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Engagement with Higher Education Surface Pattern Design Students as a Catalyst for Circular Economy Action

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Abstract: The 'circular economy' is seen as an approach by which the issue of sustainability can be addressed whilst broadly maintaining patterns of production, consumption, economic growth, and living standards. If circular economy ambitions are to be achieved, ways and processes of manufacturing need to radically change from the current linear model, and there is the potential for higher education students to act as active participants and catalysts, as explored in this research. The objective of this study is to demonstrate the potential for collaborative learning projects to generate value to all stakeholders and participants, with the definition of value pertinent to each participant's needs whilst also addressing the principles of circular economy. A case study collaborative learning design project is used to illustrate the positive direct and indirect outcomes and to show how such design projects can form part of a wider drive for transition through innovation towards circular economy ways of working. We consider this research to be at the intersection of circular economy advancement and the integration of effective methods of education for the circular economy in higher education. A cohort of 29 undergraduate surface pattern design students was engaged in a challenge-based design project co-created with an established manufacturing firm. This research shows how such projects provide learning not only for students but also the case study firm and give tangible outputs in terms of new value-generative products. Through an examination of the reflective comments of participants, an outline of key aspects to consider in delivering such projects to ensure greatest impact is identified.

Keywords: circular economy; manufacturing; systems thinking; student experience; experiential learning; fabric waste; value generation; collaborative learning

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1. Introduction

1.1. The Circular Economy and the Challenge Facing Manufactures

The circular economy (CE), a concept popularised by Pearce and Turner [1] and building on the work of Stahel [2], is seen as an approach by which the issue of sustainability can be addressed whilst broadly maintaining patterns and systems of production, consumption, economic growth, and living standards [3]. Perhaps because of this, it is a favoured path to sustainability, but it is not the only one. Contraction Economics, otherwise known as 'de-growth,' is a proposal that advocates for less rather than the pursuit of infinite growth [4,5]. However, as a pragmatic response to sustainability in the current socio-economic system, we adopt CE as a valid concept. Geissdoerfer et al. state that sustainability and CE can be considered to have different aims and beneficiaries. Sustainability has a wider, overarching concern that benefits the environment and the generalised social and economic spheres, while the main beneficiaries of CE are the economic entities (firms, individuals) that implement the system [6]. It is this context that this research explores by examining an approach that a manufacturing firm can take to transition to CE operations that generate

value (monetary) benefits. Within a consumer economy, it is the products that are made and consumed or, more accurately, how they are made that govern the possibility of achieving sustainability through CE. As Papanek states, 'There are professions more harmful than industrial design, but only a few of them.' [7] (p. ix), accusing product designers of filling the world with unsustainable garbage. Equally, it is design and designers that hold the power to make positive change.

If CE is accepted as a model to achieve sustainability, a paradigm shift is required in manufacturing in order to achieve sustainability through the adoption of CE, and this, in turn, requires innovation in design thinking, processes, and skills to achieve a successful transition. CE implementation guidance frameworks for firms are now being produced, including by BSI, who have developed BS 8001:2017 as a framework standard. Two of the key elements identified are innovation, where value is created through the design of processes, products, and business models, and collaboration, whether formal or informal, or internal or external [8]. This research addresses these two elements specifically and does so through the example of higher education engagement as an external collaborative partner to offer innovative design-led solutions. As Chick believes, it is 'the design profession [that] has a central role to play in finding new alternatives to our present unsustainable consumer culture' [9] (p. 163).

1.2. Teaching the Circular Economy

There is a significant discussion in the literature on Education for Sustainable Development (ESD). Felgendreher & Löfgren note that this has proliferated since the 1990s but that progress in refining the pedagogy framework and activity tends to exist within the conceptual, descriptive, and exploratory and lacks ambition [10]. Webster Identifies ESD as a key actor if the transition to CE is to become feasible [11]. Webster states that the existing education system reflects and reinforces the current linear economy. However, CE depends on a societal change in both values (how we think about consumption and systems), the way we provide for our wants and needs, and that radical change in education. These changes are needed to ensure that people able to think about systems, are creatively innovative, work collaboratively, and practice reflectively [11]. Blaze, cited in [12], states that disciplinary traditions and boundaries create significant inertia that is a struggle to overcome, illustrating a structural impedance to implementing ESD. Pedagogy guidance, handbooks, and toolkits exist in the literature [13,14], but these are framed to support educators within the existing bounds of current education systems rather than being situated where the challenges lie, within the production/consumption system. Friedman has described a comprehensive set of challenges faced by designers that sets out how curricula must respond. He has grouped these into four thematic areas: performance, systemic, contextual, and global, in effect creating a new context for the design process [15]. This viewpoint is clearly a complex and interlinked system-based activity and consequently reflects the CE.

