Avcı, 2019), which helped redefine these dimensions in relation to sustainability considerations. Two semi-structured interviews were conducted with individuals who provided detailed narratives of their personalisation process of four products. The interviews explored the products' original features, the personalisation process and motivations, and the perceived outcomes and personal significance of the personalised product (Appendix A). Using hybrid thematic analysis (Fereday and Muir-Cochrane, 2006), initial themes and categories were developed based on literature and the interview questions (e.g. goals, methods of personalisation). As new insights emerged from the data, additional codes and themes were generated inductively (e.g. nature of intervention, personalisation benefits). To further refine these dimensions, an online survey was conducted with 15 participants who provided images of 39 personalised products and were asked about their personalisation goals and methods. This study expanded the categories for each theme.

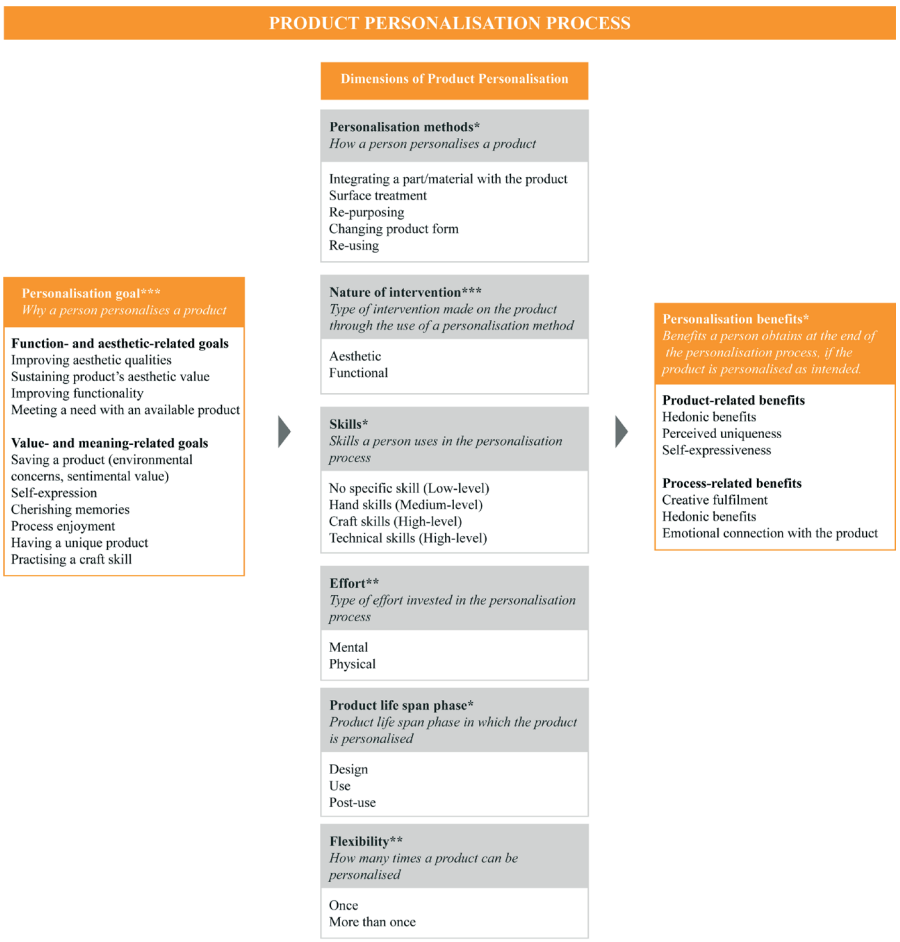

Figure 2. Product personalisation process and its dimensions.

In this model, product personalisation begins with people's personalisation goals, including aesthetic- and function-related or value- and meaning-related goals, which can co-exist in the process. Value- and meaning-related goals identified in the study, such as cherishing memories, self-expression, and process enjoyment, are known as the determinants of product attachment (Mugge et al., 2008); thus, addressing these when designing for product personalisation can strengthen the user–product relationship. Practising craft skills, another value- and meaning-related goal, can support social and economic sustainability by empowering local economies and facilitating product adaptation locally (Doğan and Walker, 2008). Empowerment of local skills and effective use of local resources are mainly connected with social innovation for enabling decentralised, creative, and circular economies (Manzini, 2015). Besides, products symbolising personal skills and accomplishment can strengthen the user-product relationship (Mugge et al., 2005). As an extension of these skills, people employ specific personalisation methods. Active mental and physical involvement enhance attachment due to the uniqueness and self-expressiveness of outcomes (Mugge et al., 2009b).

Personalisation can occur in the design, use, or post-use phases, and if the method allows, multiple times during the use phase (*flexibility of personalisation*). Upgrading components by this flexibility is vital for longer product lifespans and effective resource use (Bakırlıoğlu and Doğan, 2020; Walker, 2011). Besides, it allows products' adaptation to changing needs and continuous updates to their aesthetic and functional value, also supporting their emotional, epistemic, and social value (van den Berge et al., 2021).

If the product is personalised as intended, individuals can obtain product and process-related benefits (e.g. self-expressiveness, pleasure) which reinforce product attachment. These dimensions and their links to sustainability informed the design of the toolkits for the generative studies. The exploratory studies also supported the development of design scenarios and personas, which guided the generative studies and the design of the generative toolkits, as explained below.

