DOI:
10.1016/j.jengtecman.2024.101803

Document Version
Publisher's PDF, also known as Version of record

Journal of Engineering and Technology Management 71 (2024) 101803

Contents lists available at ScienceDirect

Journal of Engineering and Technology Management

journal homepage: www.elsevier.com/locate/jengtecman

Insights into environmental sustainability implementation during the design stage of New Product Development: An industry perspective

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ARTICLE INFO

Keywords:
Design
Environmental sustainability
Design process
Design for environmental sustainability
Innovation

ABSTRACT

Design is an important stage within New Product Development (NPD) for sustainable development, with increased research on the roles of designers and other stakeholders. However, previous studies have been predominately theoretical, which has provided little insight into the current status of industry when aiming to produce sustainable products. This study investigates these themes further from the perspective of practicing designers to determine how their role supports sustainable NPD. This has enabled the development of an illustrative process model, highlighting the thought and decision-making process of practicing designers when implementing key factors of environmental sustainability. Future research directions have also been outlined.

1. Introduction

Themes surrounding sustainability and design have become increasingly prominent within academia and industry, with previous studies aiming to understand how sustainability should be implemented throughout New Product Development (NPD) (Almoslehy and Alkahtani, 2021; Petala et al., 2010; Yang et al., 2021). With sustainability often being divided into three main themes, or pillars, social, environmental, and economic sustainability (Clark et al., 2009); however, this study will predominately focus on environmental sustainability.

The design stage has been identified by academia as an integral part of NPD, impacting up to 80% of the overall sustainability of a product (Ahmad et al., 2018; EU Science Hub, 2018). Previous studies have focused on specific factors and tools which have been suggested by academia to be implemented within the design process by designers or other key stakeholders during that the design stage of NPD (Delaney et al., 2022; Bhamra and Hernadez, 2021; Ceschin and Gaziulusoy, 2016); however, the status of industry remains ambiguous on what elements of environmental sustainability are being implemented within industry.

The primary goal of the study is to evaluate factors previously identified by Delaney et al. (2022) through an industry-focused lens, investigating the decision-making process of designers, how they implement environmental sustainability during NPD, and any tools or principles which they utilise to aid in the effective implementation of environmental sustainability factors. Research questions were developed, considering how the design process specifically was impactful (Ahmad et al., 2018; EU Science Hub, 2018), and to understand how the key stakeholders of this process can further support sustainable development. Furthermore, the two research questions as outlined below, aim to understand the decision-making process of designers when focusing on environmentally

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https://doi.org/10.1016/j.jengtecman.2024.101803
Received 28 June 2023; Received in revised form 17 January 2024; Accepted 19 February 2024

sustainable innovation, by understanding these processes and how they could be potentially replicated by the wider industry to increase sustainable NPD.

(1) What factors of environmental sustainability are currently being implemented within the design process during NPD in industry?
(2) How do designers manage the decision-making process when the aim is to develop environmentally sustainable innovation?

To address these questions, this study engages with two sets of participants, a group of sustainable-design specialists to understand environmental sustainability from a specialist perspective, before an investigation into the wider design community to determine the current status of industry. Both sets of participants explore key factors of environmental sustainability, their decision-making process, tools, and principles which aid them in their journey to sustainable product development.

2. Research background

The following subsections provide context and insight into the key themes of this study, focusing on the design process, environmental sustainability, and the current tools and principles which are suggested to aid in the implementation of environmental sustainability during the design process.

2.1. The design process

The design process outlines a series of steps taken during the design stage, found within the larger NPD process, featuring key tasks undertaken by designers and other stakeholders to achieve the development of products and/or services. Literature outlines several versions of the design process; however, the typical design process is often depicted as a six-stage process within academia, shown in Fig. 1. Various tasks occur during each stage of the design process, such as problem identification, determination of product function, concept ideation, testing prototypes, as well as finalisation and production of the product (Buchert et al., 2017; Buchert et al., 2014; Chiu and Chu, 2012).

The design process continuously evolves when presented with new challenges, whether that is from industry or global issues. Stucki (2019) highlights that there are some key differences between green vs non-green innovation, concluding that green innovation is more complex and include activities which go beyond the typical innovation or design process. With recent literature highlighting the importance of the design stage for sustainable development, the design process is expected to evolve to include relevant sustainable factors and/or principles (Ahmad et al., 2018; EU Science Hub, 2018). The design process has undergone many iterations, with the primary components or tasks of the design process remaining consistent. Although sustainability and sustainable NPD has been a focus of previous research, with some researchers highlighting key stages where sustainability should be implemented (Go et al., 2015; Gaziulusoy, 2015), there has yet to be a design process developed which encompasses the broad scope of Design for Environmental Sustainability. As innovation progresses towards more sustainable product design and development it is important to equip designers with the skills and knowledge to approach these issues, this study aims to address these themes further.

2.2. Environmental sustainability implementation within the design process

This study predominately focuses on the environmental sustainability pillar, although the remaining pillars, economic and social sustainability, may be mentioned through the study (Purvis et al., 2019). Publications surrounding environmental sustainability, NPD, manufacturing, and design has increased over the past two decades (Purvis et al., 2019). Although environmental sustainability has been a recent focus in relation to design, sustainability and sustainable development has been a prominent theme within academia since the 1980 s (Gardner and Roseland, 1989), the definition being coined by Brundtland and the United Nations (UN) discussing the importance of environmental conservation (Brundtland et al., 1987; Thatcher, 1978).

A recent study conducted by Delaney et al. (2022) reviewed environmental sustainability and design literature which enabled the development of a collection of environmental sustainability "factors" which have been highlighted by literature to be implemented by designers. The term "factors" include principles which designers can apply to enable environmental sustainability, factors which can impact the environment during use or production, socioeconomic elements which could also impact the product design process, and principles which designers must follow to ensure lawful environmentally sustainable production. Other research, such as that conducted by Bhamra and Hernandez (2021), have also identified key components of Design for Sustainability, but this study focuses on the research conducted by Delaney et al., (2022) as it focuses on the environmental sustainability pillar. The factors are summarised in Table 1.

Literature has identified tools and methodologies suggested to aid in the implementation of environmental sustainability within the

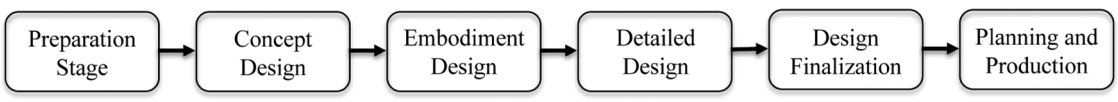

Fig. 1. The typical design process (adapted from Delaney et al., 2022; Chiu and Chu, 2012).

Table 1
Factors of Environmental Sustainability suggested to be implemented during the design process (adapted from Delaney et al., 2022).

