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Postgraduate design education and sustainability—An investigation into the current state of higher education and the challenges of educating for sustainability

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Introduction: Sustainability has remained an important issue within academia and industry, with more recent focus on sustainability education to ensure that future generations are equipped with the knowledge to continue and champion sustainable outcomes. The design and innovation industry has been continuously identified as important by academia, for having high impact on the potential sustainability of products and services during their development. However, little research focuses on the pre-professional education of designers and whether they receive an appropriate education on sustainable issues in relation to their industry.

Methods: This study investigated these issues within the context of United Kingdom-based postgraduate design courses, to determine the current state of sustainability education as well as the impact of government resources and policies on encouraging sustainability education. Courses were identified utilizing online databases and were evaluated using Sterling's model "Levels of Response to Sustainability Education" to understand the current approach to sustainability within design education, including content and pedagogy, offering recommendations for improvement.

Results: Courses were evaluated against Sterling's model "Levels of Response to Sustainability Education", which enabled the understanding of the current state of higher education and sustainability education with Postgraduate design courses in the UK. Following this review, a model for upgrading sustainability education is proposed.

Discussion: Around 80% of the courses identified throughout this study were ranked as "weak" or "very weak" according to Sterling's model, the proposed model highlights several strategies to aid postgraduate design courses to progress to the "strong" level. The framework model focuses on various sustainability themes to be included within postgraduate design education, teaching methods, as well as the inclusion of a dedicated student reflection period to improve and adapt the sustainability teaching.

KEYWORDS

sustainability education, design education, postgraduate education, postgraduate design, sustainability

1. Introduction

Sustainability is a current and prominent issue facing both industry and academia. By extension, sustainability education for upcoming students has become a recent focus to ensure that students are equipped with suitable knowledge prior to progressing into industry. New Product Development (NPD), and more specifically the design stage, has been identified as a crucial stage for successful sustainable development (Ahmad et al., 2018; EU Science Hub, 2018). Government regulations and other external factors have also focused on the design and development industry providing guidelines and incentives to encourage sustainable development (Delaney et al., 2022; The Design Council, 2022).

This study first summarizes design and the design industry, highlighting the importance of sustainability knowledge, before outlining the pathways into the design industry from United Kingdom (UK) higher education. An investigation into the current state of UK design masters courses is then conducted to understand whether and how sustainability education is being taught by reviewing each identified course using the Levels of Response to Sustainability Education (Sterling, 2003, 2004). The study then investigates government regulations and other relevant external factors impacting the industry, to understand the current status of policies and how these are potentially impacting the incorporation of sustainability into the UK design masters courses. Then, the study makes recommendations regarding the provision of sustainability education and the teaching methods and program structure that can improve and ensure sustainability education implementation with design masters courses.

2. Research background

2.1. Design and industry

Although this study focuses on design education, the design industry, and its importance for sustainable development; it is important to first define these general terms to aid in the general understanding and wider context of the study. “Design” refers to industrial, product, and engineering design, all of which are centered around New Product Development (NPD). The NPD process is generally a series of stages within industry, which enable the development of innovative products for release onto the market. Design teams play a key role throughout NPD, specifically in the design stage where design briefs are constructed, ideas conceptualized, and the development of prototypes and the preparation for manufacture takes place (Delaney et al., 2022). The design process is often collaborative, involving multiple stakeholders. Designers are expected to play a pivotal role in the communication and decision-making process to aid these relationships and the overall success of NPD (Zhang and Zhang, 2013; Krishnakumar et al., 2022).

2.1.1. Pathways into the design industry

Due to the importance of designers for the overall success of sustainable innovation, this study aims at investigating the

education journey of designers (Ahmad et al., 2018; EU Science Hub, 2018). There are multiple pathways into the design industry, which are not always linear. These pathways will be briefly outlined. The UK higher education system is divided into three main areas: typical undergraduate, postgraduate, and other undergraduate courses. Undergraduate courses are typically 3–4 years long, postgraduate courses are around 1–2 years in length for a master's degree but can be longer for a doctorate, and other undergraduate courses can last up to 5 years and result in a diploma or other certification (Edvoy, 2023).

As previously outlined, the design industry and design teams within NPD are multi-faceted, encompassing a variety of industry sectors to aid in successful innovation. However, design higher education remains a relatively new area within the UK university system, as they have historically been rooted in technical colleges and polytechnics (Hurn, 2016). The UK higher education system now features design courses at all levels in the UK higher education system, focusing on a variety of sub-disciplines within design, as well as sustainable design (Delaney and Liu, 2022). This study will focus on masters design courses.

2.2. Design and sustainability

Sustainable development has been a focus of academia for over four decades, since the publication of the Brundtland Report which defined the term as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland et al., 1987, p. 16). The focus toward a more sustainable future has impacted many industries and disciplines, however design has been highlighted as a critical industry for the successfulness of sustainable product development. Furthermore, the UN has specifically highlighted the product innovation and development industry, with Goal 12 of the United Nations (UN) Sustainable Development Goals (SDGs) focusing on responsible consumption and production (Department of Economic and Social Affairs—Sustainable Development, 2022). Designers have been identified as playing a key role for sustainable NPD, with academia suggesting that they can have up to 80% impact on the sustainability of a new product (Ahmad et al., 2018; EU Science Hub, 2018). Recent studies have focused on the relationship between design and sustainability, suggesting that there are 18 factors of sustainability which should be implemented by designers throughout the design stages of NPD to ensure effective sustainable development, these factors include material selection, government regulations/laws/guidelines, modularity, and user behavior (Delaney et al., 2022). With such a detailed list of factors/elements which designers are responsible for within NPD, it is important that designers are educated on key sustainability issues. Furthermore, the Design Council has actively supported designers' role in sustainable change, stating that “Design has a critical role to play in addressing the climate crisis. With huge power to bring about change, designers also have a huge responsibility to help save our planet” (The Design Council, 2022). With industry and academia highlighting the importance of the designers role for sustainable development, it is important that upcoming designers are equipped with knowledge of sustainability issues to prepare for these demands.

2.3. Sustainability education for designers

Education for sustainability has been raised by the UN in the 2030 agenda, which encourages both industry and education to focus on key sustainability issues (Salmond, 2020). Combined with rising awareness of key sustainability issues from global media, there has been an increased pressure to teach sustainability. As designers have been previously identified as key stakeholders within the NPD process for sustainable development, it is important that designers are appropriately educated on relevant sustainability issues (Ahmad et al., 2018; EU Science Hub, 2018). Both sustainability and design are complex disciplines individually, with sustainability encompassing three main pillars social, environmental, and economic. Design which features a range of subjects including engineering, social sciences, and design content (Seay, 2015; Purvis et al., 2019; Delaney and Liu, 2022). The combination of these disciplines is essential in the teaching of sustainability issues within a design context. It is also important that sustainability issues are related to current issues within industry so that upcoming designers can understand real-life challenges and how to solve them through design. Previous research has suggested that partnerships with industry could further aid this applied learning (Souleles et al., 2017).

As sustainability and design are complex and diverse subjects, it is important that they are taught in the most effective, integrated way. Design is often taught through two main learning styles, lecture-based and studio-based (Green and Bonollo, 2003). Studio or project-based learning has also been suggested to aid in the integration of sustainability knowledge within design courses, with McCaw (2022) stating that design students could utilize community groups who act as “clients” simulating real life experiences. Design briefs focusing on sustainability, present students with real sustainability problems which can aid sustainability learning, as it has been identified that students have previously struggled when learning in the hypothetical context (Camacho and Alexandre, 2019). An additional issue highlighted within literature is the reluctance of educators to engage and implement sustainability learning into their specific modules. This could be due to reluctance to change their course content or their own limitations in sustainability knowledge (Figueiró and Raufflet, 2015; Quam, 2016). It has also been suggested that relevant frameworks such as systems thinking could be utilized to aid in the learning of sustainability and how this effects the design process (McCaw, 2022).