As recently as 2008, the Quality Assurance Agency for Higher Education (QAA) in the UK gave only the most cursory mention of sustainability in its guidance. However, this situation has since changed with the first guidance on Education for Sustainable Development, published in 2014, and the 2021 version that builds on this and defines sustainability education as 'the process of creating curriculum structures and subject-relevant content to support and enact sustainable development' [16]. The guidance gives examples of teaching practices that are applicable to developing competencies in sustainable development, and these include:

A. Enquiry-based learning: Enquiry-based learning uses real-life scenarios, and students investigate topics of relevance that foster the skills of experimental design, data collection, critical analysis, and problem solving;
B. Problem-based learning: This approach is appropriate for interdisciplinary and interprofessional learning and to support students in problem identification and envisioning and evaluating alternative outcomes. Problem-based learning is particularly

suited to complex, multifaceted issues ('wicked problems') that are not amenable to simple problem-solving. It provides an environment for creativity, risk-taking, and learning through failure, as well as innovative thinking [16].

Both example practices were used in this research project and its activities. Whilst not specifically focused on sustainability, the QAA also give guidance relating to Enterprise and Entrepreneurship. Within the context of this research, it presents an important dimension that addresses the issue of motivation to act in terms of creating value (most often financial), as well as focusing on identifying 'real' problems and developing appropriate solutions. The guidance gives the rationale for its inclusion, as 'Enterprise and Entrepreneurship Education provides interventions that are focused on supporting behaviours, attributes and competencies that are likely to have a significant impact on the individual student in terms of successful careers, which in turn adds economic, social and cultural value to the UK' [17]. The guidance goes on to give definitions: 'Enterprise is defined here as the generation and application of ideas, which are set within practical situations during a project or undertaking' [17].

This clearly reflects the broad style of the project outlined here; the challenge developed was a 'real' problem to which students were asked to apply their own knowledge and skills whilst also addressing the application of CE ideas and principles. The guidance also goes on to define entrepreneurship education as 'The application of enterprise behaviours, attributes and competencies into the creation of cultural, social or economic value . . . Entrepreneurship applies to both individuals and groups (teams or organisations), and it refers to value creation in the private, public and third sectors, and in any hybrid combination of the three. All forms of entrepreneurship are embraced, and many new labels are evolving. For example, social entrepreneurship, green entrepreneurship and digital entrepreneurship are relatively new areas of focus, and the sustainability education agenda' [17].

Of equal importance when considering the implementation of ESD are the structures evident at the institutional level within which parameters teaching is designed and delivered, those of the course syllabus and programme validation document. The UWTSD Surface Pattern Design programme gives the following aims:

- To develop graduates proficient in the appropriate and effective application of core multidisciplinary surface pattern and textiles design skills for interiors through contemporary design thinking methodologies relating to research and ideation, materiality and process, making and innovation, and pitching and audience.
- To develop responsible graduates with socio-political, environmental, cultural, and professional awareness, and a systematic understanding of key aspects of contextual practice related to their Interiors pathway.
- To develop effective, design industry-appropriate communication skills as a foundation for current, emerging, and future advances in this field through a breadth of visual, written, verbal, and digital means.
- To develop graduates who are able to contribute to the shaping of their learning experience by providing them with a professional design studio culture environment where they can thrive, through tailored individual encouragement, through experiential learning, through collaboration, and by fostering an innovative mindset through an inspirational and forward-looking structure.
- To ensure the potential for a sustained future working in the graduate's chosen area of the surface pattern and interior textiles sector through rigorous delivery of desirable graduate skills and attributes underpinning the programme at all levels, employment positions and opportunities, commercial awareness, design thinking, creative industry liaison, and live briefs.
- To develop graduates equipped with knowledge and skills in the design and production of innovative solutions for interior surfaces and textiles using a range of analogue and digital processes for walls, floors, textiles, and accessories across a breadth of interior spaces and contexts [18].

In addition to consideration of design training related to sustainability, it is also important to consider the context in which designers will practice: companies and firms that produce goods and services. Established manufacturing firms face many difficulties in transitioning to a CE mode of operation and the literature provides significant commentary on this [19]. There is also guidance on product design for CE [20,21], including certification and labelling schemes, such as Cradle to Cradle [22]. This research addresses an example of such a company, Orangebox Ltd. (Cardiff, UK), and its engagement with Higher Education (HE) students as a method to explore a specific waste stream from their manufacturing process whilst also providing some groundwork for the future development of a replicable model of engagement that can be applied across other situations.