Factor of Environmental Sustainability	Definition
6Rs	The 6Rs are a set of six sub-areas to enable sustainable improvement, identified as: reduce, reuse, recycle, recover, redesign, and remanufacture.
Greenhouse Gas Emissions	Greenhouse Gas Emissions are divided into four main components: greenhouse, ozone depletion, acidification, and oxidation potential. Literature has also described this factor as 'Carbon Footprint'.
Waste	To enable environmental sustainability, waste should be reduced throughout the design process. Waste includes process waste, packaging waste, waste from assembly or disassembly, and defect waste.
Energy	The term energy includes energy use and energy efficiency. Energy should be minimized throughout each stage of the design process and product lifecycle.
Renewable Resources	Resources to be in a continuous renewing state, supplying materials, energy, and other resources continually.
Resource Utilization	To enable environmental sustainability, designers should reduce the overall consumption of resources, without limiting the benefits or function of the product for the consumer.
Material Selection	Designers and other stakeholders should consider materials from an environmental sustainability perspective before selecting the final material.
Process Selection	Designers and other stakeholders should select the process which prototypes, and the final product should be manufactured from whilst considering the environmental sustainability considerations.
Transport and Logistics	The selection of the transportation methods and locations throughout the life cycle of the product whilst considering environmental sustainability.
Durability and/or Longevity	To develop a product whist considering the lifespan and potential longevity, considering design elements to maximise the lifespan of the product whilst maintaining the functionality of the product.
Modularity	Modular products can be used to reorganize a product family through the sharing of common modules; this can facilitate upgrades, adaptations, and modifications.
Eco-Business	The economic benefit business can potentially can through the implementation of environmental sustainability in new products should be considered by design and marketing teams.
Structural and Functional Considerations	The adaptation of the structural and/or functional properties of a product to improve the overall environmental sustainability impacts.
Resource Depletion	The consideration taken by design teams of depleting resources and how to avoid the use of these. This is also calculated as the consumption of resources per unit production.
User Behaviour	Considering the user's concerns regarding sustainability as well as designing a product which may prevent the consumer's unsustainable habits.
Toxicity and Hazardous Production	Considering the by-products of development and production of products which could cause hard to the environment.
Government Regulations	Regulations introduced by governments to encourage environmental sustainability within specific industries, these may also include targets and restrictions to adhere to throughout the design process.
Packaging	The consideration of the packaging of the product whilst considering environmental sustainability.

design process of NPD, to be adopted by designers and relevant stakeholders to aid in understanding, assessment, or general implementation.

One of the most frequently discussed tools is the Life Cycle Analysis (LCA) tool, which examines and validates a product design in relation to green design options (Suppipat et al., 2021). Currently LCAs are predominately focused on product development opposed to service development (Sadiq and Khan, 2006). However, although widely renowned throughout academia, it is suggested that only around 18% of designers and engineers currently use LCAs within their design process (Suppipat et al., 2021). It is unclear whether the suggested limited usage of LCAs is due to company access, reluctance to implement/assess environmental sustainability, or the limited education of designers on sustainability issues.

Sustainability software packages utilised during the NPD process have also been identified as being an effective tool to assist designers in the decision-making process for sustainable development. Literature has previously identified the following software packages *EcoFit*, *EcoCAD*, and *EcologiCAD*, all of which are suggested to assist the user of the software in the assessment of environmental sustainability of a given Computer Aided Design (CAD) model, monitoring factors such as material selection and manufacturing process (Raoufi et al., 2019). One of the most frequently discussed software packaged is the *SolidWorks Sustainability* package, which measures and assesses sustainability factors such as carbon footprint and energy using the properties of the CAD model (Gallimore and Cheung, 2016). Although software which has been previously investigated, enables designers to assess CAD models prior to production based on several of the previously identified factors of environmental sustainability, it is unclear how this technology is utilised within industry for sustainable NPD.

Design principles have also been identified by previous academic studies to aid designers in the understanding of environmental sustainability and how this could be potentially applied to the design process. Green design focuses on the individual qualities of the product opposed to the entire lifecycle, focusing on factors such as waste and energy (Otegbulu, 2011). An additional design methodology identified is biomimicry, which aims to mimic nature in design forms, products, or systems through the use of nature as a model, measure, and mentor (Ceschin and Gaziulusoy, 2016). Biomimicry has also been highlighted to be an inspiration to designers rather than a structured methodology which would ensure sustainability (Küçüksayraç and Kirca, 2020). Cradle-to-cradle has also been identified as a key DfS methodology, which has three principles: to use waste as food (closing loops), the energy which fuels the closed loop comes from a current solar income, and to celebrate diversity (Bjørn and Strandesen, 2011). It has also been suggested that the cradle-to-cradle methodology can complement LCA tools in real-world scenarios (Bakker et al., 2010). Design management principles have also explored how to support sustainable development, with Design Management for Sustainability outlined by

Fargnoli et al. (2014) outlining a framework which supports designers in the early stages of the design process for sustainable NPD.

2.3. Transition design theory

As previously noted, this study centres around the factors identified by Delaney et al. (2022) and the identification of other factors and/or principles, focusing on how to prepare and equip designers in industry to adapt their design process to implement key factors of environmental sustainability, with the primary aim of developing a process model to illustrate these themes. Considering these goals, the Transition Design theory has been selected as the theoretical framework to guide this study. Transition Design is summarized by Escobar (2018, p. 156) as 'design-led societal transformations toward more sustainable futures that are place-based, utilize long-term thinking, and consider the living world in all design solutions. By applying an understanding of the interconnectedness of social, economic, political systems, it aims to address problems that exist at all levels of scale in ways that improve human life, including poverty biodiversity loss, decline of community, environmental degradation, resource, and climate change'. Irwin et al. (2013) presents the Transition Design Framework, featuring four stages: Vision for Transition, Theories of Change, Mindset and Posture, and New Ways of Designing. The framework is illustrated as a cycle to aid continuous action, learning, and self-reflection to aid Transition Design and sustainable values. Specifically, the New Ways of Designing stage of the framework highlights that there is a need for a new way of designing to enable sustainable transitions, with Escobar (2018, p.155) explaining 'New ways of designing will help realise the vision but will also change/evolve it. As the vision evolves, new ways of designing will continue to be developed.' This aligns closely with this study as it aims at understanding the current design process from an industry perspective and how this evolves when implementing environmental sustainability. Therefore, this framework is used to guide and interpret the key themes of this study.

3. Research methods

The following subsections outline the research approach, data collection, and data analysis process, investigating the current status of environmental sustainability from a design industry perspective, answering the research questions previously outlined.

3.1. Research approach

Design is multidisciplinary discipline, encompassing various subjects as well as engaging with multiple external stakeholders, Blessing and Chakrabarti (2009) acknowledge the complexity of the subject and have formulated a methodology framework developed specifically for design-focused research, the Design Research Methodology (DRM). The DRM outlines a research approach which enables systematic planning, with the suggestion of various approaches and research methods. Multiple versions of the DRM have been developed to enable flexibility within the application, for researcher to select the approach which aligns best with the given research project. Type 4 of the DRM was selected for this research project as the primary goal of this type is to evaluate the current status of a problem, to understand the support needed or the desired expectation from participants regarding the problem, to develop the support, and to make suggestions of how the support that is developed can be used or further developed in the future, this will enable a thorough investigation into the research questions previously outlined. Table 2 outlines the DRM approach used within the context this study, the DRM is an iterative research approach, but for clarity has been divided into individual stages to outline the approach used.