Development of Design Scenarios and Personas

To inform the generative research design, including the selection of participants and personalisation goals, scenarios and personas were developed based on the exploratory study, which identified five personalisation practices: repurposing to avoid new purchases, personalisation through repair, adapting products' aesthetics to changing environments, integrating meaningful components into products to cherish memories, and personalising products while practising a craft skill. Considering their sustainability implications (repurposing, integrating memorable components, and empowering craft skills), time constraints of the doctoral study, and their potential to address multiple personalisation practices, two scenarios with specific user groups were selected to help ensure coherence across exploratory and generative research phases.

Emerged from the exploratory research, low to middle-income university students living in shared or rented housing often repurposed products in the post-use phase to economise with minimal effort (**Figure 3**). Accordingly, Scenario 1 focused on personalisation through re-purposing and re-using parts, practices supporting sustainable consumption, and required an affordable lighting design that could be personalised using

post-use materials. Scenario 2 derived from personalisation examples where women practised craft skills (**Figure 3**). It required personalisation of a lighting design, which facilitated practising a craft skill, which addresses all sustainability dimensions by enabling the use of local skills and materials, employment opportunities, and creative involvement of women in value creation. Scenario 1 prioritised a function-related goal, while Scenario 2 focused on a value- and meaning-related goal to address diverse user motivations for personalisation and explore their implications for the user-product relationship. Repair, aesthetic adaptation to changing environments, and cherishing memories were addressed through the toolkits, which supported repairability, upgrade, and aesthetic evolvability enabled by the half-way design approach.

Two key personas were selected to address these scenarios, informing the purposeful sampling strategy for the generative studies, leading to the selection of two participant groups, university students and women with craft skills, with varying personalisation goals, skills, and willingness to invest effort, ranging from practical interventions to skill-driven adaptations. The university students were aged 22 and 23 and the women participants were between 54 and 67 years old; however, this age difference was not a sampling criterion nor a focus of analysis.

RESEARCH PROCESS

GS1: Toolkit Development and Methods

For Generative Study 1 (GS1), a toolkit was developed based on the affordability scenario. Cardboard was chosen for its cost-effectiveness, accessibility, and flexibility. Post-use materials were considered for personalised shadings. A versatile lighting design usable both as a table and floor lamp could address the target group's diverse lighting needs, and structural and aesthetic variety could support its use in diverse contexts. The toolkit (**Figure 4**) involved two laser-cut shading types: A with slots for attaching sheet materials, and B with holes for attaching threads. Two

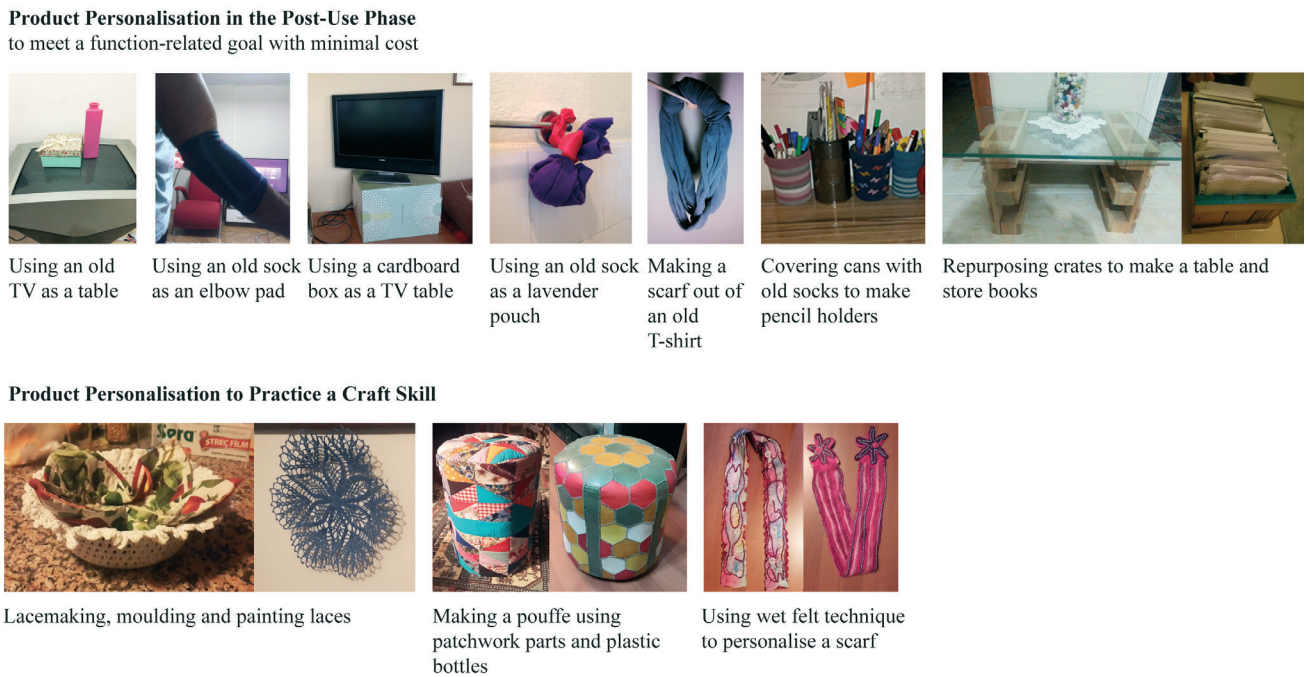

Figure 3. Examples of personalised products for two different personalisation goals (Ozan Avcı, 2019).