This research also illustrates the value to students of creating engagements of this nature to deepen and broaden their learning. It also highlights the need to understand design problems that relate to sustainability in a holistic way for students to understand both the immediate product functionality design problem and how their design decisions affect the preceding and subsequent processes and product links in a CE system and that such systems are required if a transition to sustainability is to be achieved. Indeed, Andrews recognises that by learning about and implementing CE principles, students, the design professionals of the future, will also implicitly be educated for sustainability [23].

2. Case Study

2.1. The Industry Partner

Orangebox Ltd. (Cardiff, UK) are designers and manufacturers of office seating, furnishings, and workspaces and are based in South Wales, UK. They have a turnover in excess of £60 million and employ over 400 people. In common with many companies, they have a stated commitment to sustainability, and in pursuing this, they have acted in specific areas and have also expressed an interest in pursuing a CE model. However, despite their CE ambitions, they find themselves entrenched in a linear economic model. A key obstacle that they share with most commercial organisations is that any changes implemented in pursuit of CE goals must not compromise financial sustainability.

Textile waste, as one specific existing factory waste stream, was identified for attention and provides the basis of this case study. The intention is to explore options for eliminating Orangebox's textile waste stream in a way that both addresses the principles of CE and that can be relevant and sustainable within the commercial sphere within which Orangebox operate.

In the past, Orangebox have engaged with students by, for example, running design competitions; however these engagements have been targeted at product or furniture design students. This discipline choice reflects the nature of the business and the background of the design team at Orangebox, who studied similar courses, and is a logical choice of cohort if the desire is to reflect, reinforce, and continue the status quo. However, if a transition to CE is to be made, a paradigm shift in design thinking, process, and operation is needed, and collaborative projects outside established patterns and relationships may be a route to achieve this. This is an important dimension in this research. As a result, the research team identified surface pattern students, who regularly work with textiles, as an exciting student cohort to work with.

2.2. The Need for a New Approach for CE Manufacturing: Higher Education as Source of Intellectual Innovation Now and of Design Intelligence for the Future

Fundamentally, CE is a holistic, systems-based approach to sustainability. It differs diametrically from the established mode of operation of the linear economy. In practical realisation, it is where waste is minimised and materials are kept within the productive economy wherever possible by being used again and again to create further value [24].

Critically and a fundamental characteristic of CE is the repeated use of resources within the economic and production system. This is more than the 'recycling' of post-consumer waste, for example household refuse collections, where the materials are mostly 'down-

cycled' into lower performance resources; it is about ensuring maintenance of 'value' within the waste system and regenerative loops where resource value is not diminished [25].

To illustrate this, Figure 1 represents a simplified view of Orangebox Ltd. (Cardiff, UK) in the current and established linear economy model where materials and resources are used and subsequently discarded, generally to a landfill or incineration.

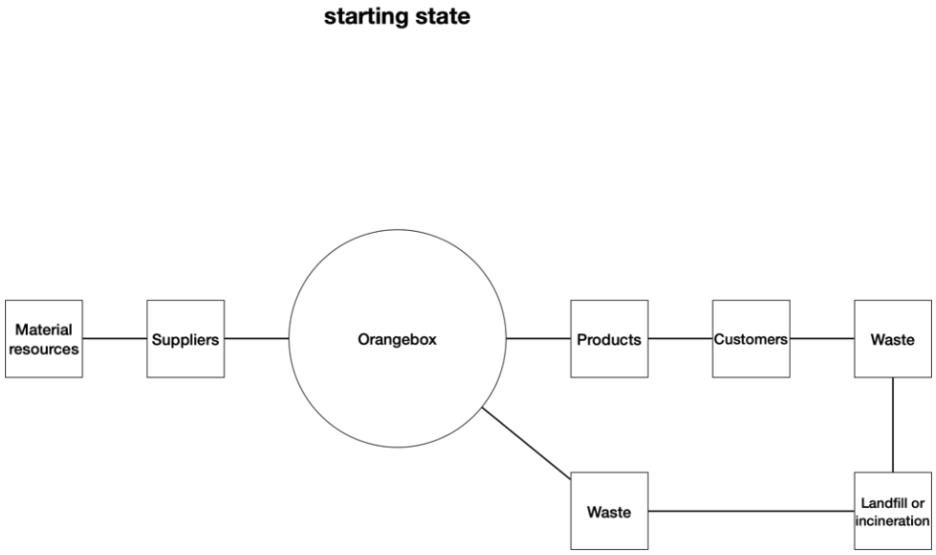

Figure 1. Starting state; linear economy model.