3.2. Descriptive study I – semi-structured interviews

The primary goal of the DSI is to form an initial understanding of the current status of environmental sustainability within the design industry. Semi-structured interviews were selected as the method for DSI, as this enabled in in-depth review and discussion of each participants current design process, and how they implement key factors of environmental sustainability throughout their role as a designer. This stage of the research methodology focuses on an expert perspective, investigating designers with previous experience

Table 2
Design Research Methodology (adapted from Blessing and Chakrabarti (2009)).

Stage **DRM**	**1** **Research Clarification**	**2** **Descriptive Study I**	**3** **Prescriptive Study A**	**4** **Descriptive Study II**	**5** **Prescriptive Study B**
Approach **Study Context**	Review-based Review the current literature to understand the current status of environmental sustainability within academia and industry.	Review-based Understand environmental sustainability from an industry-expert perspective. Review the primary needs of industry.	Initial Develop an initial support to aid in the understanding of the current status of industry.	Comprehensive Complete a comprehensive study to evaluate initial findings and enable deeper investigation into the design industry's perspective of environmental sustainability.	Comprehensive Develop a final support to aid designers within industry implement environmental sustainability during the design process. Make recommendations for future research.
Research Method	Theoretical Background	Semi-structured Interviews	Initial framework development	Survey	Final framework development and Suggestions for Future Research

in environmentally sustainable innovation, to understand experienced perspectives within this field. However, as this study aims at understanding environmental sustainability within the design process, which will require a more comprehensive review into the wider design industry (Descriptive Study II).

3.2.1. Participant information (DSI)

A total of 21 participants were interviewed as part of the DSI, and a selection criterion was used to ensure that participants were suitable for the study, which was implemented during the reach out process:

Participants had to have industry experience within the field of design.
Participants had to have industry experience of implementing environmental sustainability within their design process.

The reach out process was completed via LinkedIn, utilising the database and network of the research team, identifying sustainability-focused designers within industry. Reviewing and ensuring that participants met the selection criterion was a priority during the reach out process. Many participants were identified through the investigation into the LinkedIn database, where elements such as their job title to identify any sustainability relevant expertise, the company the potential participant worked for to determine whether they were advocates for sustainable initiatives, as well as training and/or education taken relevant to sustainability which would indicate an expansion of design for sustainability knowledge were investigated. Some participants also self-identified via the call for participants post on LinkedIn, however, their profile would also be reviewed prior to the acceptance of an interview. No specific limits such as time spent as a sustainability-focused designer, or years training was set. Once a potential participant was identified, the research team would contact them directly, to discuss the study and determine whether they would be interested in participating. See Table 3 for a summary of participants.

3.2.2. Protocol development (DSI)

Interview questions were formulated to enable a thorough investigation into each participants' design process. The Research Clarification stage or literature review of the methodology, explored further within Section 2 of this study, aided the development of the interview questions and overall research protocol for the DSI stage of the study. Questions focused on the design process, environmental sustainability, as well as the implementation methods and tools which participants currently use to implement identified factors of environmental sustainability. The interview structure was guided by the principles outlined by Easterby-Smith et al. (2018) which enabled unstructured follow-up questions, to enable the investigator and participant to elaborate on topics which were evaluated as important or relevant to the study.

3.2.3. Data collection (DSI)

Interviews were arranged at a time convenient for each participant and were completed throughout a 6-month period. Participants were provided an information sheet which detailed the themes and purpose of the interview, this also informed participants that this was entirely voluntary with no direct benefit to them, and that they would remain anonymous in any published work. This information was confirmed, through participants signing a consent form. Interviews lasted around 40 minutes, and due to the ongoing restrictions surrounding the Covid-19 pandemic, all interviews were conducted online.

3.2.4. Data analysis (DSI)

A transcript was developed for each interview, and NVivo R1 was used to analyse and code the data into key themes. Coding the data followed a 2-stage method, outlined by Easterby-Smith et al. (2018), which coded the transcript through an open-coding method before conducting focused recoding. This enabled researchers to first identify descriptive themes, before performing an in-depth analysis of each theme further.

3.3. Descriptive study II – survey

To provide a more holistic view and understanding of the current status of the design industry for environmentally sustainable NPD, a comprehensive method was selected to investigate the wider design industry. Considering the needs of the study, a survey was selected to be the method for the comprehensive Descriptive Study II (DSII). Additionally, the survey method has previously been adopted to investigate similar themes, such as greenwashing from a graphic design perspective, or eco-design practice within broader manufacturing industries (Deutz et al., 2013; Sansoni et al., 2023). This further supports this method being implemented to investigate Design for Environmental Sustainability from a design industry perspective.

3.3.1. Participant information (DSII)

A total of 378 participants were involved in the survey, where a similar reach out method and selection criterion was used to the DSI:

- Participants had to be currently working within the design industry

The reach out process was completed via LinkedIn, utilising the database and network of the research team, identifying designers within industry. Once a potential participant was identified, the research team would contact them directly, to discuss the study and

Table 3
Summary of DSI Participants.