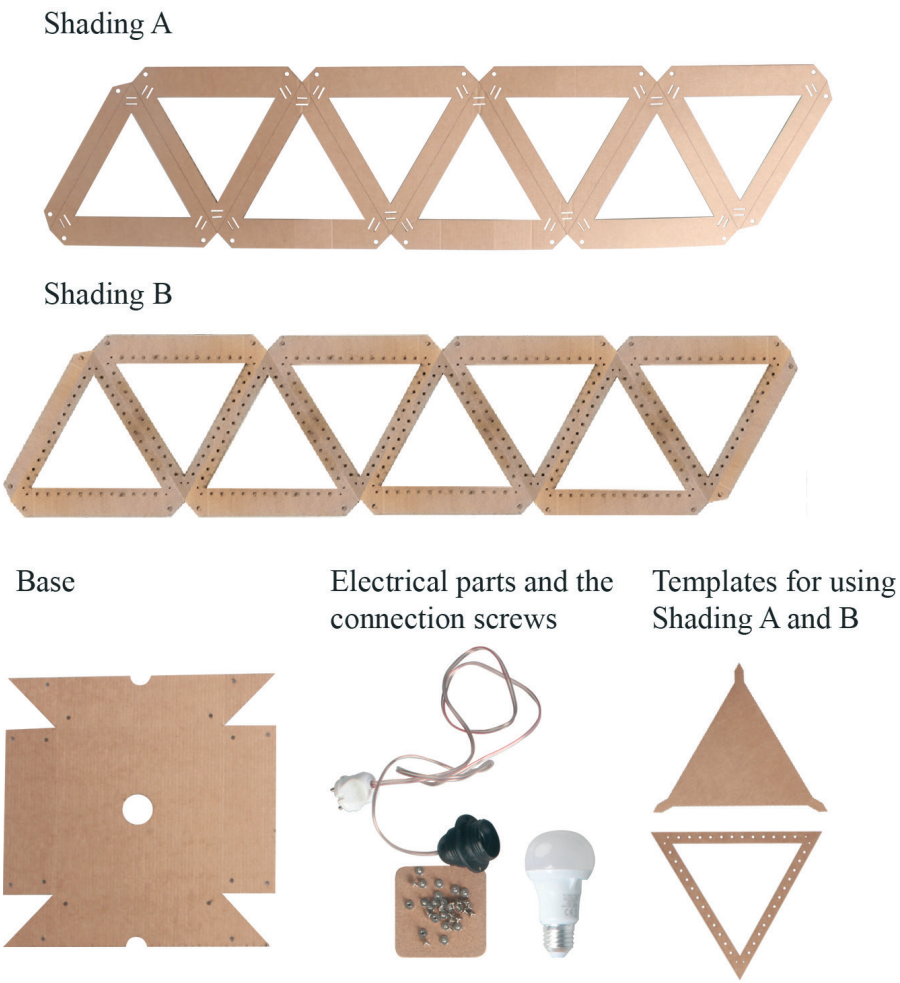

Figure 4. Generative toolkit 1 (Ozan Avcı, 2019).

templates supported cutting sheet materials and exploring the variations. The toolkit involved a base for the bulb and holding the shadings, electrical components, and binding screws for attaching the shadings to the base and each other. Cardboard parts could be shared as open-source templates, allowing local reproduction using post-use materials. The electrical and connection parts could be sourced externally, and the toolkit could be completed using post-use materials.

GS1 involved a three-hour design workshop and one-week individual generative studies. The workshop call was open to university students living in student housing and disseminated through the mailing lists of the first author's university and campus notice boards, to attract a diverse group of participants. While the workshop was open to 12 participants, six students, all from design-related departments, responded and confirmed their participation. Considering the time, labour, and financial constraints involved in toolkit (re)production and data collection, along with the study's aim for in-depth exploration of participants' personalisation processes using multiple data collection methods, this number was deemed sufficient for the scope of the study. After obtaining participants' consent and introduction on the research procedure and toolkits, participants partly built and personalised the toolkits using the materials and tools provided by the researcher in a seminar room. Verbal data were collected via a questionnaire and a focus group session exploring participants' opinions

about the workshop and personalisation process and toolkits, while visual data were collected through photographs and videos.

The participants then personalised the toolkits at home for a week using post-use materials. Visual data were collected via the toolkits and photos documented by the participants. Verbal data were collected through diaries (**Figure 5**) and 45-minute semi-structured interviews conducted after the personalisation process. Interviews covered participants' interventions, rationales, challenges, and evaluations of the generative toolkits (Appendix B). Thematic analysis followed a hybrid inductive–deductive approach. Workshop videos were reviewed and coded inductively. Diaries and interview responses were jointly analysed since they complemented each other. Interview responses were transcribed verbatim and coded inductively, with diary entries reviewed for additional insights. Emerging issues in diaries were coded, and by comparing them to existing ones, the codes and categories were refined. Emergent codes were clustered under broader thematic categories that aligned with the evolving conceptual model of product personalisation. This allowed for a grounded interpretation of the data, linking participant insights to broader design considerations.

GS1: Findings

Three overarching themes emerged: (1) personalisation goals, (2) personalisation dimensions, and (3) personalisation benefits. Personalisation dimensions included personalisation methods, effort, and flexibility and PLS phase. **Figure 6** presents the personalised generative toolkits.