In contrast, Figure 2 shows a representation of an illustrative ideal state of CE in which waste is eliminated in the sense that no resources are diverted to a landfill or incineration. Instead, materials move through so-called regenerative loops [25] and are used for further value generative products. These loops can be small, close, and tight, for example where waste material generated in the factory is diverted back into the same production process, or loops can be complex, involving many processes and stakeholders that are spread over time and several locations.

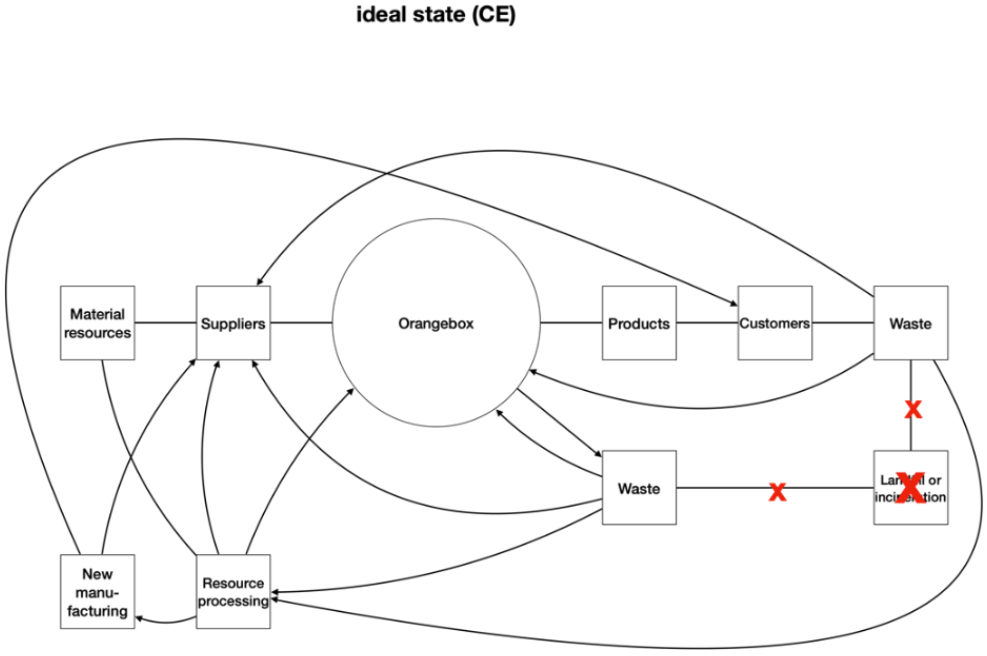

Figure 2. Illustrative ideal state of CE.

The challenge is to transition from the state illustrated in Figure 1 to that illustrated in Figure 2. It can be seen that there is a significant number of entirely new links and processes that must be generated. A logical way to do this is to use and exploit the existing research, design, and development resources within the organisation or those which the organisation has used and developed in the past. However, these existing systems and processes have created, and are optimised for, the existing (linear) state, and, therefore, expecting the radically different solutions that are required for transition to be generated may be too optimistic.

Instead, this research project looked to HE students as innovation partners, wherein the students were encouraged to introduce new design thinking that could illustrate where new value could be generated, new system links made, and new approaches adopted within the firm or beyond. As identified by Lieder and Rashid, educational approaches are required to change the general perception of waste and uncover the potential of circular product systems and their competitive edge [26].

Figure 3 shows how HE can be seen as a catalyst for the radical change required for a transition to CE. It should be stressed that although the trigger for developing this project was the desire to find a solution to a problem identified by a commercial firm (Orangebox Ltd. Cardiff, UK), the motivation was not exploitative, mining students' ideas for commercial gain. The ethos was of mutual and multiple benefits for all participants. Indeed, as suggested by Meyer (Melbourne, Australia) and Norman (Torrance, CA, USA), it is necessary for today's designers to use technologies that continue to evolve. In addition, they are required to demonstrate an understanding of social issues, human behaviour, and modern business models. In an increasingly global marketplace, they must meet new ethical challenges, tackling differing sustainability issues, cultures, and value systems [27].