Accreditation has been a prominent theme within design education, and this has extended into sustainable education for designers. Accreditation may aid students in reviewing or considering courses to understand if they are (a) reputable within the design and/or engineering community and (b) whether they align with their own personal values and are already recognized through a relevant accreditation body. The Institution of Engineering Designers (IED) has announced that they will be using the UN 17 Sustainability Development Goals as guidance for their accreditation (Institution of Engineering Designers, 2022). The Engineering Council also has also released the Accreditation of Higher Education Programmes 4.0 (AHEP 4.0), who in 2020 published guidance on sustainability which focused on how to

contribute to building a sustainable society and how to go further than the current legislation (Engineering Council, 2021). These are two of the most prominent accreditation organizations within the UK for design higher education courses. Both have been proactive in incorporating sustainability education within their accreditation awarding procedure, which should provide greater incentive to include sustainability education in design curriculums. Accreditation organizations such as the IED also form close relationships with other organizations such as the Society for the Environment. This aids the maintenance and learning of relevant sustainability issues, but also enables the IED to support designers as they progress into industry. For example, they offer registration for Chartered Environmentalists and Registered Environmental Practitioners (Institute of Engineering Designers, 2023). This showcases an example of an accreditation body who is proactively seeking to learn, include, and share sustainable knowledge into their organization.

2.4. Government impact on sustainability

Government impact can be reviewed from multiple perspectives, for example government regulations within industry, potential government influence on universities, and the role governments play in K12 education, all of which have been found to influence design and sustainability. The following sub-sections review the impact of government on sustainability issues from an industry and higher education perspective, relevant to the design discipline.

2.4.1. Industry

Government policy has been identified as a key factor for the progression of sustainability implementation within the design industry (Delaney et al., 2022). It is therefore essential that government regulations, laws, and policies are reviewed to ensure that sustainability is a priority for NPD. The UK Government and Environment Agency have recently updated their research and analysis in the “Regulating for people, the environment and growth” document which outlines some of the key approaches and regulations currently in place or being developed to support sustainable innovation and development (Environment Agency, 2022a,b). Alongside regulations, the UK government are offering incentives to encourage and support businesses in more sustainable endeavors, such as The Climate Change Agreements, which offers tax benefits for those committed to energy efficiency targets (Environment Agency and Department for Business Energy and Industrial Strategy, 2021). This is important for the design sector as they have the potential to be energy efficient in both their design process/production as well as in the product/service which they develop. The UK government are committed to working toward a more sustainable future through promoting schemes and principles such as the Circular Economy to aid in the overall growth and development of sustainability within industry (Environment Agency, 2022a,b). In addition, the Environment Agency have developed the EA2025 translating their vision for sustainable futures within industry, with goals set for 2025. This champions

sustainable development and aims to aid in the development of a nation resilient to climate change (Environment Agency, 2022a,b).

However, the UK Government and Environment Agency acknowledge the limitations regarding regulations for sustainable development, stating “Older or more prescriptive legislation can limit the scope for innovation and new ways of working by not being outcome focussed or allowing flexibility in implementation... Changes in legislation can be slow, while the speed of technological development or new evidence of environmental harm may mean action is needed quickly” (Environment Agency, 2022a,b, p. 4). This highlights the current limitations within industrial legislation for industry, where legislation may be a current hindrance to designers. An additional limitation was identified where the guidance was too general opposed to focusing on specific factors for each industry or similar industry sectors (Environment Agency, 2022a,b). This presents two main disadvantages, first, the legislation can be confusing and hard to identify for specific projects, and second, some legislation restricts new innovation for sustainability. It is important that designers have access to relevant and updated legislation and guidance to ensure that sustainable product development is optimized.

2.4.2. Education

The Department for Education within the UK Government have recently published a strategy for sustainability and climate change for education. The main goals of the strategy are to enable students to learn more about sustainability issues whilst also building a greater connection to nature (Department for Education, 2022). However, this strategy primarily focuses on students aged 5–15, opposed to those in higher education. The strategy discusses higher education by stating “For those that continue their studies in further and higher education, there are many excellent opportunities to gain a more in-depth knowledge into sustainability and climate change. Many further and higher education providers are already taking steps to embed the relevant teaching of sustainability and climate change across the full range of their courses” (Department for Education, 2022, p. 1). While the ethics of government influence on independent higher education institutions can be problematic for institutional autonomy it is also essential to highlight the need for equipping students to address sustainability issues for the greater good. This is of particular importance for an industry shaped by government regulations.

2.5. Levels of Response to Sustainability Education

Previous studies have investigated the presence of sustainability education within design and engineering courses. Edilson Shindi UEDA (2016) reviewed students’ attitudes toward sustainability within their education, design style, and purchasing behavior. The study found that only around 21% of the participants had taken some form of sustainability education within their current year of program registration, however many of the students had a positive mindset toward sustainability and demonstrated their knowledge. The lack of education received, however, reduced their capabilities in implementing sustainability principles throughout

TABLE 1 Levels of Response to Sustainability Education (adapted from Sterling, 2004 and Kolmos et al., 2016; Bateson, 2000; Hay et al., 2010; Jamison et al., 2014).

Level	Response indicator	Sustainability education implementation
Level 1	Very weak	No change to the current structure of the course, this is identified as “zero learning” in relation to sustainability education.
Level 2	Weak	Education about sustainability, not linked to the primary subject of the course. This is identified as an “add-on” strategy, which is mostly content-orientated, which can limit the overall effect/impact of sustainability issues and values for the student.
Level 3	Strong	Education for sustainability, sustainability education linked to specific areas related to the primary subject. This is identified as the “built-in” strategy, where coordination between sustainability and subject discipline takes place, enabling students to apply what they have learnt to real life problems.
Level 4	Very strong	Entire sustainable education reform, sustainability education linked to the primary subject, with additional evidence that the entire university and faculty displayed progression toward sustainability futures. This is identified as the “transformation” strategy, which would require a total redesign of the curriculum and institution, this requires support from course leaders and institutions.

their work. Other studies have focused on undergraduate courses, reviewing the rate of sustainability offerings and the potential teaching styles used throughout these courses. Delaney and Liu (2021) found several undergraduate courses had sustainability learning throughout the typical 3-year program, however very few courses had specific modules dedicated to sustainability or sustainable design learning. In a later study conducted by Delaney and Liu (2022), they investigated sustainability design specialists and their education journey. Through this study it was found that only around 10% of participants had received any sustainability education at undergraduate level. However, around 67% of participants had gone on to take a sustainability focused masters course, which provided them with their fundamental knowledge in sustainable design. This contrast displays the educational needs of these participants as well as the importance of masters courses to improve the knowledge and skillset of designers progressing into industry with sustainability roles. There is limited in-depth knowledge about the sustainability content of these masters courses investigated in this study.

To evaluate these themes further, this study utilizes the model outlined by Sterling (2004), which have since been adapted and developed by other authors such as Kolmos et al. (2016). The Levels of Response to Sustainability framework for this study is shown in Table 1.

Sterling’s framework (Sterling, 2003) has been used previously to evaluate other university courses, such as in the field of civil engineering. It explores the context, mechanisms, outcomes, enablers, and barriers of sustainability education within undergraduate university courses (Gutierrez-Bucheli et al., 2022). Other studies have acknowledged the importance of Sterling’s framework in the overall development, progression,

and implementation of sustainability education within various education institutions (Hegarty et al., 2011; Goworek and Molthan-Hill, 2013). However, this model has not been applied to current UK design masters courses to review the current status of sustainability education.

2.6. Transition design theory

This study, although centered around design education, focuses on how to equip, and prepare upcoming designers for the challenges currently being faced by industry. Sustainability is a global and continuous issue, with the design industry being identified as a key stakeholder for change within NPD. Considering these important themes, 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” (p. 156). Irwin et al. (2013) present the Transition Design Framework, which has four stages: Vision for Transition, Theories of Change, Mindset and Posture, and New Ways of Designing. This framework encourages a continuous cycle and promotes continuous learning, action, and self-reflection to aid in the development toward Design for Transition (Irwin, 2015). The framework encourages scenario development, the incorporation of theories of social change to aid innovation, and collaborative networks (Escobar, 2018). Specifically, the theories of change encourages designers to reflect on their work, aside from some of their perceived biases surrounding sustainable change, and employ transdisciplinary learning. This framework is used to interpret the key themes of this study (Irwin, 2015; Escobar, 2018).

3. Method

This qualitative study utilizes case study method. The case in this study was a selection of design course prospectuses from eight universities, where the data from the university and faculty was published via an online platform. This enabled an insight into the current state of masters design courses, where information published could be utilized and coded to determine the level of implementation of sustainability education within each course identified. The following subsections outline the data collection and analysis process.