Personalisation Goals: Although participants' personalisation goal appeared utilitarian in the exploratory research, value- and meaning-related goals, such as self-expression and memories, emerged as important personalisation goals for them. Some participants used post-use materials with no personal meaning since they were asked to use the materials at hand. In the interviews, these participants expressed a desire to use materials reflecting their identity better:

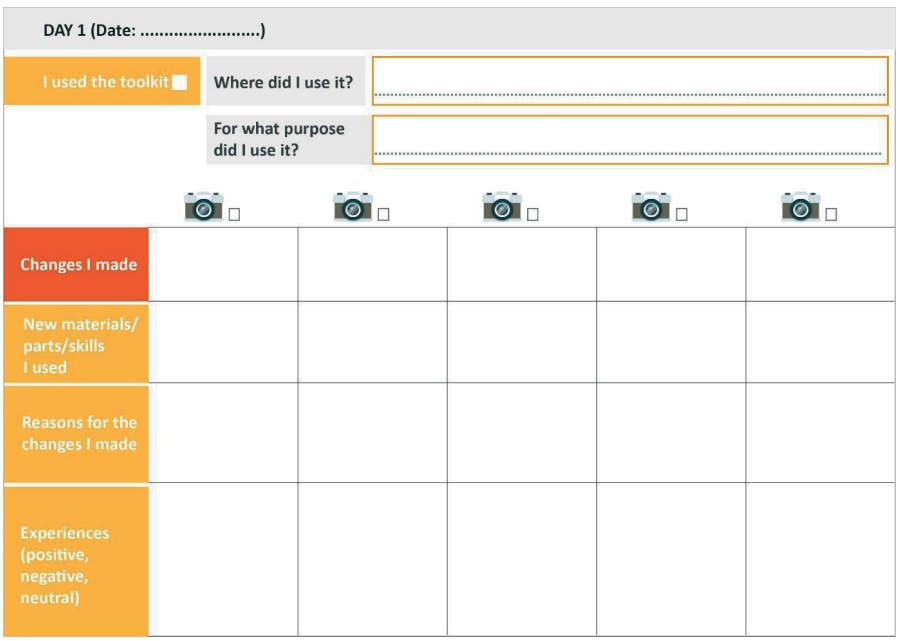

Figure 5. Sample page from the diaries.

Figure 6. Toolkits personalised in GS1 (Ozan Avcı, 2019).

> "Although these (fast-food packages) reflected my lifestyle, the logo of my team or cartoon characters would reflect me better". (P2)
>
> "Using post-use materials limited my personalisation process. I would like to use materials that reflect me better". (P5)

Participants had concerns about the "visibility of the personalised parts" due to the toolkit's small size, seeking self-expression and recognition of their design contribution by others for social visibility.

Personalisation Dimensions

Personalisation method: Differences in personalisation methods across different shading types caused confusion. One participant noted personalising Shading A was easier when unfolded, whereas Shading B was easier to personalise when folded.

Effort: Some participants struggled to assemble the toolkit due to "difficulty in using the connection details". Hence, an easier assembly method could reduce the effort required. Looking for practicality, the participants made simple interventions, which did not require significant physical effort. "Weaving strings to create a shading required too much

effort" for the participants. Thus, the personalisation method offered by Shading B did not fit the participants' skills and motivation, necessitating the redefinition of the required effort by the personalisation method considering people's goals and skills. One participant inserted materials into Shading A from two different sides and had to correct it. Accordingly, self-explanatory design details for correct material placement could guide and minimise the effort spent in the personalisation process.

Flexibility of personalisation: Some participants struggled to change the shading materials due to design details, which can hamper flexibility of personalisation. Some of the materials attached to Shading A remained loose; participants proposed "adapting it for various material thicknesses" for changing the toolkit in the use phase. One participant wished to attach a valuable ticket without cutting it into a triangular form. Thus, the toolkit could be adaptable for different materials and forms to improve the flexibility of personalisation. Adjusting lighting intensity with shading B was more challenging for some participants, as it required weaving more strings for different lighting quality, demanding greater physical effort than shading A. Thus, easy adjustment of lighting intensity through the adaptability of the shading for changing lighting needs could facilitate the flexible personalisation of lighting products. The participants appreciated the toolkit's adaptability, with one perceiving the variations as "endless" and another noting the ability to make "various interventions on the toolkit," reflecting how they experienced half-way design, as open-ended and flexible in terms of expression and modifications. Moreover, the participants continued spending mental effort even after the personalisation process by generating ideas on alternative ways of personalising the toolkit. For instance, some participants wondered "how the toolkit would look when three identical shadings were used", and the "potential effects of lighting on diverse materials and colours". Therefore, investing mental effort during and after the personalisation process due to the flexibility of personalisation can sustain people's interest in the toolkit, which may strengthen the user-product relationship.

Personalisation benefits: Most participants found personalised generative toolkits matched their aesthetic and functional preferences, deriving hedonic benefits like enjoyment and relaxation, from the process. However, many felt limited in self-expression due to material constraints, aside from one participant (P3), as below. These findings also highlighted the importance of self-expression and memories for a stronger user-product relationship:

> "I felt happy to see the dance shoes (her memorable object) on the lighting, there's a piece of me there and I would definitely continue to use this lighting".

GS2: Toolkit Development and Methods

Reflecting on the results of GS1, sustainable design considerations for product personalisation were formulated, leading to refinements in the generative toolkit and the research design for generative study 2 (GS2). The practising craft skills scenario, aimed to enable the use of craft skills to empower women having such skills to enhance their economic and social opportunities. Embroidery techniques were chosen for their variety, ease of changeability of the parts produced, the duration they required, and the light transmittance and naturalness of the materials used in these techniques. The toolkit (**Figure 7**) featured frames for stretching fabrics and directlt applying embroidery. These were inserted into the slots on