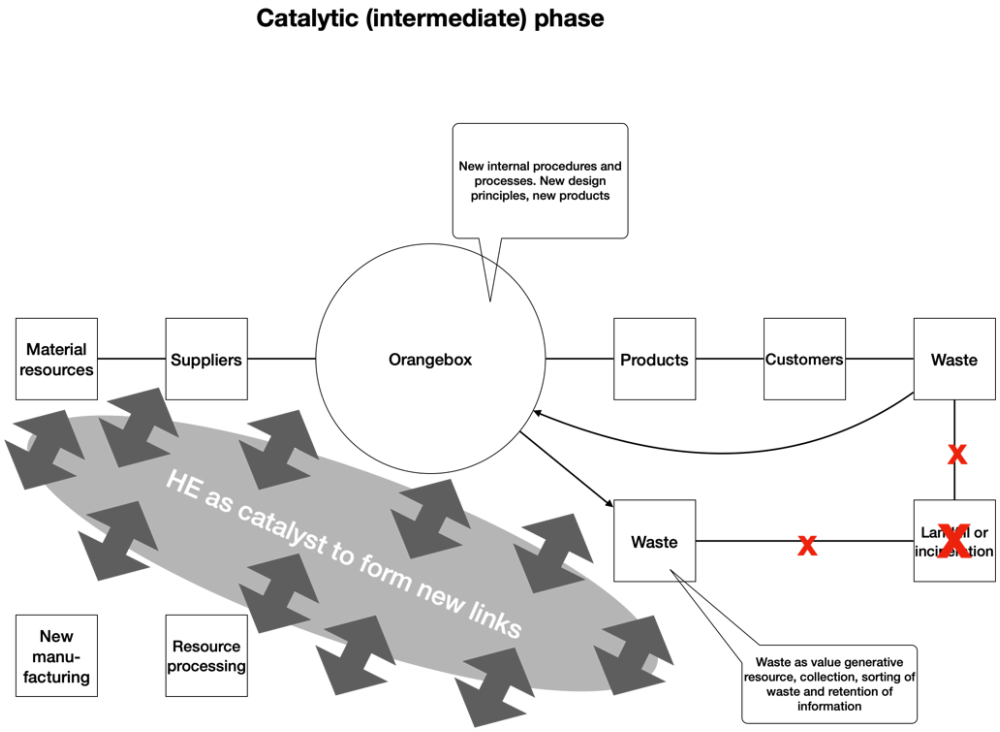

Figure 3. Intermediate phase using HE as the catalyst.

Therefore, development of effective strategies to deliver these skills and knowledge within HE is also a pressing need. This research project provides an example of how a collaboration between HE and industry can be a catalyst for embedding sustainability education, as well as addressing the needs of firms in realising CE ambitions.

3. Methodology

The research uses a mixed-methods approach, centred on an action research project. An action research methodology was used since the research sought to provide positive outcomes and influence for the research subjects [28]. Development of this project followed on from previous research in partnership with Orangebox Ltd. (Cardiff, UK) and their desire to address the reduction and ultimately eliminate fabric waste from their production process. The project was developed and created collaboratively by the authors, the academic team at the Surface Pattern Design course at the University of Wales, Trinity Saint David (UWTSD), and the senior design team at Orangebox. In addition, technical support was provided by production staff at Orangebox together with technicians at UWTSD. The project was framed around a practical challenge-based live brief to create a new upholstery fabric for an existing Orangebox product. The student group consisted of the second year (level 5) students of the BA Surface Pattern Design course at UWTSD, a total of 29 students. This student cohort was selected on the basis that they had knowledge of and an affinity with textiles, which was the material resource under scrutiny. Students were introduced to the project by members of the research team and also given a written brief that provided introductory information on the CE and Orangebox, inviting the students to respond to the challenge. As an additional steer, students were encouraged to apply biophilic design principles (with a focus on health and wellbeing) to their design work. A list of required outcomes was given:

- A sketchbook/journal of ideas that clearly articulates thinking, design development, contemporary context, and market awareness;
- Mood boards to communicate design rationale and the issues addressed within the project;
- Visualisations to support design direction and the application of textiles;
- One innovative textile design that addresses the CE, sized to fit the upholstery of a Sully Stool [29];
- A selected exhibition of work at the Orangebox premises.

Additional activities were also undertaken to expand the students' engagement and understanding with the topic and with Orangebox. A full factory tour was given where students were shown the entirety of the design and production process and were able to see how and where the waste textiles were generated. Students attended a lecture on the principles of the CE and an exploration of how project stakeholders and other organisations have responded in terms of waste utilisation to CE principles. The significance of the retention and generation of value associated with the waste stream was singled out for emphasis, as it is this that is the most powerful driver to adopting CE measures for a commercial firm.

Fabric waste was collected from one day's worth of factory production, which is around 150 kg. The fabric was not sorted in any way, with the colour, composition, size, and shape all dependent on the factory production schedule for that day. There was a total of 46 different fabric types in varying proportions.

The Sully Stool [29] from the Orangebox product portfolio is a moveable, upholstered stool for use in flexible workspaces and other environments. It was chosen for being a relatively simple product in terms of its pattern pieces and construction, which would allow students to achieve a completed design, whilst creating an integrated and popular product for clients of Orangebox.