3.1. Data collection

Two platforms were used to identify the masters courses: first was *The Universities and College Admissions Service* (UCAS)

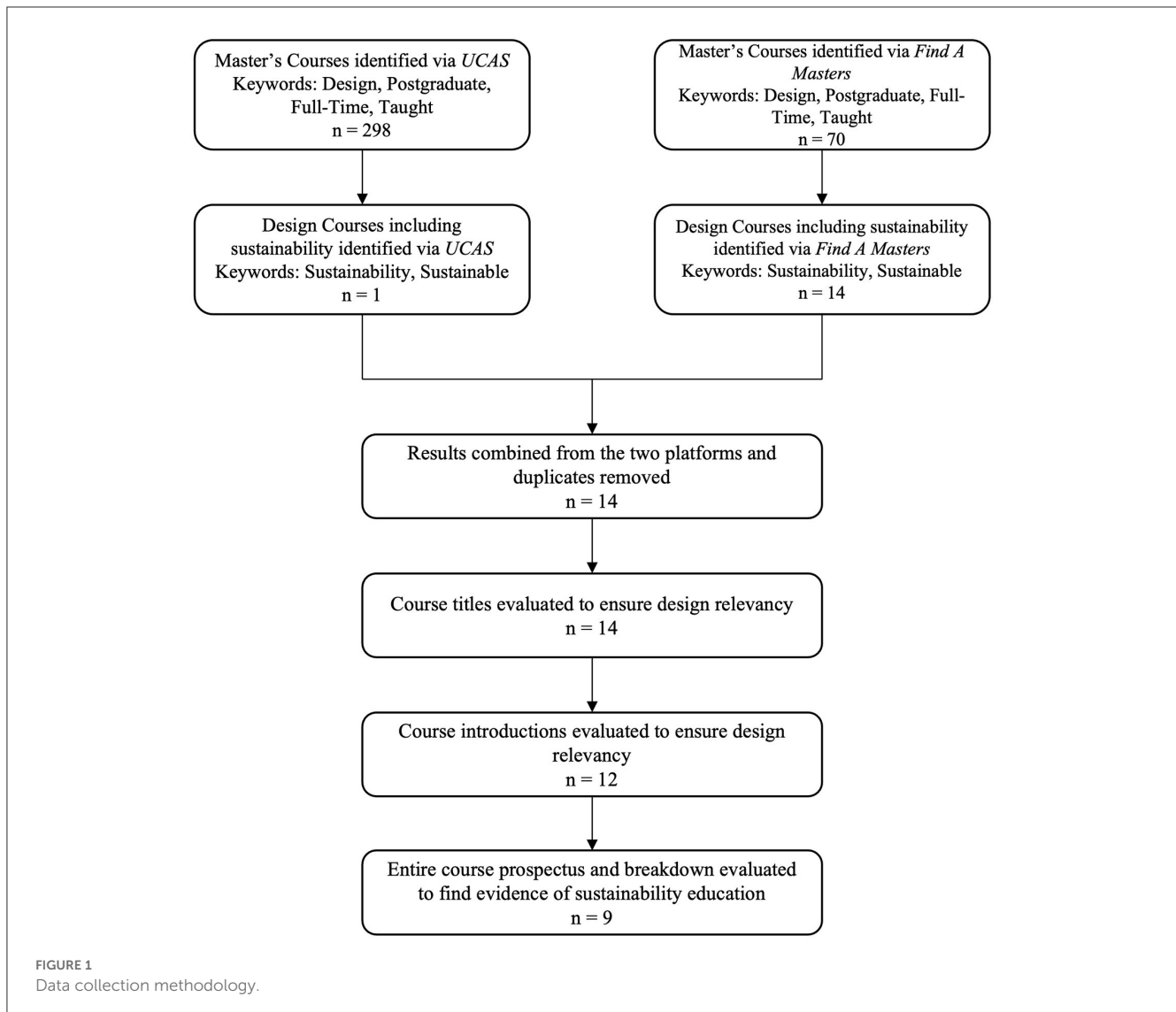
and the second was *Find a Masters*. Both are online platforms which are utilized by current and upcoming students to identify university courses in which they may wish to register. Both platforms highlight courses from around the globe, however UCAS primarily focuses on the UK. To ensure that the review remained relevant, only courses from the upcoming academic year 2023–2024 were reviewed.

The methodology aimed at stimulating a potential students journey to find a masters course in design with some inclusion of sustainability education in which they could potentially apply for the next academic year. Both platforms were used to identify all the design courses available, refining the search by discipline, being full-time offering, and part of postgraduate programme. Then key words were used to identify those courses advertising that they provided some form of sustainability education.

Following this, any duplicates from the two platforms were removed and the remaining courses went through a three-step screening process. First course titles were evaluated to ensure relevancy to the design subject. Next, the course introduction was evaluated to also ensure relevancy. As some titles such as “Design” remained ambiguous, it was important that only subjects related to product design, innovation, and development progressed forward in the methodology. Courses focused on other subjects such as fashion or architecture were excluded. Finally, the entire course prospectus was reviewed, including module/course breakdowns, to identify any sustainability teaching present within the course. Any courses without some form of sustainability information were excluded. Similar research methods have been used by Delaney and Liu (2022). Figure 1 outlines the data collection methodology, including the key words used to refine searches and results.

3.2. Data analysis

Following the data collection process, eight universities were identified, with nine courses available across these institutions. Relevant data from the individual course prospectus and breakdown were extracted to NVivo to code the data into key themes, including sustainability, sustainable design, teaching methods, and course structure (Easterby-Smith et al., 2018). Once key themes had been identified, each course was then evaluated individually using the Levels of Response to Sustainability Education (Bateson, 2000; Sterling, 2003, 2004; Hay et al., 2010; Jamison et al., 2014; Kolmos et al., 2016). The Levels of Response to Sustainability model was used to rank each university course according to the level system outlined. This enabled deep analysis and comparison between courses. Table 2 demonstrates the levels found and how the courses were evaluated throughout data analysis, utilizing a checklist developed based on Sterling’s model which identified the factors the courses were evaluated against. Similar evaluation methods utilizing Sterling’s framework have been used previously throughout academia (Gutierrez-Bucheli et al., 2022). The data analysis process enabled the review of the current state of design masters courses and their level of response to sustainability



education. The results of this review are outlined in detail in Section 4.

4. Results

The following sub-sections outline the results found in this study; the results explore the current state of sustainability education within design masters courses focusing on the level of response to sustainability education, teaching methods, and accreditation.

4.1. Current state of the level of response of sustainability education in design master's courses

Following the initial review, data extraction, and coding, the courses were then be evaluated using the Levels of Response to Sustainability Education framework (Bateson, 2000; Sterling,

2003, 2004; Hay et al., 2010; Jamison et al., 2014; Kolmos et al., 2016), previously detailed in Table 2. Supplementary Table 1 encompasses these themes into one succinct table, showcasing each university, their respective course/s, the general sustainability education information available, as well as any specific module on sustainability education, their education level response indicator, and the justification for this ranking. This review has enabled a closer investigation into the current teachings and methods used to implement sustainable education. It also highlights the limitations of sustainability education within higher education design courses.

Supplementary Table 1 identifies that out of the nine courses, only two of those were assigned the “strong” indicator, five were labeled as “weak,” and 3 “very weak,” no course was identified as “very strong.” This evaluation system has provided a clear review of the current state of design masters courses. The results suggest that the overall current state is “poor” when aiming to implement sustainability education into design masters courses. Furthermore, the methodology identified that there were ~350 design masters courses available for the next

TABLE 2 Data analysis utilizing Levels of Response to Sustainability Education (adapted from Sterling, 2004 and Kolmos et al., 2016; Bateson, 2000; Hay et al., 2010; Jamison et al., 2014).

Level	Response indicator	Sustainability education implementation	Course evaluation checklist
Level 1	Very weak	No change to the current structure of the course.	<ul style="list-style-type: none"> • Sustainability themes included in the introduction. • No evidence of sustainability in the module breakdown.
Level 2	Weak	Education about sustainability, not linked to the primary subject of the course.	<ul style="list-style-type: none"> • Sustainability education included in the module breakdown. • No sustainability education related to design. • Sustainability education was presented as an optional or extracurricular activity.
Level 3	Strong	Education for sustainability, sustainability education linked to specific areas related to the primary subject	<ul style="list-style-type: none"> • Sustainable design education was included in the module breakdown. • Sustainability education was presented as compulsory. • A minimum of one course was available.
Level 4	Very strong	Entire sustainable education reform, sustainability education linked to the primary subject, with additional evidence that the entire university and faculty displayed progression toward sustainability futures.	<ul style="list-style-type: none"> • The entire design course centers around sustainability issues. • The university and/or faculty prioritize sustainability. • Student feedback is listened to, focusing on course content and structure surrounding sustainability education and learning.

academic year. This suggests that the courses which were excluded due to the sustainability education criteria of this study contain no sustainability education. Thus, higher education design programmes in the UK are not effectively incorporating sustainability in their offerings.