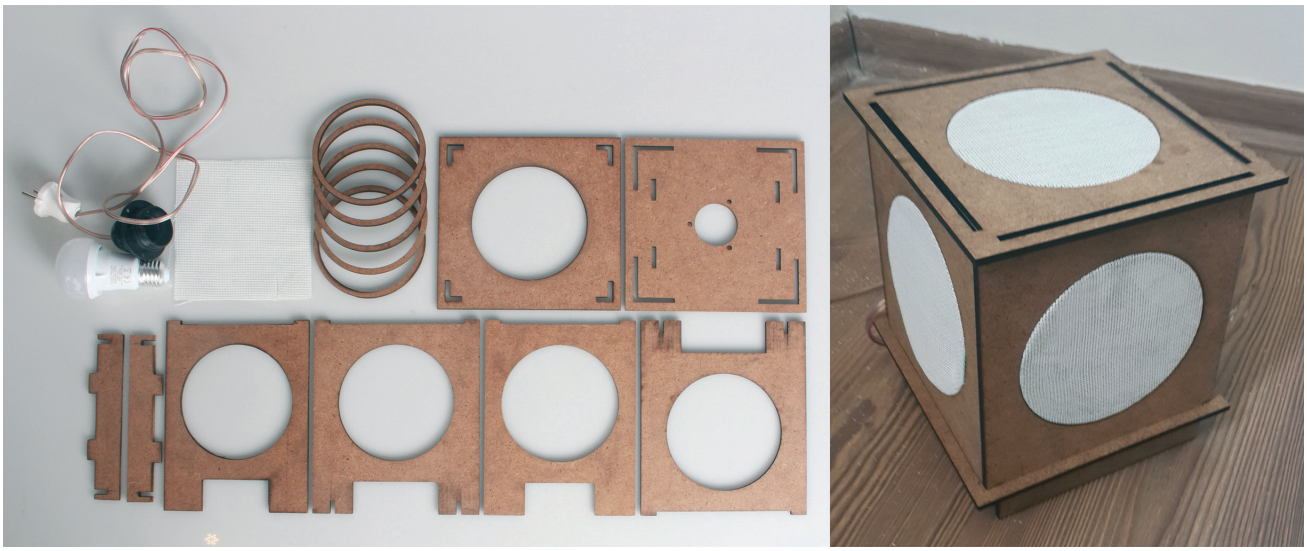

Figure 7. Generative toolkit 2 (Ozan Avcı, 2019).

the base holding the bulb to create a 3D form. Laser-cut MDF frames were used to ensure technical durability when making embroidery, and to better meet participants' expectations regarding aesthetic appeal. The toolkit, obtainable as an open-source design template, involved surfaces with circular holes, fabric-stretching rings, a base, and two pieces to elevate the toolkit and accommodate electrical components. Compared to GS1, this toolkit had reduced structural flexibility due to the time-intensive nature of embroidery and the goal to avoid added complexity.

Six women with varied embroidery experience were recruited via snowball sampling; while some were attending a craft course organised by the local municipality at the time, others were not. Each participant received a toolkit and ten etamine fabric sheets and personalised them using their own materials at home for two weeks, as completing the embroideries required a longer time. Visual data were collected through the toolkits and photos documented by the participants. Verbal data were collected via diaries (**Figure 5**), 45-minute semi-structured interviews (Appendix B) and think-aloud protocols conducted after the personalisation process. Think-aloud protocol was used to verify the participant responses in the diaries and interviews for triangulation and to observe how the participants assembled and personalised the toolkits. In this process, participants disassembled, modified, and re-assembled the toolkits, and expressed their opinions about these processes. As with GS1, analysis used a hybrid thematic approach, guided by categories and themes from the previous study. Combining all the data, final categories and themes were generated.

GS2: Findings

Three themes were identified: (1) personalisation goals, (2) personalisation dimensions, and (3) personalisation benefits. Personalisation dimensions included personalisation methods, skills, effort, and flexibility and PLS phase. **Figure 8** displays the personalised generative toolkits. The toolkit met the design criteria identified in GS1: ease of changing the shading materials, practical connection details for ease of personalisation and assembly, intuitive construction of the toolkit, and lighting adjustability (**2**).

Personalisation Goals: Participants reported they selected materials and patterns matching their taste, being content with the aesthetics of the

2. Some preliminary findings related to the second generative study were previously presented at the UTAK 2018 Conference.

Figure 8. Toolkits personalised in GS2 (Ozan Avcı, 2019).

outcomes. Social visibility of the outcome was important to them, with one participant emphasising the role of toolkit size in enabling this:

> "I would like the toolkit to be bigger to show what I made to others". (P1)

Personalisation Dimensions

Personalisation method: The familiarity of the embroidery frame appeared to facilitate the personalisation process, as the participants quickly understood how to adapt it. They experimented with various materials to assess their lighting quality. They found it easy to attach different materials and appreciated the immediate feedback the toolkit provided, which helped them identify combinations that matched their preferences.

Skills: The participants suggested incorporating other craft skills like "fabric painting, lacing, macrame, and weaving". Considering this, design details can be refined or diversified to enable the application of multiple craft skills.

Effort: Challenges included resizing digital patterns, centring the patterns, and cutting fabrics other than etamines. Despite having craft skills, they still required templates to support cutting, drawing, and adapting patterns for an easier and less effortful personalisation process. The participants also noted affordances and constraints, such as interlocking connection details, dimensional differences between parts, and clear directional cues facilitated easy assembly, highlighting the importance of self-explanatory design details. One participant expressed, "a larger toolkit would have made assembly and personalisation easier", highlighting how toolkit size can influence the level of effort required during the process.