The student project ran for a total of eight weeks, but in parallel to other taught modules, at the mid-point, senior design staff from Orangebox took part in a design crit to understand how the students were engaging with the topic and offer the students feedback on their progress.

Students were encouraged to use any and all knowledge and skills to explore, experiment, and generate a final completed piece. Techniques included over-printing, bleaching, embellishing, felting, stitching, etc., and students were actively supported in their working by the academic and technical staff of the university.

Students (n = 29) taking part in the module were encouraged to complete an anonymous online survey following completion of the project. Of the total cohort, 45% (n = 13) completed the survey. The questions asked are provided in Table 1. In addition, students were asked to provide three words that they associated with CE.

Table 1. Student survey question summary.

Did you enjoy the project?
How relevant do you think this project was to your degree?
Before this project, did you consider sustainability to be relevant to your own work?
Since completing the Orangebox project, do you intend to explore ideas of sustainability and Circular Economy in your final year work?
Do you think you could explain the basic idea of the Circular Economy to somebody who didn't know about it?
How important do you think the ideas of sustainability and the circular economy are to you as a designer?
Did this project help with developing your skills in presenting your ideas and work to clients?
Did this project help your understanding of commercial production?
After completing this project, do you feel more confident in listening and responding to client feedback?

Upon completion of the design project, interviews were conducted with the academic lead on the project from UWTSD and also with the senior design team at Orangebox. These interviews were unstructured and discursive to facilitate a full range of thoughts and opinions to be gathered. These interviews were recorded and transcribed.

4. Results

4.1. Design Outcomes

Figures 4 and 5 show students' work, as submitted at the end of the module. This was a portfolio of sketchbooks, exploratory design work, practical experimentation, and finished cloth cut to the upholstery pattern.

Figure 4. Students' work as submitted at the end of the module.

Figure 5. Students' work as submitted at the end of the module.

The project was not run as a competition, which again was a departure from many of the collaborations Orangebox had undertaken with students in the past, but seven students' designs were chosen to be made into fully functional products (Figures 6–8). The limit of seven was primarily a result of available resources at Orangebox for the sewing and upholstery process, and it was felt that many, if not all, submissions were of a standard worthy of a completed product. The choice was made collaboratively between the teaching staff and the design team at Orangebox, and the selection aimed to show a variety of design thinking and techniques.

Figure 6. Student work sewn and upholstered onto three of Orangebox's Sully stools.

Figure 7. Student work sewn and upholstered onto an Orangebox Sully stool.

Figure 8. Close up of student work sewn and upholstered onto a pair of Orangebox's Sully stools The student work was exhibited internally at Orangebox (Figure 9). Orangebox also invited the students to show their work and to visit Clerkenwell Design Week. This is a major annual week-long design event held in Clerkenwell, London that is used to showcase interiors and furniture design to both clients and other design industry professionals [30]. In both locations, Orangebox and Clerkenwell, people viewing the work were asked to provide feedback to inform the research.

Figure 9. Student work exhibited at Orangebox.

4.2. Student Feedback

The students that completed the feedback survey were able to identify the benefits of taking part, with 70% (n = 9) of participating students stating that they had enjoyed taking part in the CE project. Whilst only 31% (n = 4) of these students stated that they had considered sustainability to be relevant to their work prior to taking part in the CE project, 85% (n = 11) agreed that the nature of the CE project and related experiences added value to their degree programme. Indeed, 92% (n = 12) agreed that sustainability and CE were either 'extremely' or 'very' important to them as future designers. Additionally, 85% (n = 11) were confident they could explain the idea of CE to someone with no knowledge of the subject, and 70% (n = 9) believed they were likely to further explore ideas of sustainability and CE in future modules, including their final year (L6) undergraduate thesis.

Students were asked to provide three words that they associate with CE. The results are shown in Figure 10. Other benefits demonstrated included the development of soft skills, such as communication skills, with 85% (n = 11) agreeing that the CE project had helped them further develop skills in presenting ideas and work to designers and clients whilst 77% (n = 10) agreed that on completion of the CE project, they felt more confident in listening and responding to client feedback. Finally, 70% (n = 9) agreed the project had helped to further develop their understanding of commercial production through their visit to the factory and interactions with Orangebox's design team.

It was evident from the student responses that the project was well received and that the students attached value to the experience and considered it a worthwhile, relevant, and enjoyable project. For example, one student reflects, 'This has been an experience that I will carry with me throughout the rest of my design career. Learning how to solve a waste problem and having the opportunity to work with a manufacturing company has been great. I will also now take into consideration the waste of the work I produce in future projects, and how to minimise this problem and save the next generation future in doing so'.