Participant ID	Job Title	Industry Experience	Academic Experience
ID-1	Product Designer	3 Years in Industry	Completed a bachelor's degree in Product Design and a master's degree in Sustainability.
ID-2	Product Designer and Sustainability Consultant	9 Years in Industry. Founder of a sustainable product-based company	Completed a bachelor's degree in Industrial Product Design.
ID-3	Designer of Sustainability in the Built Environment	8 Years in Industry	Completed both a bachelor's and master's degree in Architecture Design. Lecturer for 9 Years, Researcher for 7 Years.
ID-4	Product Designer and Developer	2 Years in Industry, 1 Year for a sustainability product-based company	Completed a bachelor's degree in Industrial and Product Design.
ID-5	Sustainable Designer	10 Years in Industry	Completed a bachelor's degree in Ceramic and Glass Design, Graphic Design, and a master's degree in Creative Sustainability.
ID-6	Sustainable Designer	1 Year in Industry	Completed a bachelor's degree in Sustainable Product Design.
ID-7	Interdisciplinary Designer	4 Years in Industry	Completed a bachelor's degree in Architecture, a master's degree in Bionic Architecture and an additional master's degree in Fine Arts, 1 Year as a researcher focused on bio-based fabrics.
ID-8	Sustainable Designer	7 Years in Industry, 3 Years employed as a Sustainable Designer	Completed a bachelor's degree in Product Design, a master's degree in design, an additional master's degree in research and innovation, and a Business Sustainability Management Course.
ID-9	Sustainable Designer and Researcher	11 Years in Industry, 5 Years employed as a Sustainable Designer	Completed a bachelor's degree in Design, a master's degree in Eco-Design and Eco-Innovation, an additional master's degree in Computation Design, currently working towards a PhD in Design.
ID-10	Product Developer and Sustainability Consultant	14 Years in Industry, 2 Years employed as a Sustainability Consultant	Completed a bachelor's degree in Industrial and product Design, and a Business Sustainability Management Course.
ID-11	Product Designer and Developer	8 Years in Industry	Completed a bachelor's degree in Design and Craft and a master's degree in Product Design.
ID-12	Designer	15 Years in Industry, Member of a collective called the Climate Designers	Completed a bachelor's degree in Advertising, a master's degree in Communications Design, a course on Sustainability Education, a course on Design for Social Change and has a certificate in Climate Change.
ID-13	Sustainable Designer and Creative Researcher	7 Years in Industry	Completed a bachelor's degree in Fashion and Apparel Design and a master's degree in Sustainable Fashion and Creative Industries.
ID-14	Fashion Designer in Sustainable Fashion	4 Years in Industry	Completed a bachelor's degree in Fashion Technology and a master's degree in Sustainable Fashion and Creative Industries.
ID-15	Sustainable Product Designer	5 Years in Industry	Completed a bachelor's degree in Innovation and Design Engineering and a master's degree in Sustainable Energy Engineering.
ID-16	Product Designer	8 Years in Industry	Completed a bachelor's degree in Sustainable Product Design.
ID-17	Interaction Designer	10 Years in Industry	Completed a bachelor's degree in Fine Art, a master's degree in Industrial and Product Design and an additional master's degree in Design Engineering.
ID-18	Sustainable Design and Innovation Strategy Consultant	21 Years in Industry	Completed a bachelor's degree in Transport Design and a course in Business Sustainability Management.
ID-19	Sustainable Designer	1 Year in Industry	Completed a bachelor's degree in Sustainable Design and a master's degree in Design.
ID-20	Junior Designer	1 Year in Industry	Completed a bachelor's degree in Industrial Product Design.
ID-21	Industrial Designer and Sustainability Strategy	5 Years in Industry	Completed a bachelor's degree in Graphic Design and a master's degree in Industrial Design.

determine whether they would be interested in participating. A reach out statement was also broadcast to the research team's network. Participants had to complete the survey in its entirety, so that the data could be analysed, this omitted some participants. See Table 4 for a summary of participants.

Table 4
Summary of DSII Participants.

	Industry Sectors				Total
Years' Experience	**Consumer Product**	**UX and UI**	**Automotive**	**Miscellaneous**	
Less than 1 Year	38	14	4	4	60
1 – 4 Years	99	30	9	8	146
5 – 9 Years	37	17	1	6	61
10+ Years	24	4	3	3	34
Total	198	65	17	21	**301**

3.3.2. Protocol development (DSII)

Survey questions were formulated to enable a detailed insight into each identified factor of environmental sustainability, which had been identified through the Research Clarification and DSI, these provided the foundation to the survey question development. The survey questions aimed at determining whether each factor was considered by designers, where a given factor would be considered during the design process, and how this factor was implemented from an industry perspective. Survey questions also aimed at identifying any additional factors which were not previously identified. Prior to the main body of questions, participants were asked several self-identifying questions, such as how many years' experience they had within the design industry, and what sector of the design industry they were a member of. This enabled the overall characterisation of the designers, as seen in Table 4. The questions were organised through sub-sections, determined by theme, to ensure questions were understandable and easy to follow for participants. Sample questions can be seen in Appendix A.

3.3.3. Data collection (DSII)

The survey was launched via an online platform and ran throughout an 8-month period. The survey was rolled out via an online platform to enable a safe process due to the ongoing Covid-19 pandemic as well as to increase response rate due to easy access for participants. Prior to the survey questions, participants were provided with an introduction paragraph detailing the themes and aims of the study. Participants were informed that this was an entirely voluntary survey, with an opportunity for 3 participants to win gift vouchers, as an incentive to encourage participation. Participants were also required to consent to their participation in the survey, to demonstrate they understood the purpose of the study and how their anonymous data would be used. If they did not consent, they would immediately and automatically exit out of the survey. The surveys, based on the data collected during the pilot study, were anticipated to take participants between 10 and 20 minutes to complete.

3.3.4. Data analysis (DSII)

Following the completion of the survey, the data was exported to a Microsoft Excel spreadsheet so that the quantitative data could be analysed, the qualitative data on the spreadsheet was further exported to NVivo R1, which was used to analyse and code the data into key themes. Coding the data followed a two-step methodology, first the data was subject to open coding, here the codes were descriptive, and the aim was to organise the data (Easterby-Smith et al., 2018). Following this, researchers conducted focused re-coding, to establish significant codes and themes within the data, this was a highly iterative process to ensure that an in-depth analysis was achieved (Easterby-Smith et al., 2018).

4. Results

The following subsections outline the results from the study, key themes will be discussed using quotations; however, codes were developed using the full manuscripts and the survey responses in their entirety.

4.1. Sustainability designers' perspective

The primary goal of the DSI was to investigate environmental sustainability within the design process, from the perspective of those who had previous experience and education in Design for Environmental Sustainability. The interview process focused on understanding which factors of environmental sustainability, as previously identified through literature, were being implemented within industry, whether any additional factors were considered, and any information regarding the implementation of these factors.

4.1.1. Factors of environmental sustainability

Literature has previously identified 18 factors of environmental sustainability, which are suggested to be implemented within the design process of NPD (Delaney et al., 2022), however, it remains unclear which of these factors are currently implemented by key stakeholders within industry. The DSI was designed to understand this from a specialist perspective within industry. The interviews and data analysis process enabled the identification of 25 factors of environmental sustainability, Table 5 details these factors. Interview participants identified 17 of the 18 factors previously identified by literature, with only Government Regulations not categorised as a factor.

4.1.2. Perceptions of environmental sustainability factors

Throughout the interview process, it was clear that participants considered factors on two levels of priority, describing how some factors had become prompts to implement other factors within the design process. For the purpose of this study these have been described as 'primary' and 'indirect' factors, although these terms were not coined by the participants, these terms will aid in the overall understanding of the concept conveyed throughout the interviews. Primary factors are those described by participants as factors which were 'drivers for designing sustainability' (ID-5), whereas indirect factors were factors which were identified when a participant was discussing a primary factor within their design process. Data analysis identified 10 primary factors, 11 indirect factors, whilst 4 factors were emitted due to there being little support for the factors. See Table 6 to view the primary factors and their corresponding indirect factors as identified by the interview participants.

Table 5
Factors of Environmental Sustainability (DSI).