Flexibility and PLS phase: One participant struggled with disassembly after applying spray paint on the toolkit's surfaces, highlighting the need for clear guidance on the applicable methods to enhance the flexibility of personalisation. Two participants faced issues with frames when using different fabrics, indicating a need for design adjustments to accommodate

various material thicknesses. The participants wanted to use the outcomes in varied settings, such as on a floor or table, suggesting a need for structural adaptability. As in GS1, because the toolkit could be personalised further in the use phase, the participants kept spending mental effort after the personalisation process, which can maintain their interest in the product, and stimulate their emotional bonding with it:

> "I can attach different materials on the wooden surfaces later, or I can try different colour combinations on the embroidered parts". (P4)

> "I would renew the embroidered parts each year and create a different variation". (P3)

Personalisation benefits: The participants expressed high levels of self-expression and enjoyment, which is important for enhancing their attachment to the toolkit. Some took pride in their outcomes and expressed a desire to make it socially visible by placing and using it in shared spaces like living room, reflecting a sense of ownership, the value placed on their invested effort, and a wish to share the story behind its making, suggesting the personalisation process helped embed personal meaning into the product.

> "I want to place this lighting in my living room, where everyone can see it because I made it". (P5)

> "I would put this lighting on a table in my living room. I would show it to my guests and tell its story". (P3)

Some participants expressed their feelings of accomplishment and creative fulfilment regarding the joy of producing something new:

> "I discovered my own capabilities and saw what I could make. The joy of making something is invaluable". (P4)

> "Producing something new is very enjoyable. I would proudly show this to everyone". (P1)

Finally, several participants highlighted an emotional connection with the outcome, which stemmed from both the effort invested in the process and the collaborative, memorable experience of personalisation:

> "The toolkit has a special place for me since it is hand-made and I spent effort to make it". (P2)

> "I would not change such a product having a memory with any lamp since it is the collective work of you and me". (P3)

Considering the insights that emerged from GS2, focusing on the empowerment of local skills, further insights could be derived by evaluating the two studies based on sustainability considerations.

DISCUSSION AND CONCLUSION

The sustainable design considerations for product personalisation derived from GS1 and GS2 are displayed in Table 1.

Personalisation goals and emotional durability: The study showed that addressing *value- and meaning-related personalisation goals*, such as practising a craft skill, self-expression, and cherishing memories, can foster a stronger user-product relationship than function- and aesthetics-related goals. In GS2, the participants described their outcomes as irreplaceable and unique, with strong expressions of *personal accomplishment, self-expression, and process enjoyment*. In contrast, only one GS1 participant, who had

		Sustainable Design Considerations	GS1	GS2
	Personalisation Goals	Addressing value- and meaning-related personalisation goals	X	
		Visibility of the personalised parts for self-expression and social visibility	X	X
Personalisation Dimensions	**Personalisation Method**	Consistency in personalisation methods	X	
		Familiarity with the personalisation method		X
		Quick feedback for personalised part's lighting effect*		X
	Skills	Adaptability to different skills		X
	Effort	Practical connection details for ease of building	X	
		Defining effort required by the personalisation method based on people's skills	X	
		Guiding through self-explanatory design details and templates	X	X
		Toolkit size for ease of building		X
	Flexibility and PLS Phase	Flexibility of personalisation for extended mental effort	X	X
		Ease of changing the personalised parts	X	
		Adaptability to different material types	X	X
		Adaptability to different material forms	X	
		Easy adjustment of lighting intensity*	X	
		Adaptability to different contexts of use through structural variety*		X
		Guidance on applicable personalisation methods		X
	Personalisation Benefits	Enabling the use of self-expressive/memorable materials	X	
		Providing an enjoyable personalisation experience		X
		Facilitating use in shared/social spaces for social visibility of the outcome		X
		Enabling users to invest effort		X
		Facilitating collaborative creativity for a memorable personalisation experience		X

Table 1. Sustainable design considerations for product personalisation
* Design considerations specific to lighting product category.

attached a personally meaningful object to the toolkit, emphasised her positive emotions towards the outcome, which highlights the significance of memories in the user-product relationship. These findings are consistent with previous research on determinants of product attachment (Mugge et al., 2005; Mugge et al., 2008; Schifferstein and Zwartkruis-Pelgrim, 2008). While using post-use materials supports environmental sustainability, their emotional value depends on their personal relevance, as seen in GS1. Both groups' emphasis on the *visibility of the personalised parts* indicated their need for self-expression and social visibility of their contribution, suggesting aesthetic interventions can enhance self-expression and social value, especially as a product's appearance is more readily perceived than its function (Mugge et al., 2009b). *Toolkit size* was also found to be important for the visibility of the personalised parts.

Personalisation method: *Consistency in personalisation methods* emerged as a key design consideration in GS1, where the toolkit included two different shadings. As greater effort in personalisation can increase perceived task complexity and the likelihood of confusion (Mugge et al., 2009b), ensuring consistency in the personalisation process can help make it more intuitive, reducing cognitive load and supporting user confidence. Additionally, *familiarity with the personalisation method* for the target group can reduce effort and enhance their engagement in the personalisation process. In GS2, this facilitated participants' creative involvement, giving them a sense of control over the personalisation task and resulting in more self-expressive outcomes.

Toolkit's adaptability to various skills: In GS2, the participants suggested *integrating additional craft techniques*. Offering diverse design details can accommodate a range of skills, which aligns with empowering local skills for social and economic sustainability (Doğan and Walker, 2008).

Effort and guidance: GS1 participants prioritised practicality and minimising effort, while GS2 participants were willing to invest more effort in the personalisation process. This supports Mugge et al.'s (2009a) argument that *personalisation methods should match users' skills and motivation*. As Mugge (2019b) highlighted, designers need to guide the personalisation process to reduce the possible spoiling of the product. This study also revealed that *guidance via self-explanatory design details, templates, and instructions* is needed for the understandability of personalisation details, to ensure part longevity, to reduce the required effort, and not to hamper the flexibility of the product for re-personalisation, which are important for longer product lifetimes. Moreover, *practical connection details* and an *appropriately scaled toolkit* emerged as important factors in reducing the effort invested in the assembly process.