The feedback indicates a positive student experience but also reflects learning in multiple dimensions, including a knowledge of waste and sustainability, of technical problem solving, of commercial application and constraints; an experience of personal confidence and growth; and the ability to enact positive change for the future.

Figure 10. Words associated by students with CE (size proportional to frequency).

4.3. Orangebox Feedback

Two senior members of the design team were interviewed on completion of the project. Their thoughts on the project itself and on engaging with students in general were sought. Overarchingly, they found the experience of working with the surface pattern students very positive, particularly the breadth of ideas developed by this cohort of students that could be taken forward. Certainly, the design team really valued this external collaboration, to the extent that they stated, 'We were pleasantly surprised by the [surface pattern student] group. The visual communication was outstanding when compared to anything we've done [student competitions] in the last two decades.' This reflects poorly on the design competitions they have previously engaged with whilst highlighting the benefits of seeking collaboration outside of the established parameters of engagement. Indeed, they acknowledged that different cohorts of students apply their knowledge in different ways, and as a consequence, the design team felt the outcomes were broader than they had envisaged when setting the brief. When asked about expectations of the project before it started, they said,: 'We had low expectations because we understood the scale of the challenge and how difficult it is to do something with that waste stream. We were pleasantly surprised that they brought [ideas] to the table that we didn't know about in terms of process and were surprised [with] the creativity and artistry [on display]'.

When commenting on the brief given to students and contrasting it with previous design competitions, they felt the very focussed approach taken should be replicated with future design competitions. A comment was made on the importance of referencing the commercial environment within which the firm operates. Solutions must be assessed against a whole raft of criteria, not least areas such as engineering and financial; creativity alone is not enough. According to Orangebox staff, 'The one thing about our world [a commercial company], is the need not only to be creative, but also analytical. You have to be able to explore something and dismiss it [if it is not viable].' Overall, the design team felt that the design competition could not have gone much better, stating, 'When we made the 3D product there was an interest and a buzz in development [department] and in design [department] and anyone that [saw it] was hooked straight away and wanted to know more'.

This final comment illustrates the students' ability to produced finished work: cloth that was ready to fit to a product and that conveyed a resolved concept to a viewer without the need for further explanation. Furthermore, the comment shows the potential for an

external collaborative exercise to further stimulate ideas, interest, and action within the firm; it could be viewed as having a multiplier or priming effect on idea generation.

4.4. The Academic Feedback

A key member of the academic team made a number of observations regarding the students' engagement with the project and evidence that students were applying conceptual knowledge gained across other areas of their learning and to other projects. It was reported that the students were much more aware of sustainability as a consequence of taking part in the project, and this was evidenced through their focus on CE and sustainability in other modules, including their dissertations. The academic commented that seeing the physicality of the waste whilst at the factory was shocking to the students and spurred them into engaging further with CE and sustainability. Indeed, the factory visit was seen as pivotal, as it also allowed the students to see how their own experience of designing and making can be replicated on an industrial scale. One example is the recognisable technology of fabric cutting on the Gerber CNC machines Orangebox own. This is the same technology used in the university but on an industrial scale: 'Seeing the Gerber was like seeing a massive version of our plotter... that can do way more, more quickly and more efficiently and more effectively than we can do in-house. So, the speed of their ideas on that machine quadrupled on that potential, and even just seeing the physicality of [the size of] that bed; that they could cut two stories worth of a shape if they wanted, in ten-fold means that their ideas work quicker... that kind of realisation of industrial practise'.

The overarching view was that taking part in the project enabled students to realise the scale of their ambition and to be aware and therefore achieve more after understanding the possibilities shown by the themes explored within the project. At the factory visit, students were shown the library of fabric sample cards as supplied by textile manufacturers and asked to create their own prototype colour palettes using the waste fabric supplied. This was one activity that drew a particularly complimentary comment from the Orangebox design team, and the students were bowled over by the positive feedback they received from their client. It showed to the students that they had valuable and specialised skills that were in demand in a commercial setting. Indeed, in commenting on the collaborative nature of the project, the academic referenced the co-creation of learning and teaching content: 'In terms of teaching practice, essentially learning was co-produced by me [academic] and the client, which is a good teaching practice model'.

5. Discussion

The results from the project can be viewed from several perspectives, and the students, the academics, and Orangebox learned from the project. The project was a successful endeavour in terms of developing ideation for a solution to the waste textile stream from the perspective of Orangebox. However, it can only be viewed as an exploratory 'proof of concept' exercise since there are several further steps that are needed before implementation. As was made clear by the Orangebox feedback, they operate in an environment where there are multiple factors to be assessed and analysed before any new product idea can be taken forward.