Factor	Participant's description of the term
Material Selection	'Material selection is a massive part of sustainable design, and you have to be so meticulous with what material you select… you look at the carbon footprint, how it's transported, how it is manufactured and processed.' (ID-6)
Modularity	'Sometimes our life requirements change, or our device can implement new technology, so modularity helps with that.' (ID-9)
Greenhouse Gas Emissions	'The world is focusing on global emissions, more CO_2, but is not the only gas we should avoid.' (ID-8)
Packaging	'You have to develop your product first and then decide how it is going to be packaged. It's an integral part of the product development and of design because of how the product will be presented.' (ID-12, ID-4)
User Behaviour	'Consumers are paying attention to sustainability. After I have made this product, someone is going to use it and then what is going to happen.' (ID-2, ID-6)
Waste	'Sometimes waste is inevitable it is very hard to design a product that doesn't make waste. I try to work with materials that were going to waste.' (ID-6, ID-2)
Localism	'Local manufacturing and distribution systems, so that manufacturing can take place as close as possible to the place of use.' (ID-1)
Structural and Functional Considerations	'The key elements of that are workout in the most efficient way to produce the product, ensure it's safe, function and easy to assemble.' (ID-20)
Resource Utilization	'At the beginning when the product is being prototyped you start thinking whether you can be using less material.' (ID-2)
Process Selection	'We factor it in of how we are going to manufacture it and minimize harmful techniques.' (ID-20)
Energy	'I think about more energy use than energy efficiency. I try to consider it for both material selection and also if I design a device which uses energy to see if there is a way to save it.' (ID-2, ID-9)
Transport and Logistics	'I think that you know when you are considering your product journey you need to consider how is this travelling, how far is it travelling.' (ID-2)
Business	'If you really want to push for sustainability although it's even the ethos of the brands or the brand strategy at the time it's something that you really need to push for it and you need to find a way to sell it.' (ID-13)
Resource Depletion	'If we are thinking about sustainability and whether it will be in a loop, if we are depleting something from nature and we don't have a way of putting it back, then that is not sustainable inherently and we have to try and keep the materials that are in use for as long as possible.' (ID-2)
Renewable Resources	'I think the really great thing about discussing renewables is that it's like it's a really easy step that manufacturers and offices and businesses can take it's almost like especially considering the costs have come down significantly.' (ID-10)
Durability	'We take into consideration what they're (the supplier) doing about it and the life span of their products and the afterwards how are they going to be affected or changed.' (ID-15)
Ethics	'The broadened perspective includes social elements fair trade how people are treated during the process if they're getting there getting a fair wage if they're getting company benefits if they have enough time off all that stuff.' (ID-16)
Toxicity and Hazardous Production	'The selection of the material in the in its production in this use phase sometimes material or object can emit quite bad substances or chemicals let things about indoor air pollution.' (ID-9)
6Rs	'The 6Rs are the base minimum that anyone should even think about. But then, I think many of the sustainability projects have some, one R or two Rs from those what can be somehow utilised in the project, but yeah it depends on the project as well and how deep we want to go basically on the sustainability issues in a way.' (ID-6, ID-5)
End-of-Life	'At the end of a project, it they don't need to be the assets anymore, we will dispose of it responsibly when we do the disassembly, we'll try and make decisions at the beginning so that when we come to take it all apart, it can actually be disposed of responsibly, or where we can we try and reuse components.' (ID-20)
Repairability	'I think usability also fits in within that and creating something that people understand how to fix and that there are pieces that they can replace.' (ID-4)
Water	'We talked about energy and of course water is part of that, but I also feel how we use the water resources is not something we talk about as much as we should. We take water, pure water, for granted because we have a lot of it but in some parts of the world it's not as easy anymore to get water, maybe that is something we should consider more if we want to think holistically.' (ID-5)
Aesthetics	'If you design something in a trend, then you take the risk that it will end very soon if you create a minimal design, it will be a minimal design if you create something from a classic style that's okay it's not in a trend it is not in an obsolete design cycle.' (ID-8)
Regenerative Design	'What I would maybe say it is also important to consider, well at least for me because I studied regenerative design, I don't know if you are familiar with it, but it takes sustainability further. It is not only about aiming for carbon neutral but carbon negativity. So, what I try to do at my work is always try and push the team further about what we do after we achieve carbon neutral, and we should aim for the carbon negativity and not just neutral.' (ID-8)
Craft Techniques	'More than having interconnecting loops of industries that are complementing each other and that one industry or one specific craft even the waste by that specific loop can be taken as an input for another process and again and again until the waste portion is sort of negligible. By focusing a lot of traditional craft techniques, they end up having a much lower level of energy use than other processes that are reliant on machinery.' (ID-1, ID-2)

4.2. The development of the design process for environmental sustainability (Prescriptive Study A)

Following the data analysis and coding enabled the placement of factors within the design process according to the interview participants. At different stages of the design process, primary factors were linked with different indirect factors, which was driven by the different tasks at each stage of the design process. The design process also differed from what was previously highlighted by literature (Delaney et al., 2022; Chiu and Chu, 2012), as participants often described their design process using terms such as 'beginning', 'middle' and 'end' (ID-2, ID-20), and sub-stages were named using the coding and often correlated to tasks being undertaken such as 'prototype'. Data analysis has enabled the development of an initial illustration of the design process, as depicted by the interview participants, which is shown in Fig. 2, and fulfils the Prescriptive Study A as outlined in the methods, as well as providing

Table 6
Primary and Indirect factors (DSI).

Primary Factors	Indirect Factors
Material Selection	Transport and Logistics
	Business
	Resource Depletion
	Durability
	Ethics
	Toxicity and Hazardous Production
	6Rs
	Localism
Process Selection	Renewable Energy and Resources
	Localism
Waste	Toxicity and Hazardous Production
	End-of-Life
Modularity	Durability
	Repairability
Greenhouse Gas Emissions	Transport and Logistics
Structural and Functional Considerations	Durability
Packaging	
User Behaviour	
Energy	
Resource Utilisation	

initial insight into the Research Questions previously outlined.

4.3. Design for environmental sustainability

The main objective of the DSII survey was to understand the design process from a wider industry perspective when focusing on implementing environmental sustainability, enabling an insight into the decision-making process regarding the pre-identified factors.

Interview participants outlined that they considered the factors to be either 'primary' or 'indirect', however coding of the survey data identified a different decision-making/implementation style of the identified factors, survey participants focused on developing groups where factors would coexist and link together within the typical design process. The coding process identified three groups, namely, *user*, *resources*, and *company values*. These terms were not coined by the participants, but from the coding process utilising the language participants used when describing the implementation of individual factors. Each group features a selection of factors, with some factors being included within multiple groups. Due to the extensive list of factors, only factors which were implemented by 50% or more of the survey participants were included within the second round of coding, and therefore any tool or framework developed through the survey results.