Flexibility and product life span phase: Flexibility in personalisation can sustain a product's functional and aesthetic value by enabling adaptability and upgradability, making it more resilient to wear and fashion changes, which is important for resource efficiency and emotional durability. The study showed that *flexibility can encourage continued mental engagement*, which may strengthen the user-product relationship. Flexibility can stimulate active product use and reduce the fear of spoiling the product, fostering greater creative involvement in personalisation and supporting product attachment (Mugge et al., 2005; 2009a). Participants highlighted the need for *easy-to-change personalised parts* and *adaptability to various material thicknesses and forms*, the factors that designers can address to enhance flexibility. Moreover, *providing guidance on applicable personalisation methods* can help preserve this flexibility over time, as some irreversible techniques may limit future modifications or disassembly. Furthermore, personalised parts should also be technically durable to prevent product damage and support sustained flexibility in personalisation.

Personalisation benefits and emotional durability: *Enabling the use of self-expressive and memorable materials, providing an enjoyable personalisation experience, facilitating social visibility of the outcome, and investing effort* may be effective in strengthening the user-product relationship. These findings align with the existing literature on factors that foster product attachment (Mugge et al., 2005; Mugge et al., 2009b). Moreover, *the product personalisation process itself and the collaborative creation experience involving the partnership of designer and participants can create memories*, which can

foster user-product relationship, as memories significantly influence product attachment (Schifferstein and Zwartkruis-Pelgrim, 2008).

Insights for the lighting product category: In GS1, participants struggled to receive *prompt feedback on lighting quality and adjust lighting intensity* due to the complicated attachment of parts. Considering this feedback, the generative toolkit was developed further and GS2 participants could quickly achieve these through easy attachment/detachment of parts. Both groups valued *structural adaptability*, which was offered only in GS1 and highly appreciated by the participants.

Design implications across product categories: Based on the personalisation goals identified in this study, the half-way design appears suited to product categories that support *self-expression, social visibility,* and *adaptability*. These include products used in shared or visible settings, such as lighting, decorative objects, and small furniture in home and office contexts, as well as toys, DIY kits, and hobby-related items that invite users to display craft skills. Additionally, personal accessories and products, as well as more complex technological ones adopting open design principles, may benefit from the flexible personalisation opportunities offered by this approach.

Potential implications for open and evolving design: The generative toolkits were developed as design templates, which can be shared openly and produced locally in different sizes. These can be changed in the use phase for changing needs, and enable the re-use and upgrade of parts, which are important considerations for design for sustainability. Besides, involving people in the design and making processes can simplify and enable maintenance and repair, as this enhances users' product comprehension (Bakırlıoğlu and Doğan, 2020). Moreover, *the collaborative nature of half-way design engages diverse stakeholders (users, local producers, designers, makers) across the product lifespan*, can empower local skills, as well as facilitate the creation of memories, and thus product attachment.

The study has several limitations. The use of affordable materials limited structural quality in GS1, and the sample lacked diversity, especially as all GS1 participants were from design-related fields. While age differences existed among the two groups, the study did not examine age as a factor influencing personalisation or user-product relationship. Due to the time frame of the research, the personalisation process was primarily explored during the design phase, without tracking actual usage over time.

Future research could explore the long-term use of half-way products to assess their impact on product longevity and how flexibility of personalisation affects user-product relationship. Further studies can also investigate sustainability implications of half-way design across diverse user groups and product categories, as well as how users with varying skill levels can be supported in personalisation. Additionally, research could investigate how collaborative creation and social visibility influence attachment and sustainability outcomes. Future directions may also include developing toolkits that combine structural flexibility with aesthetic adaptability to integrate local crafts and support post-use repair, as well as conducting longitudinal studies to evaluate generative toolkits adopting half-way or open design approaches.

This paper presents a conceptual model for product personalisation based on user research that re-contextualises existing personalisation dimensions through a sustainability lens. It also reveals design considerations for

product personalisation through the development of half-way design explorations aligned with sustainability principles, paired with an in-depth generative research approach to understand participants' personalisation experiences. The study advances understanding of personalisation through half-way design by employing multiple methods, including design workshops, individual generative sessions, diaries, think-aloud protocols, and interviews, to deeply explore how participants personalise half-way products. The resulting insights offer sustainable design considerations and guidance for developing half-way products.

Appendix A. Interview questions asked in the exploratory study
Product Features Before Personalisation

1. Did you purchase the product or did you make it yourself?
2. (*If purchased*) When did you purchase it? (*If made*) When did you make it?
3. Could you give information about the attributes of the product before personalisation?

(*Production method, aesthetic appearance, functionality, material, etc.*)
Personalisation Process

1. How did you personalise the product?
2. When did you personalise the product?
3. Could you explain your reasons or goals for personalising this product?
4. Considering the product's original version, which attributes enabled or facilitated personalisation?
5. How do you evaluate the personalised version of the product aesthetically?
6. How do you evaluate the personalised version of the product functionally?
7. If any, could you describe the advantages/disadvantages you experienced as a result of personalising this product?
8. What does the personalised product mean to you?
9. How would you like to personalise this product further in the future?