4.2. Teaching methods

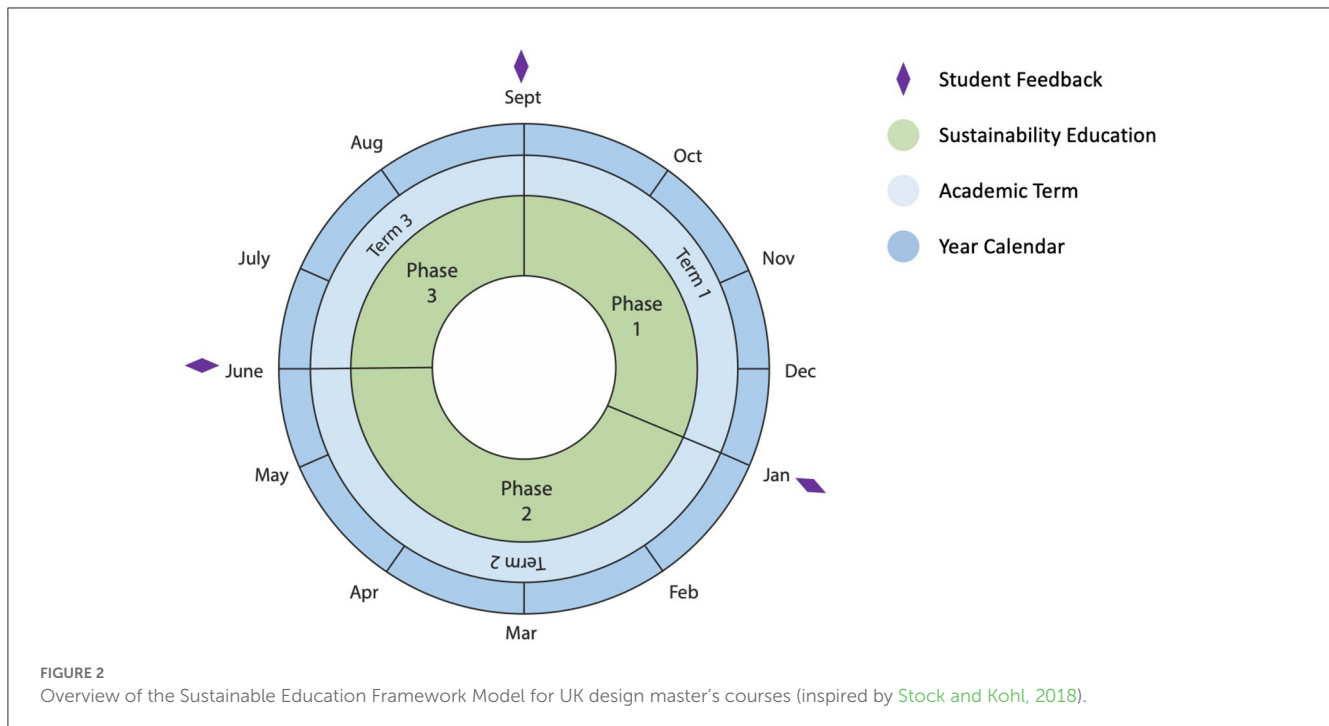
Throughout the investigation coding focused on the presence of the sustainability education as well as how the pedagogy of how sustainability was potentially being taught to incoming students. Several of the courses detailed the current teaching methods, utilizing methods such as lectures, tutorials, workshops, seminars, e-learning, and collaboration within design studios (Cardiff Metropolitan University, 2022; London Metropolitan University, 2022). This provided a brief insight into the current teaching methods, with some of those methods aligning with those previously identified in the literature. However, the course prospectuses were ambiguous on whether these were the teaching methods used for sustainability education or for the design course in its entirety. Many courses did not outline any kind of teaching methods used, so it was more unclear how sustainability was being taught within these courses. Some courses introduced industry partners to support and provide inspiration to students, for example, setting live briefs to simulate real life sustainability issues being faced within the design industry (Brunel University London, 2022; London Metropolitan University, 2022; UAL Central Saint Martins, 2022a,b). This method of introducing industry realities into learning has been previously identified as a positive by literature, as this can aid students in understand issues faced globally and moves away from being taught in the hypothetical context (Souleles et al., 2017).

4.3. Government education regulations

Following the detailed review into the available design masters courses, two out of the nine courses reviewed mentioned government regulations, London Metropolitan University, and the Royal College of Art. The course provided by London Metropolitan University focused on the importance of reviewing government regulations alongside the issues being faced by industry in relation to sustainability (London Metropolitan University, 2022). Consequently, this course ranked “Strong” in showing that course leaders were integrating sustainability education with design. The Royal College of Art also discussed similar themes in relation to government regulations, as well as the UN SDGs. However, they ranked “Very weak,” there was no evidence that the course had changed included sustainability education within specific teachings. This presents ambiguity surrounding government regulations, as there is no clear result of whether government regulations are having an impact on design courses, or whether this is aiding in the successful development of design courses for sustainability education.

4.4. Accreditation

Following the analysis for sustainable education present within the identified design masters courses, the courses were reviewed to determine whether any had been accredited by relevant organizations. From the nine identified courses, two highlighted that they had been accredited via their prospectus websites. The first



course, “Product Design” from Cardiff Metropolitan University, had been accredited by the IED ([Institution of Engineering Designers, 2022](#)), who had announced that they would be using the UN SDGs as guidance for their accreditation ([Cardiff Metropolitan University, 2022](#)). The second course identified as being accredited was “Product Design” from the University of Strathclyde, which had been accredited by the IED and the Institution of Engineering and Technology (IET) as well as stating that they had also met the UK standard for Professional Engineering Competence from AHEP ([University of Strathclyde, 2022](#)). Yet, both AHEP and IED have been previously outlined within Section 2.3 with both accreditation organizations containing some form of sustainability education requirement to receive the accreditation ([Engineering Council, 2021](#); [Institution of Engineering Designers, 2022](#)). The IET is also a well-recognized and established accreditation organization. Both courses who were accredited by the IET were evaluated as “Weak,” suggesting that there was only limited or optional sustainability education available. Further investigation and development are needed into accreditation bodies, and the potential impact they may have for sustainability education moving forward. However, it is important to note that the accreditation organizations investigated accredit a large number of courses who are diverse across design and engineering disciplines, and these results may not reflect the wider consensus of those awarded these accreditations in relation to sustainability education.

4.5. Proposed framework model

It was previously found that around 80% of the courses evaluated were ranked as “weak” or “very weak,” but only around 3% of the total design masters courses available were identified as having any sustainability education at all. Therefore, it is a priority

to ensure that future/current course leaders are equipped with the structure and knowledge to enable sustainable education within design subjects during higher education. Utilizing the findings in the literature and this investigation, a framework model has been developed to display to current course leader’s an ideal design masters course structure including the components that would transform “very weak” or “weak” courses to a “strong” level as suggested by [Sterling \(2004\)](#).

[Figure 2](#) highlights the overall structure of the framework model. The framework model is structured in a wheel style, inspired by [Stock and Kohl \(2018\)](#), which represents the continuous cycle of academic study and improvement. The framework starts in September to represent the start of the UK academic year, and is further divided into three sections, representing Term 1, Term 2, and the Term 3, following the structure of the university courses evaluated throughout this study. The framework is also divided into three phases for sustainability education development, with goals which correlate to the given academic term timetable. Finally, the framework has three diamonds which represent student feedback opportunities. This was a critical factor of a “strong” or “very strong” course as [Sterling \(2004\)](#) states that continuous student feedback was a key factor in sustainability education. The September diamond check point should focus on what students would like to see out of the course in relation to sustainability education as well as relevant design education. The following two student feedback check points are situated at the end of each Term. This enables students to provide feedback on their teaching as well as what they would like to see next term or as feedback for future academic years, regarding sustainability education as well as other general commentary.

Furthermore, UK masters courses typically work on a 180-credit system, where these credits are distributed throughout the three terms, and are awarded based on the grade of the student

for each module. Throughout each phase, shown in the figures in the following sub-sections, the suggested credits to be awarded are also highlighted.

The following subsections explore the key themes found through each Phase of sustainability education.

4.5.1. Phase 1

Phase 1, as shown in [Figure 3](#), takes place during Term 1 of the academic year and focuses on providing students with an academic foundation to basic sustainability concepts. The framework suggests that an Introduction to Sustainability module be included within the first term of the masters course, although this does not qualify as a “Strong” component ([Sterling, 2004](#)), [Delaney and Liu \(2022\)](#) found that many students receive no sustainability education during their undergraduate education, and it is therefore important that these themes are introduced so that they have a foundational understanding of sustainability issues. Introduction to sustainability is suggested to be taught through the lecture method, which has been recognized as one of the main methods to educate design students ([Green and Bonollo, 2003](#); [Vallet et al., 2014](#)).