The *user* group was identified as having two key components by the participants, the first element focuses on factors that would be attractive to the consumer for promotion purposes of the product of service in the realms of environmental sustainability, 'It's

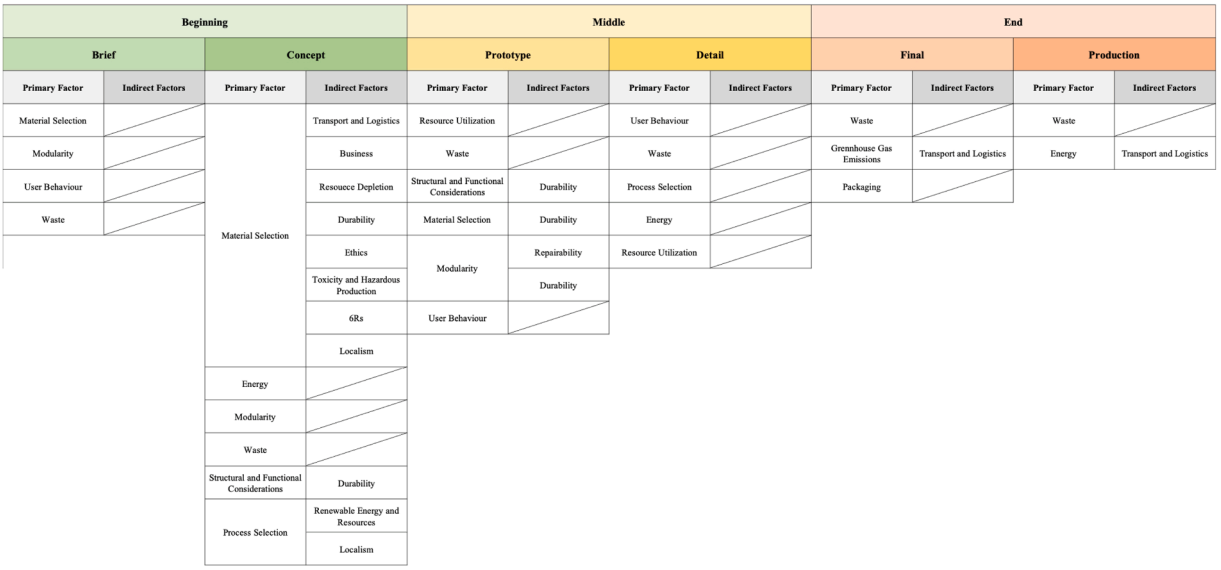

Fig. 2. Initial environmental sustainability design process (Prescriptive Study A).

something "real" that consumers can see, feel, and quickly understand how they are making a difference. It's much more relatable to say, "this product is made from ocean plastic" than something like "this product is offsetting its carbon"', suggesting this will make a positive impact on their purchasing behaviour. The second element of the *user* group focuses on how design could impact the users' potential unsustainable habits, to educate them through design, to make positive changes, 'I would focus on achieving both a good user experience and one that encourages sustainable habits'. Factors identified as being in the *user* group included user behaviour, the 6Rs, material selection, repairability, modularity, waste, and packaging.

Resources were also a focus of survey participants, with coding identifying that participants often grouped factors together to aid in the selection and use efficiency of resources throughout the design process. 'Mostly the design is arrived at and then we try to make it as material efficient as possible.' 'Through the development for manufacture process we design for disassembly so when the product does come to the end of the life parts can be separated and recycled. We look to use a high proportion of recycled content where possible. More recently we have been looking at ways of reducing part count to increase likelihood of a product being separated into its different parts for recycling.' The survey participants also focused on the importance of resources to extend product lifetime to aid in environmental sustainability as well as having some cost benefits to the user or the business, 'I always try to find ways in which the concept can use less material, or how it could be made for disassembly and repair - as it's better to be able to design to lengthen the product life than design for it to be thrown away.' Factors within the *resources* group featured, user behaviour, the 6Rs, material selection, process selection, durability, modularity, waste, end-of-life, renewable resources, and packaging.

The final group identified by participants was *company values*, this was discussed from a variety of perspectives by the survey participants. Participants discussed factors within this group in the context of what was missing from current company values which was possibly hindering sustainable development progress, current company values which were aiding the design for environmental sustainability process, and other elements within the design process which they considered but were at times out of their full control. 'Ethics is increasingly important to business, maybe not for the right reasons (e.g., PR, virtue signalling etc), but still a step in the right direction regardless. I believe it is the responsibility of those with privilege to build ethical solutions, we shouldn't be exploiting for growth.' The importance of ethics to sustainability and business is discussed by the participant in a positive and negative way, however, it is apparent that they feel that any progress should be highlighted. Other participants had sustainability at the forefront of their company, 'I work for a company that has its core business in recycling industrial waste into new products. So, since it is our core, all the design process is done with the recycling process and circular economy into consideration.' With others being offered incentives to include sustainability, 'Company changes such as incentives for sustainable practices and offsetting our footprint.' Factors which were included in this group were government regulations, ethics, the 6Rs, waste, toxicity and hazardous production, and transport and logistics.

The identification of the three groups by the survey participants were an interesting insight into the decision-making process throughout the design stage of NPD. The *user*, *resources*, and *company values* are all areas which would typically be considered by the designer in any design process, regardless of environmental sustainability. This potentially highlights that designers are utilising key areas of a typical design process, to understand how to implement and communicate environmental sustainability best and most effectively to their customers, external stakeholders, and businesses.

4.4. *Design for environmental sustainability process model (Prescriptive Study B)*

A final process model was developed to encompass the findings from the survey data alongside the initial findings from the interview data, as this would reflect the wider design community, shown in Fig. 3. Opposed to showcasing primary and indirect factors, the final process model showcases the three identified groups, highlighting which factors belonged to each group and where they

Fig. 3. Design for Environmental Sustainability Process Model (Preliminary Study B).

Table 7
Rate of factor implementation by DSII participants.

Factor	Participants who implemented the factor (%)	Participants who did not implement the factor (%)
6Rs	63	37
Greenhouse Gas Emissions	45	55
Waste	79	21
Material Selection	76	24
User Behaviour	72	28
Modularity	63	37
Structural and Functional Considerations	49	51
Process Selection	57	43
Packaging	76	24
Energy	60	40
Resource Utilisation	49	51
Transport and Logistics	52	48
Business	49	51
Resource Depletion	41	59
Durability	76	24
Ethics	54	46
Toxicity and Hazardous Production	64	36
Localism	48	52
Repairability	69	31
End-of-Life	63	37
Renewable Resources	56	44
Government Regulations	52	48
Water	33	67
Aesthetics	45	55
Regenerative Design	28	72
Craft Techniques	26	74

should be implemented throughout the design process. Placement of the factors in the specific stages of the design process was found through the quantitative data collected throughout the survey, the individual stages and stage names remain the same as what was found through the interview data collection process.

Only factors which were considered by more than 50% of participants are included in the process model this is to ensure that the model remains relevant and succinct. However, these statistical insights provided clarity of which of the factors were currently a priority within the wider industry. Table 7 highlight the percentage of implementation rate of the factors as identified by DSII participants. The factors which were considered by more the 50% of the survey population have also been reflected within the previously identified coding groups.