Appendix B. Interview questions asked in GS1 and GS2
A. Personalisation Process

1. Could you explain the changes you made to the toolkit during the one-week/two-week period?
2. Could you explain your reasons for making these changes to the toolkit?
3. Which materials or product parts did you use during your personalisation process?
4. Could you explain the reasons behind your material or product part choices?
5. Which other materials could be used when personalising the toolkit, besides the one(s) you used? Why?
6. Which skills did you use during your personalisation process?
7. Which additional skills could be used when personalising the product, other than the one(s) you applied? Why?
8. If you carried out any preliminary work during the personalisation process, could you describe it?
9. How would you evaluate the personalisation process overall? *(Positive and negative aspects)*

10. If you have any suggestions regarding the personalisation process, could you explain them?
11. (*Reviewing the diaries*) How long did each intervention take during your personalisation process?

B. Personalised toolkit and the suggestions

12. How would you evaluate the design details of the two shading options? *(In terms of ease of personalisation, lighting effect, etc.) (for GS1)*
13. How would you evaluate the toolkit you personalised? *(Positive and negative aspects)*
14. If you have any suggestions regarding the toolkit design, could you explain them?

C. Use phase

15. *(If you used the toolkit)* When did you start using it?
16. Where did you use the toolkit?
17. How do you evaluate the use of the toolkit? *(Positive and negative aspects)*
18. What are your suggestions regarding the use phase?
19. Did you make any changes after you started using the toolkit? If so, what were they?
20. Would you like to continue using the toolkit? If yes/no, could you explain your reasons?

D. Questions about the photographs taken by the participant

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Anahtar Sözcükler: Yarı tamamlanmış tasarım; ürün tasarımında kişiselleştirme; sürdürülebilir tasarım; ürün ömrü; yaratıcı tasarım araştırması

ÜRÜN TASARIMINDA YARI TAMAMLANMIŞ TASARIM YAKLAŞIMIYLA KİŞİSELLEŞTİRME İÇİN SÜRDÜRÜLEBİLİR TASARIM ÖLÇÜTLERİ

Ürün tasarımında kişiselleştirme, bakım ve onarım gibi davranışlarla sonuçlanabilecek güçlü bir ürün-kullanıcı bağının geliştirilmesini destekleyerek ürün ömrünü uzatabilir. Ancak, çevresel ve sosyal sürdürülebilirliğe katkıda bulunmak için, yerel üretim yöntemlerinin, yerel becerilerin ve malzemelerin tasarım ve üretim süreçlerinde kullanımı, ürünlerin yeniden kullanımının ve yükseltilmesinin kolaylaştırılması ve evrilen ürünler geliştirilmesi gibi tasarım ölçütleri de kişiselleştirme stratejilerine entegre edilmelidir. Bu çalışma, ürün tasarımında kişiselleştirmeyi ve bu sürdürülebilirlik ölçütlerinin ürün tasarımına dahil edilmesini destekleyen yarı tamamlanmış tasarım yaklaşımına odaklanır. Çalışma, tasarımla araştırma sürecine birlikte tasarım sürecini entegre eden bir birlikte tasarım yoluyla araştırma yöntemi benimsemekte ve ürün tasarımında kişiselleştirmeye yönelik sürdürülebilir tasarım ölçütlerini araştırmaktadır. Bu amaçla, farklı kullanıcı gruplarının kişiselleştirme hedefleri doğrultusunda iki tasarım senaryosu—yeniden kullanım yoluyla erişilebilirlik ve zanaat becerilerini güçlendirme—geliştirilmiştir. Bu senaryolara dayanarak, iki farklı yarı tamamlanmış aydınlatma tasarımı oluşturulmuş ve yaratıcı tasarım araçları olarak araştırma sürecine dahil edilmiştir. Farklı katılımcılar bu yaratıcı tasarım araçlarını birbiriyle bağlantılı iki yaratıcı tasarım araştırması çalışmasında kişiselleştirmiştir. İlk çalışma sonucunda sürdürülebilir tasarım ölçütleri belirlenmiş ve bulgular, ikinci çalışmanın yaratıcı araç setinin ve yöntemlerinin geliştirilmesine katkı sağlamıştır. İkinci aşamada, ikinci yaratıcı araç setinin yeniden kişiselleştirilmesi ile yeni içgörüler elde edilmiştir. Çalışma, aydınlatma tasarımı bağlamında, ürün tasarımında sürdürülebilirlik açısından önemli olan kişiselleştirme boyutlarını ve tasarım ölçütlerini ortaya koyar.

SUSTAINABLE DESIGN CONSIDERATIONS FOR PRODUCT PERSONALISATION ADOPTING HALF-WAY DESIGN APPROACH

Product personalisation can potentially prolong product lifetimes by fostering product attachment, which can result in care behaviours such as maintenance and repair. To contribute to environmental and social sustainability, personalisation strategies should also incorporate local production methods, local materials and skills, support re-use and upgradeability of product parts, and enable evolving products. This study focuses on half-way design approach, which facilitates personalisation while embedding these sustainability principles. The study employs research through co-design methodology that integrates a co-design process into the research through design process and explores sustainable design considerations for product personalisation. Two design scenarios, enabling affordability through re-use and empowering craft skills, were developed considering diverse target user groups' personalisation goals. Based on these scenarios, two diverse half-way lighting design explorations were developed as generative toolkits. Adopting co-design process, various participants personalised these generative toolkits in two connected generative research studies. In the first study, sustainable design considerations were identified, which informed the refinement of both the generative toolkit and research design for the second study. Further personalisation of the second generative toolkit revealed new

insights in this second phase. The paper reveals key dimensions and design considerations for sustainable product personalisation adopting half-way design approach within the context of lighting design.

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