4.5.2. Phase 2

Phase 2, as shown in [Figure 4](#), focuses on expanding students’ knowledge into more detailed concepts surrounding design and sustainability, with the introduction of the Design for Sustainability compulsory module. This would classify the course as a “strong” in that it encompasses sustainability education within the context of design, as well as being suggested for an individual module. Furthermore, it is suggested to focus on studio-learning, as suggested by [McCaw \(2022\)](#) as being a key method for sustainability education. Focusing on industry issues to aid in taking sustainability out of the hypothetical context for students ([Souleles et al., 2017](#); [McCaw, 2022](#)). This is especially important as students have previously discussed their appreciation of the involvement of industry and industry-focused scenarios when learning about sustainability ([Gutierrez-Bucheli et al., 2022](#)). This component aids at preparing the student for their final term, an individual research component, and for industry involvement, providing more discipline-focused content alongside sustainability issues.

4.5.3. Phase 3

Finally Phase 3, as shown in [Figure 5](#), outlines the sustainability education focus of the final term (Term 3). The majority of courses investigated identified that students would complete an individual research project in Term 3, which would be their greatest contribution to their learning, this aligns with this the framework model in that sustainability elements should be compulsory within this project. Furthermore, it is suggested that industry partners should be invited to work with students, and replicate live briefs from industry. In addition, with addition of the sustainability component within the final project module, the framework also outlines the importance of assessment for sustainability, to ensure that students understand the teachings as well as enable students

to potentially use industry tools, such as a Life Cycle Assessment (LCA) to evaluate their product/service sustainable development. The combination of design and sustainability learning further reinforces the “strong” level status/approach to sustainability education and can be applied to specific and general areas of the design masters courses through the application of this learning in the main project stage.

Phase 3 of the framework model also focuses on the course leaders role in preparation for the next academic year. First, following the guidance of [Sterling \(2004\)](#), it would be the course leaders role to review the student feedback to ensure that the course focuses on relevant sustainability topics as raised by the students. This should further focus on individual course leaders toward opening discussions around how their specific module or subject could be expanded to include sustainability education. Secondly, course leaders are advised by the framework to review policies and regulations surrounding sustainability, including both education and industry regulations. This ensures that the course teaching stay focused on relevant issues as well as policies/regulations that students will be facing as they progress into the industry. Phase 3 of the framework model further suggests that accreditation organizations such as the IED should be monitored to ensure that an obtained accreditation remains accurate of skill sets as well as reflective of any new developments in sustainability education relevant to the design discipline.

5. Discussion

5.1. Sustainability education and design master’s courses

The investigation into the literature on sustainability education and a case study on the state of current design masters courses within the UK has highlighted the limited opportunity for students to learn about sustainability issues within the context of their specialism. This is of particular importance as sustainability is a growing issue, with worldwide interest in the education of students on these important topics ([Department of Economic and Social Affairs—Sustainable Development, 2022](#)). It is even more so for future designers, as design has been identified as a discipline with great influence on sustainability during NPD ([Ahmad et al., 2018](#); [EU Science Hub, 2018](#)).

The initial review conducted as part of the methodology of this study, identified only nine of 350 course offerings with some form of sustainable education available, which is around 3% of all design masters courses currently available for incoming students in the UK. Around 80% of those ranked as “weak” or “very weak” using the Sustainability Education Level Review ([Sterling, 2004](#)). Teaching methods were also explored within the masters courses identified, including lectured, seminars, and collaborative design studio work; aligning with suggestions in the academic literature ([Green and Bonollo, 2003](#)). However, it is important to highlight that the two courses identified as strong in this review had a commonality, which was the integration of industry and live briefs to learn about key sustainability issues. Hypothetic scenario-based teaching has previously been highlighted as a general weakness in design and sustainability

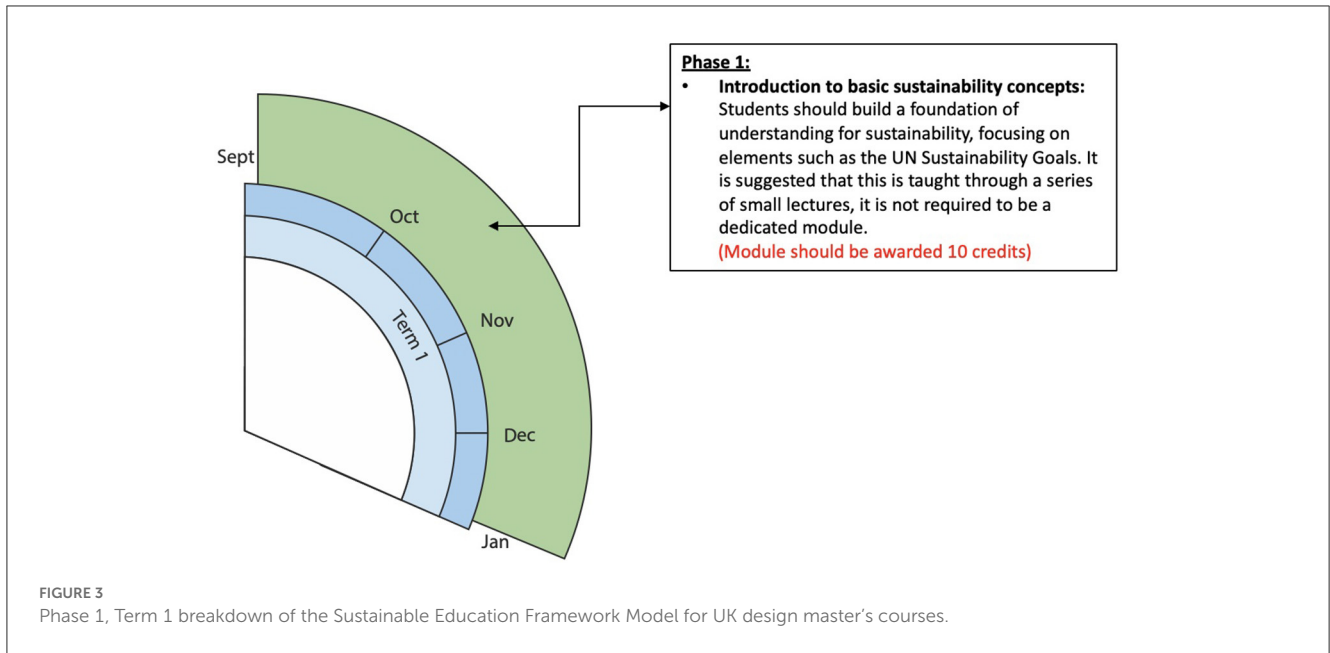


FIGURE 3 Phase 1, Term 1 breakdown of the Sustainable Education Framework Model for UK design master's courses.