4.5. Tools and principles to aid environmental sustainability

Both interview and survey participants were questioned on tools and principles surrounding environmental sustainability within the design process to understand whether any current tools/methodologies aided in the implementation of the factors. Both sets of participants identified that CAD software aided their implementation process, however interview participant ID-21 stated 'some of the CAD programmes do have plugins but again all that stuff is quite unreliable it's not because people didn't have the best intentions in mind but it's quite unreliable too say okay whatever SolidWorks calculates this environmental impact to be is definitely right', although CAD is used, there are some negative perceptions around the reliability and accuracy of the tools. Similar to interview participants, CAD software was identified by around 63% of survey participants as a tool which they used to aid in the implementation of environmental sustainability within the design process. This was identified to be the most frequently used tool by survey participants to aid them in their pursuit of environmentally sustainable design. However, it remains unclear from both sets of participants whether the CAD software encompasses all of the factors that they identified whether the software aids in the prevention of unsustainable development or if it is used more as an evaluation tool. This further supports the findings from literature that CAD software is an essential tool for environmentally sustainable design and development. However, it was clear that some participants valued these CAD-based evaluation tools to provide succinct, digestible data to manage and review some factors of environmental sustainability. Furthermore, these figures were often presented via quantifiable data which they could present to other stakeholders. Participants also indicated that material databases were a tool which they used to aid the understanding of the sustainability impacts during the design process, ID-9 suggested that they were detrimental to their process 'if a designer cannot access to good database, it's really hard to understand how much CO2 is embedded, water or energy and waste are behind a material'. Although material databases were a key tool for interview participants, less than 40% of survey participants indicated that this tool was currently used within their design process. Additional research is needed to understand whether this tool is fundamental to sustainable design so that all designers can be educated on how to use it effectively, as this may support the management of material selection, and the implementation of this factor. Unlike literature, LCAs were only mentioned by a few participants, this supports the more recent findings of Suppipat et al. (2021) who argues that only around 18% of designers use LCAs.

Methodologies and principles were also something identified throughout the study as something which assisted designers in the

implementation of environmental sustainability. The most frequently discussed principles throughout both participant groups were circular economy, cradle-to-cradle, and zero waste. For example, ID-12 discusses how they actively encourage their clients/external stakeholders to focus on circular economy, 'I would definitely encourage my clients to pick and go with resources that and materials that would you know fit into the circular economy, but the circular economy is such a systemic issue', this then enables and encourages them to implement factors of environmental sustainability. ID-17 also discusses how cradle-to cradle was a 'real eye-opening book for me' which shifted their perspective on some environmental sustainability issues. Cradle-to-cradle was also identified by survey participants as being used within their design process to aid their implementation; however, principles were arguably less important to survey participants compared to interview participants, with cradle-to-cradle being the most frequently used. Although literature and interview participants highlighted the importance of these principles, it appears not to have impacted the wider design industry and further research is needed to explore this and to understand how these principles can be implemented into future design processes.

Tools and principles, although not factors themselves, can greatly support designers in the management, implementation, and education of aspects of the factors of environmental sustainability identified. This should be further investigated to determine how new technologies, such as Artificial Intelligence (AI), could shift sustainable NPD.

5. Discussions

Utilising the research methodology, concepted by Blessing and Chakrabarti (2009), an investigation into the current state of the design industry was conducted, investigating sustainability design specialists and the wider design industry. These results have enabled review of key factors of environmental sustainability, and the thought and decision-making process surrounding design for environmental sustainability, comparing the two participant groups, as well as reviewing these findings in comparison to the current literature. Furthermore, the results have answered the two research questions outlined for this study, as the Design for Environmental Sustainability Process Model (Preliminary Study B) has illustrated the factors considered, their placement within their design process, how the design process has been adapted to accommodate for sustainability, the language used by those in industry, and the decision-making process identified.

5.1. Factors of environmental sustainability

Following the review of academic literature into the suggested factors of environmental sustainability, the study aimed to understand these factors from an industry perspective, determining whether they were considered and where within the design process. The results found that both sets of participants implemented factors of sustainability throughout all stages of the design process, however there were some key differences between the two data sets and previous literature. The first difference was between the DSI participants and previous literature, where DSI participants did not identify government regulations to be a factor of environmental sustainability, although some elements of regulations such as those around 'fire safety' (ID-2) were discussed to be potentially limiting to environmental sustainability progress. However, this was contrasted by DSII participants, where over 50% of participants supported existing literature that government regulations should be considered as a factor, with them categorising it as a company value factor, which may lead to other stakeholders aside from designers having greater input on this factor or further support needed from the greater infrastructure of the company. However, as Gifford et al. (2021) suggests, innovation and entrepreneurial activity require policy alternatives to optimise and aid sustainable developments within traditional industries. Therefore, the factor of government regulations, although not considered by the majority of participants at this time, may need to become more of a focus to enable effective implementation of sustainability within NPD.

Following the DSI, a total of 26 factors had been identified, the DSII study was used to provide a final evaluation of these factors. Out of the 26 factors, only 16 factors were implemented by 50% or more participants, with only 4 of those being implemented by 75% or more of participants during their current design process, this can be seen in Table 7. This identified a limitation in the current status of the design industry, as this suggested that around 40% of the identified factors were not being considered by the wider design industry. These limitations could be due to a variety of aspects such as limited education on key Design for Sustainability themes, lack of support from managers or external stakeholders for sustainable development, or inadequate infrastructure to support Design for Sustainability, some of which have previously been identified as green innovation barriers (Stucki, 2019). As explained in Transitions Design theory, posture and mid-set are important to enable the effective implementation and progression towards sustainable design (Escobar, 2018); therefore, further research is needed to explore these issues further, and to determine how to best support designers in the implementation of these factors.

5.2. Decision-making in the design process

Information surrounding the decision-making process for design for environmental sustainability has been limited within current literature, with little evidence on how designers in industry enable sustainable NPD. Data analysis identified two different decision-making methods for environmentally sustainable design. DSI participants primarily divided factors into primary and indirect factors, which aided in the direct implementation of all of the key factors which they had identified. This appeared to be a somewhat complex process with some indirect factors being assigned to multiple primary factors across the entire design process. A notable difference between the DSI and DSII participants was that DSI participants had experience and/or received specific education on sustainable issues, which may have made them more knowledgeable and capable of implementing a more complex decision-making style.

Data analysis of the survey showcased that the decision-making process of the wider design industry differed in comparison, although some of the survey participants indicated that they had received some education experience on sustainability issues, whether it be from industry or education. Typical designers, unlike sustainability-design specialists, made decisions throughout the design process based on three groups (*user*, *resources*, and *company values*). These groups enabled the wide acceptance and effective implementation of some of the factors of environmental sustainability within the design process. It was also found from the survey results, that typical designers were generally more confident in implementing factors which were implemented by 50% of the total participants, therefore these factors were the ones included in the process model shown in Fig. 3. Reflecting on the survey results and codes generated, it is clear that these groups acted as a lens for designers to consider and apply sustainability principles and/or factors through perspectives which are common to every design process. This further showcases the themes described in the Transition Design Framework, as the proposed process model (Fig. 3) illustrates an evolved version of the design process, which has been enabled through the data collection process of this study, further supporting the New Ways of Designing stage of the framework (Escobar, 2018). However, with increasing pressure on designers and NPD teams to be more sustainable there may need to be future emphasis on the lesser-known factors to ensure total environmentally sustainable development.