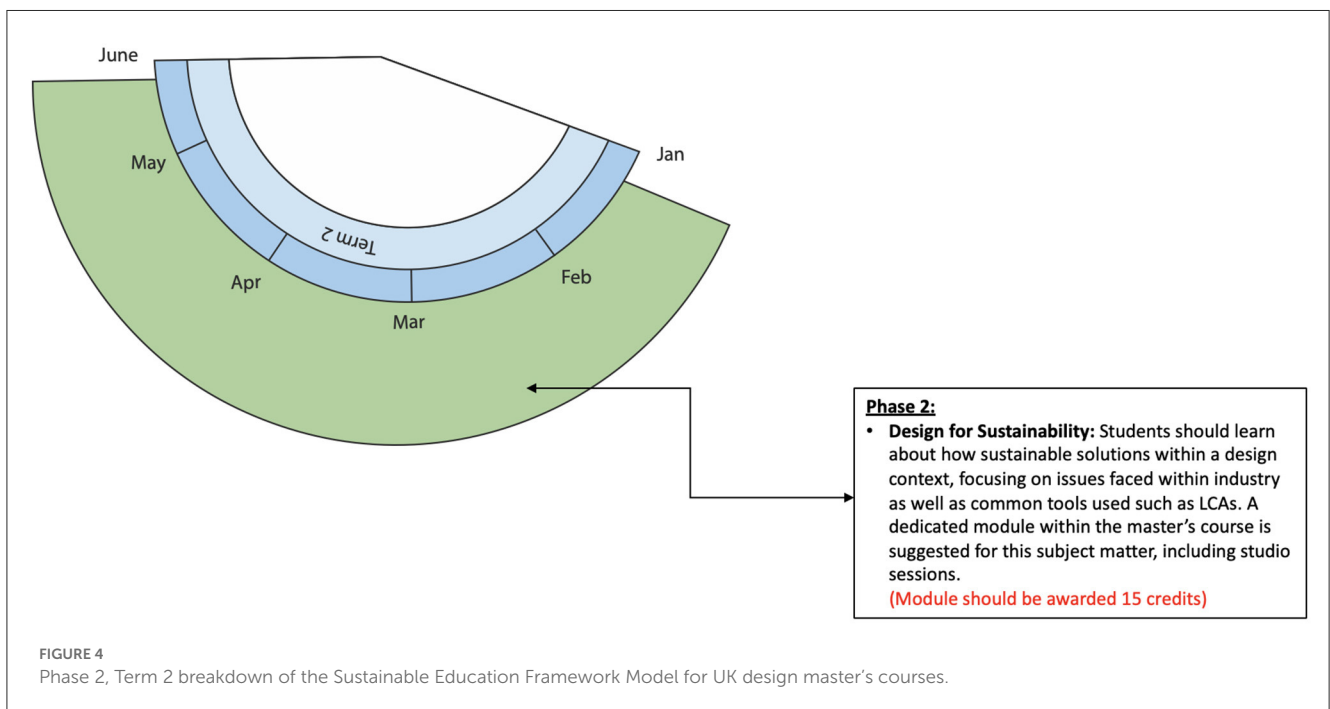
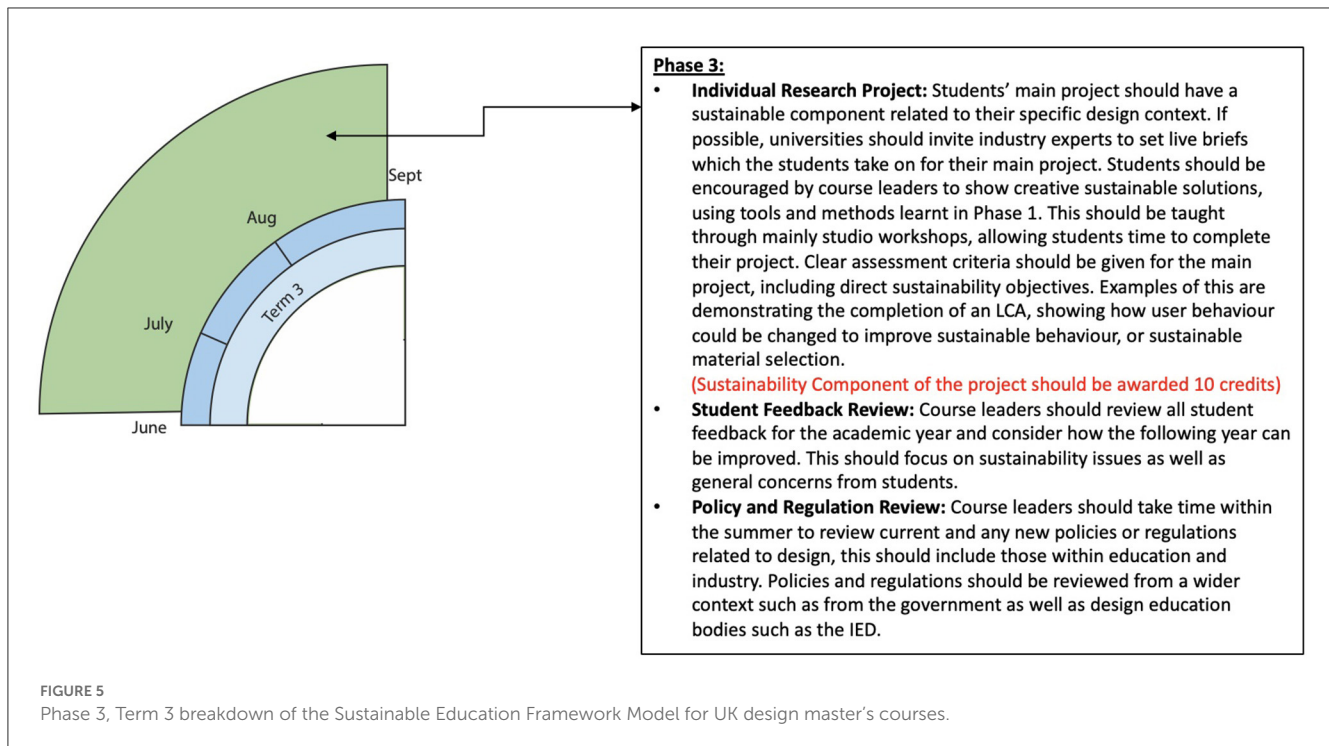


FIGURE 4 Phase 2, Term 2 breakdown of the Sustainable Education Framework Model for UK design master's courses.

education (Souleles et al., 2017; McCaw, 2022), showcasing the benefit of a teaching method that addresses real industry challenges as part of sustainability learning within design courses. Furthermore, the Design for Transitions theory encourages the use of transdisciplinary learning (Escobar, 2018), particularly as the integration of industry takes steps toward this, and enables students to learn from dynamic real-world scenarios. The sustainability education level system used throughout this study (Bateson, 2000; Sterling, 2003, 2004; Hay et al., 2010; Jamison et al., 2014; Kolmos et al., 2016) enabled reflection and insight into the current state of available design masters courses available, their limitations, as well as suggestions on how this could be improved. This

led to the development of the Sustainable Education Framework Model, shown previously in Figure 2. In addition to analyzing the results in comparison to the Response to Sustainability Education model, the current status of sustainability education in UK design masters courses can also be guided by the Design for Transition theory (Sterling, 2004; Irwin, 2015; Escobar, 2018). Utilizing the Design for Transition theory, it is clear that the current state of design masters education in the UK is not yet equipped to facilitate Design for Transition, with few of the university courses investigated integrating any form of sustainability education into their curriculum. However, this should be a goal within design programming.



Although this study has identified and evaluated nine postgraduate design courses, the methodology has some limitations and may have overlooked other courses within the UK who do implement sustainability education, but were not identified in this methodology. Due to the time limitations of the study, every design course could not be investigated individually. Future research should focus on all design courses to determine if any additional lessons can be learned. Furthermore, courses focusing on themes such as the Circular Economy or Industry 4.0, who have some design elements included should also be investigated.

5.2. Government impact on sustainability education

Following the review of government regulations for sustainability within industry and pre-professional education, as well as the investigation into current design masters courses, government regulations and policies currently have a limited impact on the successfulness of sustainability education implementation in higher education. Regulations surrounding design were limited and acknowledged as potentially outdated with the speed of sustainability progression in the field. Regulations for higher education stipulating the incorporation of sustainability education were non-existent, suggesting that universities and course leaders were responsible for sustainability input within any higher education course. Furthermore, the Design for Transition theory encourages cross-disciplinary working, including the potential integration of government legislation and other external bodies such as accreditation organizations aiding in the progression into more transitional design for sustainable outcomes. This will aid designers in their pre-practice education, but also as they

progress into industry, and join teams with external stakeholders. Additionally, legislation and industry practices can encourage designers to reflect on their work by referring to external guidelines, which support Design for Transition (Irwin, 2015; Escobar, 2018). Further investigation is needed into education which has been directly affected by sustainable-focused government policy, for example those which have been implemented for 5–15-year-olds (Department for Education, 2022), to understand how effective this grade school education is and to determine whether stricter policies should be implemented for all stages of lifelong education.

5.3. Sustainability education framework model for UK design master's courses

The primary focus of the framework model is to outline key aspects of a structure for a typical design masters course for it to be recognized as "strong." The framework model is divided into three main stages, following the trajectory of the academic year, with three corresponding phases outlining sustainability education and how this can be embedded into current design education in higher education. The framework utilizes the main goals of the sustainable education level system as well as the information gained through the investigation into previous literature, highlighting key teaching techniques as well as introducing industry scenarios into the education system to aid with the understanding of real sustainability issues (Green and Bonollo, 2003; Souleles et al., 2017; McCaw, 2022). In addition to the use of the model outlined by Sterling (2004), the framework model proposed in this study aims at enabling the progression outlined by the Design for Transition theory. By embedding proactive learning throughout the three terms of the masters course will aid in the facilitation of continuous

learning and action outlined in the theory, as well as in preparing students to lead societal-level, sustainable change through design (Irwin et al., 2013; Irwin, 2015).

The framework model also includes a new component during Term 3, which focuses on the responsibility of the course leaders during their preparation period for the next academic year. One of the major findings from literature, was the limited regulations and policies from the government for sustainability education within the higher education system, with the expectation that this would be implemented by the higher education institutions themselves. However, the investigation into design courses shows that this is limited. The framework aims at encouraging course leaders in investigating regulations and policies relevant to their courses, such as reviewing policies related to the design industry so that they can implement this in future lectures. Regulations and policies within the design industry outline certain restrictions and incentives available to designers. This will be important for future students to understand, and therefore it has been included in the framework model.

The framework model also proposes a student reflection period after each term, allowing students to feedback to course leaders on the education, and more specifically the sustainability education received. This further supports the progression into the Design for Transition approach, as one of the primary factors of the theory was the importance of reflection by designers. The framework model proposed extends this into the education sector, by encouraging course leaders to utilize student reflections on sustainability education to improve and adapt their module.

There are four levels within the Response to Sustainability Education Level model, with “very strong” being the highest. However, this was not the goal of the framework as it requires two things a) the course to be focused totally on sustainable design, and b) the university to have a sustainable mission which correlates with the course (Jamison et al., 2014; Kolmos et al., 2016). Although the “very strong” level would be an optimal outcome, it would require major restructuring of every design course as well as university restructuring.

6. Suggestions for future research

6.1. Sustainable university

One of the limitations of the framework model, as previously outlined in the results section, was that it only demonstrates how design courses can be categorized as “strong” using the Levels of Response to Sustainability Education (Sterling, 2004; Hay et al., 2010) opposed to the highest level of the ranking system “very strong.” The main component which elevates a “strong” course to a “very strong” course for sustainability education is the role the wider faculty and university play for sustainable development, which would be a challenging task to implement into a framework model designed for a certain level and subject of course. However, moving forward it is suggested that research focuses on the impact of institutions at a broad level for sustainability education, to determine whether this has any impact on the sustainable education levels of courses provided by that institution. *People and Planet* are a UK based organization which evaluate universities across

14 categories comprising sustainability, providing insight into the university’s priorities surrounding sustainability such as education, carbon reduction, and ethical investment (*People and Planet*, 2022). This resource has previously been used by Ramirez (2015) and Delaney and Liu (2021) to evaluate the sustainability levels of universities. This could be further used to determine if there is any correlation between the sustainability of universities and the inclusion of sustainability education within higher education courses. Clear correlation could enable more development in the framework model to include suggestions that aid in the development of universities for sustainability and sustainability education. Furthermore, the embodiment of sustainability and societal change throughout a university organization would also support outcomes indicated by the Design for Transition theory, as it would aid in the continuous learning and action toward sustainable change, extending this learning beyond design into other disciplines.

6.2. Accreditation

Accreditation organizations have previously been highlighted to demonstrate the influence they have on higher education design courses, with accreditation organizations more recently focusing how they can introduce sustainability principles as a mandate to obtain their accreditation status (*Engineering Council*, 2021; *Institution of Engineering Designers*, 2022). However, the results suggests that accreditation is currently having negligible effect on the success of sustainability education within design masters courses, with the two courses accredited only being ranked as “weak.” Although the accreditation organizations investigated throughout this study actively investigate and highlight key areas of sustainability which should be included within pre-professional education, further developments or suggestions may be needed to showcase this work in an applicable way to higher education courses.

6.3. Application of framework model

The Sustainable Education Framework Model for UK design masters courses, shown previously in *Figures 2–5*, has been developed using the findings collected from both literature and the review into current design masters courses within the UK. However, due to the size and time limitations of the study there was limited opportunity to apply the framework model to a design masters course to monitor the potential improvement in relation to the sustainability education levels (Bateson, 2000; Sterling, 2004; Hay et al., 2010; Jamison et al., 2014 and Kolmos et al., 2016) and to the general sustainability knowledge of design students. Future research should focus on the application of the framework model, specifically for a design masters course that ranks as “weak,” to monitor overall improvement of sustainability education, to understand the usability of the framework, and to receive feedback from course leaders and students to determine any improvements or iterations needed. The framework has also

been primarily designed for UK-based design masters courses as this was the primary focus of the study, future research should also review whether the methods taken to develop the framework model can be applied to undergraduate level courses, or courses outside of the UK, specifically as design has been identified as an important discipline for sustainable development (EU Science Hub, 2018).

7. Conclusion

This study has focused on the current status of UK design masters courses and their level of response sustainability education. External factors such as accreditation and government policies related to the higher education systems were also investigated. The study utilized Sterling's model to evaluate the current level of response to sustainability education. The investigation into current design masters courses found that sustainability education was limited, and further development was needed to improve the overall level of response to sustainability education. The data analysis process facilitated the review and ranking of 9 identified courses, which enabled the development of the Sustainable Education Framework Model for UK Design Masters Courses. The development of the framework model outlines the key areas for design masters courses to implement sustainable education, utilizing the sustainability education levels and previous literature which showcases suggested themes and teaching methods, as well as highlighting the course leaders responsibility. The framework model encompasses the Sterling's model as well as Design for Transition theory to guide design masters courses with the progression to more effective sustainable education and learning.

The contribution of this study centers around the UK higher education system, providing guidance for course leaders on the structure, teaching, and content for sustainable education for design. The findings of this study may also aid in the general understanding of sustainability education within the design discipline, showcasing the importance of upcoming designers' education on sustainability issues, as well as highlighting areas for future development. Future research suggestions have also been outlined; development is needed in these areas to further support the framework model developed through this study as well as sustainability education implementation within the design discipline.

References

- Ahmad, S., Wong, K. Y., Tseng, M. L., and Wong, W. P. (2018). Sustainable product design and development: A review of tools, applications and research prospects. *Resour. Conserv. Recycl.* 132, 49–61. doi: 10.1016/j.resconrec.2018.01.020
- Bateson, G. (2000). *Steps to an Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution, and Epistemology*. Chicago, IL: University of Chicago Press.
- Brundtland, G. H., Khalid, M., Agnelli, S., Al-Athel, S., and Chidzero, B. J. N. Y. (1987). *Our Common Future*. New York: Oxford University Press, 8.
- Brunel University London (2022). *Integrated Product Design MSc*. Available online at: <https://www.brunel.ac.uk/study/postgraduate/integrated-product-design-msc> (accessed March 22, 2023).
- Camacho, B., and Alexandre, R. (2019). Design education. University-industry collaboration, a case study. *Design J.* 22, 1317–1332. doi: 10.1080/14606925.2019.1594958
- Cardiff Metropolitan University (2022). *MSc Product Design*. Available online at: <https://www.cardiffmet.ac.uk/artanddesign/courses/Pages/mscapd.aspx> (accessed April 17, 2023).
- Delaney, E., and Liu, W. (2021). "Sustainability and design education: The current status of product design higher education in the UK," in *ASME 2021 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (Minneapolis). doi: 10.1115/DETC2021-68461

Data availability statement

Publicly available datasets were analyzed in this study. The remaining data presented in this study are available on request from the corresponding author.

Author contributions

ED and WL contributed to the conception and design of the study. ED organized the database, performed the statistical analysis, and wrote the first draft of the manuscript. WL supported the analysis with overall supervision. All authors contributed to the revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/frsus.2023.1148685/full#supplementary-material>