Evaluation of the two implementation and decision-making techniques used to implement factors of environmental sustainability within the current design process enabled the development of the Design for Environmental Sustainability Process Model. The process model combines the findings from the two studies. First, the process model follows the design process identified by interview participants, using the language used within industry opposed to academia. The process model highlights the three groups identified through the coding process of the survey data, the factors assigned by participants to those groups, and where the factors are currently being implemented within the design process in industry. The Gantt Chart style used within the process model enables easy visualisation of the factors whilst also allowing designers to consider them within their individual contexts. A key finding demonstrated from both the interview and survey results was that designers implement factors of environmental sustainability throughout all stages of the design process, this contradicts some research who have previously suggested that a devoted stage should focus on sustainable development (Petala et al., 2010). Further investigation of the Design for Environmental Sustainability Process Model within an action-research context would enable the validation and improvement of the model as well as a deeper understanding of these groups and how they affect other areas of decision-making within the design process as well as how these factors are managed throughout the entire design process. This may enable further iterations of the model, developments of the design process for sustainable implementation, or a development of a tool to support designers further.

5.3. Limitations

Following this investigation, it is important to outline potential limitations of the study. First the limitations associated with the methods, specifically recruitment and population of the DSII survey study. The survey data was the largest collection point of this study, with around 300 participants; however, 66% of those participants were from the consumer product sector. It is therefore unclear whether the process model collected as part of this study reflects this sector of the design industry opposed to a more holistic representation. Furthermore, around 49% of the survey participants were identified as having 1–4 years industry experience, which was a great difference to those participants who had over 10 years' experience (approx. 11%). Here, it is apparent that the data may also be bias towards designers who could be classified as still relatively early within their design career, and an additional investigation may aid the understanding of the wider design industry. There are also some potential limitations of the recruitment process of the DSI study, as it relied on data inputted by participants on LinkedIn to identify potential sustainability-focused designers. Although LinkedIn is a credible site it is not possible to determine the accuracy of the data inputted and depends on user honesty.

An additional limitation of this study is the applicability of the process model proposed, Fig. 3. Although the Design for Environmental Sustainability Process Model highlights the key factors and where they should be implemented throughout the design process via a typical Gantt Chart format further guidance or illustration may be needed for designers to understand the concept further. The data collected in this study should be taken forward to potentially develop a toolkit or digital application which offers designers additional advice on implementation, tools, and other stakeholders to support them in the pursuit of environmentally sustainable designs.

6. Suggestions for future research

6.1. Industry sectors

The survey participants originated from three industry sectors, consumer product, transport design, and UX/UI design, however further investigation is required into these and other sectors. Around 66% of all participants were identified as consumer product designers, this would suggest that the evidence of this study could be skewed for this design sector, this would include the suitability of the final process model developed. It is anticipated with the changing roles of designers and more diversity within the design community, such as service design, differences may become clearer in the future. This includes how the design process looks like and what is a priority regarding sustainability implementation. Future research should focus on current and upcoming design sectors and disciplines to ensure that they are suitably supported when aiming for environmentally sustainable product or service development.

6.2. Factor implementation

A process model has been developed to illustrate the key factors of environmental sustainability and where they should be implemented throughout the design process. Although designers have demonstrated an understanding of the key factors, it remains unclear how each specific factor is measured or evaluated during each identified stage of the design process or at the end of the design journey. Furthermore, due to the some of the limitations of the data population as previously discussed, it is yet to be determined whether which and where these key factors are implemented differs between design sectors. Further exploration into cases from a variety of design sectors needs to be investigated to determine if there are any adjustments to the process model shown needed depending on these sectors. Any findings from this needed to be presented in an accessible and understandable format from the perspective of the designer to optimise the effectiveness of the tool/process model during the design stage of NPD within industry. Furthermore, as outlined within the limitations section of the discussion, the process model should be experimented with to develop a toolkit or application to support and guide designers further.

6.3. Design education

How education on sustainability impacts the implementation of environmental sustainability throughout the design process remains somewhat unclear. The majority of the sustainability-design specialists had received or taken some form of education on the theme of sustainability, whether this was related to design or not; however, it could not be determined whether this was the element which changed their thought process compared to typical designers. It is also unclear whether industry encourages education to enable sustainable production/futures and how this could change the design industry and process during NPD. As only 4 of the identified factors had been considered by 75% or more of the survey sample, there is an apparent gap in knowledge between the survey and interview participants, which may limit the effectiveness of environmental sustainability implementation. Further research is needed to effectively develop design courses to prepare upcoming designers for the sustainable demands of industry as well as on how current designers can be educated to aid in their current design process. Design education on sustainable issues is also supported by the Transition Design Framework's theories of change which supports the dissemination of ideas, theories, and methodologies on the theme of sustainability to aid in the overall vision of transition (Escobar, 2018).

7. Conclusion

This study has enabled an investigation into the current status of the design industry for Design for Environmental Sustainability, identifying and reviewing key factors of environmental sustainability, determining where they are implemented and managed within the design process, as well as any tools or decision-making methods used by designers. The comparisons drawn between literature, and the two data sets have enabled a detailed review into the factors identified, as well as how to best illustrate the implementation of these factors into the design process, whilst considering the decision-making styles of the design industry. Furthermore, the research methodology enabled the differences between sustainability design experts and the wider design community to be highlighted, resulting in a process model illustrating the design process and findings from the study. This has further aided in the understanding of the design process when aiming for environmentally sustainable development, the process model also has the potential to be used by future designers to replicate this process, aiding in their understanding and education of design for environmental sustainability in industry. Future research directions have also been outlined, additional research is needed to develop understanding in these areas for theory and current practice.

Informed consent

Informed consent was obtained from all subjects involved in the study.

CRediT authorship contribution statement

Emelia Delaney: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing. **Wei Liu:** Conceptualization, Formal analysis, Methodology, Project administration, Resources, Supervision, Validation, Writing – review & editing.

Declaration of Competing Interest

This work was supported by the UK Engineering and Physical Sciences Research Council (EPSRC), grant number: [EP/T517963/1].

Data Availability

The data presented in this study are available on request from the corresponding author.

Appendix A. Survey Sample Questions

Notes:

- If a participant indicated No to a question, they would not be required to answer the relevant, following sub-questions.
- Many questions had pre-determined checkboxes, such as the stages of the design process, or pre-identified tools, but there were also opportunities for participants to provide their own unique answer and more detailed thoughts throughout the survey.

Sample Questions:

- Do you consider the 6Rs as a factor of environmental sustainability during your design process?
- During which stages of the design process do you consider the 6Rs? (Please select all which apply)
- If possible, please use the space below to detail how you implement the 6Rs into your design process.
- Do you evaluate environmental sustainability at the end of your design process?

Please indicate any tools that you use throughout your design process, regardless of environmental sustainability. (Please select all which apply).

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