- Delaney, E., and Liu, W. (2022). "Design and engineering education for sustainability," in *2022 ASEE Annual Conference & Exposition*.
- Delaney, E., Liu, W., Zhu, Z., Xu, Y., and Dai, J. (2022). The investigation of environmental sustainability within product design: A Critical Review. *Design Sci.* 2022, 11. doi: 10.1017/dsj.2022.11
- Department for Education (2022). *Sustainability and Climate Change: A Strategy for the Education and Children's Services Systems*. United Kingdom: GOV.UK.
- Department of Economic and Social Affairs—Sustainable Development (2022). *Do You Know All 17 SDGs?* United Nations. Available online at: <https://sdgs.un.org/goals> (accessed December 8, 2023).
- Easterby-Smith, M., Thorpe, R., Jackson, P. R., and Jaspersen, L. J. (2018). *Management and Business Research*. Newcastle upon Tyne: Sage.
- Edilson Shindi UEDA (2016). Design education for sustainability (I) a survey of product design students' attitude toward environmental consciousness. *Bullet. Japan. Soc. Sci. Design* 63, 4–10. doi: 10.11247/jssdj.63.4_1
- Edvoy (2023). *The UK Higher Education System Explained*. Available online at: <https://edvoy.com/articles/uk-higher-education-system/> (accessed April 20, 2023).
- Engineering Council (2021). *Guidance on Sustainability*. Available online at: <https://www.engc.org.uk/sustainability> (accessed April 16, 2023).
- Environment Agency (2022a). *Regulating for People, the Environment and Growth, 2021*. GOV.UK. Available online at: <https://www.gov.uk/government/publications/regulating-for-people-the-environment-and-growth-2021/regulating-for-people-the-environment-and-growth-2021#our-approach-to-regulation-1> (accessed April 20, 2023).
- Environment Agency (2022b). *Environment Agency EA2025: Updates 2022 to 2023*. United Kingdom.
- Environment Agency and Department for Business Energy and Industrial Strategy (2021). *Environment Agency Helps Industry Reduce Carbon Emissions to Fight Climate Emergency*. United Kingdom: GOV.UK.
- Escobar, A. (2018). *Designs for the Pluriverse: Radical Interdependence, Autonomy, and the Making of Worlds*. Durham, NC: Duke University Press.
- EU Science Hub (2018). *Sustainable Product Policy*. European Commission. Available online at: <https://ec.europa.eu/jrc/en/research-topic/sustainable-product-policy> (accessed October 23, 2020).
- Figueiró, P. S., and Raufflet, E. (2015). Sustainability in higher education: A systematic review with focus on management education. *J. Clean. Prod.* 106, 22–33. doi: 10.1016/j.jclepro.2015.04.118
- Goworek, H., and Molthan-Hill, P. (2013). "Embedding CSR within the undergraduate business curriculum: The development of a Sustainable Organisation module," in *Education and Corporate Social Responsibility International Perspectives*, eds J. Ahmad and D. Crowther (Bradford: Emerald Group Publishing Limited), 57–76. doi: 10.1108/S2043-0523(2013)0000004006
- Green, L. N., and Bonollo, E. (2003). Studio-based teaching: History and advantages in the teaching of design. *World Trans. Eng. Tech. Edu* 2, 269–272.
- Gutierrez-Bucheli, L., Reid, A., Kidmana, G., and Lamborn, J. (2022). "Exploring a tertiary civil engineering curriculum program to envision engineering education for sustainability (EEFS)," in *33rd Australasian Association for Engineering Education Conference (AAEE 2022): Future of Engineering Education: Future of Engineering Education* (Sydney).
- Hay, I., Freeman, M., Holmes, J., Cameron, I., Hadgraft, R., Henderson, A., et al. (2010). *Learning and Teaching Academic Standards Project. Arts, Social Science and Humanities, History, Learning and Teaching Academic Standards Statement*. Australia.
- Hegarty, K., Thomas, I., Kriewaldt, C., Holdsworth, S., and Bekessy, S. (2011). Insights into the value of a 'stand-alone' course for sustainability education. *Environ. Educ. Res.* 17, 451–469. doi: 10.1080/13504622.2010.547931
- Hurn, K. M. (2016). Joined up thinking? A review of the impact of a higher education and industry partnership on undergraduate product design students. *Indus. High. Educ.* 30, 129–139. doi: 10.5367/ihe.2016.0298
- Institute of Engineering Designers (2023). *Environmental Design Registration*. Available online at: <https://www.ied.org.uk/professional-registration/environmental-design/> (accessed March 22, 2023).
- Institution of Engineering Designers (2022). *Sustainable Development Policy*. Available online at: <https://www.ied.org.uk/sustainable-development-policy/> (accessed March 22, 2023).
- Irwin, T. (2015). Transition design: A proposal for a new area of design practice, study, and research. *Design Culture* 7, 229–246. doi: 10.1080/17547075.2015.1051829
- Irwin, T., Tonkinwise, C., and Kossoff, G. (2013). "Transition Design: Re-conceptualizing whole lifestyles," in *Head, Heart, Hand: AIGA Design Conference* (Virginia).
- Jamison, A., Kolmos, A., and Holgaard, J. E. (2014). Hybrid learning: An integrative approach to engineering education. *J. Eng. Educ.* 103, 253–273. doi: 10.1002/jee.20041
- Kolmos, A., Hadgraft, R. G., and Holgaard, J. E. (2016). Response strategies for curriculum change in engineering. *Int. J. Technol. Design Educ.* 26, 391–411. doi: 10.1007/s10798-015-9319-y
- Krishnakumar, S., Berdanier, C., Lauff, C., McComb, C., and Menold, J. (2022). The story novice designers tell: How rhetorical structures and prototyping shape communication with external audiences. *Design Stud.* 82, 101133. doi: 10.1016/j.destud.2022.101133
- London Metropolitan University (2022). *Environmental, Sustainable and Regeneration Design - MA*. Available online at: <https://www.londonmet.ac.uk/courses/postgraduate/environmental-sustainable-and-regeneration-design--ma/> (accessed April 17, 2023).
- McCaw, C. (2022). Education for sustainability: Learning from and with living systems. *Fut. Educ. Cult. Nat. Learn. Become* 1, 130249. doi: 10.7146/fecun.vii.130249
- People and Planet (2022). *People and Planet University League 2022/23*. People and Planet. Available online at: <https://peopleandplanet.org/university-league> (accessed December 8, 2022).
- Purvis, B., Mao, Y., and Robinson, D. (2019). Three pillars of sustainability: In search of conceptual origins. *Sustainabil. Sci.* 14, 681–695. doi: 10.1007/s11625-018-0627-5
- Quam, A. (2016). *Integrating Sustainability Literacy into Design Education*. Brighton: Design Research Society International Conference.
- Ramirez, M. (2015). "Commitments of university leaders to the Talloires Declaration: Are they evidenced in industrial design teaching and learning?" in *Integrative Approaches to Sustainable Development at University Level*, eds W. Leal Filho, L. Brandli, O. Kuznetsova and A. Maria Finisterra do Paço (Berlin: Springer), 225–244. doi: 10.1007/978-3-319-10690-8_16
- Salmond, J. (2020). *Interdisciplinary Methodologies to Teach Sustainable Design: Case Studies from a "Sustainability University"*. International Conference on Sustainable Development.
- Seay, J. R. (2015). Education for sustainability: Developing a taxonomy of the key principles for sustainable process and product design. *Comput. Chem. Eng.* 81, 147–152. doi: 10.1016/j.compchemeng.2015.03.010
- Soules, N., Savva, S., and Ferreira, A. M. (2017). "The challenge of embedding design for social change and innovation in Higher Education curricula and the role of DISCERN (DesIgn for Social Change and innovation through a European Network)," in *9th International Conference Senses and Sensibility 2017* (Madeira Island).
- Sterling, S. (2003). *Whole Systems Thinking as a Basis for Paradigm Change in Education: Explorations in the Context of Sustainability*. (Ph.D. thesis), Centre for Research in Education and the Environment, University of Bath, Bath, United Kingdom.
- Sterling, S. (2004). "Higher education, sustainability, and the role of systemic learning," in *Higher Education and the Challenge of Sustainability*, eds P. Blaze Corcoran and A. E. J. Wals (Berlin: Springer), 49–70. doi: 10.1007/0-306-48515-X_5
- Stock, T., and Kohl, H. (2018). Perspectives for international engineering education: Sustainable-oriented and transnational teaching and learning. *Proc. Manufact.* 21, 10–17. doi: 10.1016/j.promfg.2018.02.089
- The Design Council (2022). *Sustainability*. Available online at: <https://www.designcouncil.org.uk/who-we-are/about-us/sustainability/>
- UAL Central Saint Martins (2022a). *Postgraduate MA Design (Ceramics, Furniture, Jewellery)*. Available online at: <https://www.arts.ac.uk/subjects/3d-design-and-product-design/postgraduate/ma-design-ceramics-furniture-jewellery-csm>
- UAL Central Saint Martins (2022b). *Postgraduate MA Biodesign*. Available online at: <https://www.arts.ac.uk/subjects/textiles-and-materials/postgraduate/ma-biodesign-csm> (accessed April 17, 2023).
- University of Strathclyde (2022). *MSc Product Design*. Available online at: <https://www.designcouncil.org.uk/who-we-are/our-foundations/sustainability-commitment/> (accessed June 5, 2023).
- Vallet, F., Eynard, B., and Millet, D. (2014). Proposal of an eco-design framework based on a design education perspective. *Proc. CIRP* 15, 349–354. doi: 10.1016/j.procir.2014.06.011
- Zhang, L., and Zhang, X. (2013). Multi-objective team formation optimization for new product development. *Comput. Indus. Eng.* 64, 804–811. doi: 10.1016/j.cie.2012.12.015