5.1. Technical Feasibility

The demonstration of a wide range of finished products using a full range of material derived from the waste stream and made using technical skills and processes that are well-developed and established shows that the technical feasibility of the production is proven. Furthermore, the very broad range of responses the students submitted illustrates that there is a robust and wide range of options available for the re-purposing and use of the waste textiles. However, if technical feasibility is demonstrated, that is not to say practical feasibility is proven. Techniques and processes used in this project were diverse and applied in the context of one-off, experimental production. As identified above, what was produced by the students is of a vastly different scale from that of Orangebox's application

in a factory-scale context and would require significant further exploration. This is likely to present a considerable barrier to adoption if the ideas and concepts were the project outcomes to be transposed to the existing manufacturing facility.

5.2. Commercial Viability

A commercial viability assessment is not within the scope of this study; however, it would be critical for this to be carried out if the concepts were to be developed further. A commercial viability assessment would combine a critical analysis of technical, practical, and financial aspects in a quantitative form, likely to be expressed in monetary value, to show the viability of potential options. One critical parameter to this analysis is the value recovery of the activity of re-purposing the resource compared to the value deficit (cost) of disposing of the waste stream in the existing scenario. Figure 11 shows an illustration of the monetary value of an example textile fabric at different stages of the production process: at the factory gate (purchase price), as part of a product (retail price), at the moment of waste generation, and the liability value (disposal cost). The potential recovery of value from negative liability to the full value obtainable as part of a product is very large, in this example £42120 per tonne. As acknowledged by Lieder & Rashid [26], products designed with the awareness of CE must have economically feasible value recovery activities attached to them.

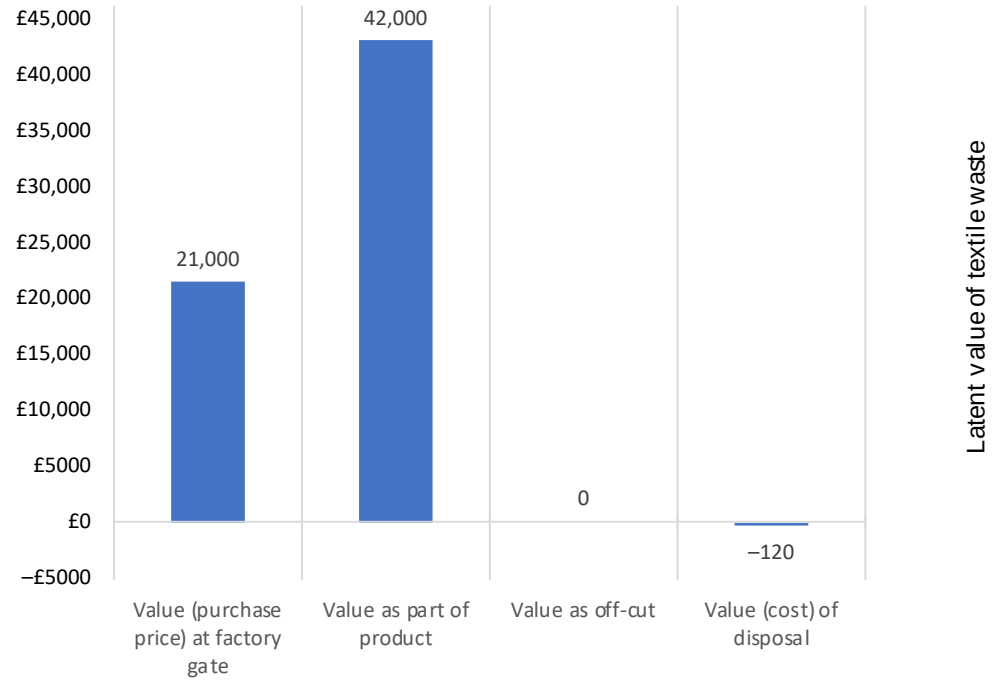

Figure 11. Illustration of fabric value during the manufacturing process.

This project has shown both how waste textiles can become value generative and how the waste stream can potentially be used within Orangebox, albeit with some new and different ways of working. However, if use within Orangebox is not desired or found to be possible or practical, then the activity could become something that happens elsewhere. In relation to CE, this is of little consequence since the regenerative loops are not required to operate within existing organisational structures. However, those existing structures, firms, suppliers, clients, etc. do present obstacles in terms of factors such as intellectual property rights, product liability, resource supply, etc., and are all complicating factors to the practical implementation of CE principles.

5.3. A Proto-Model for CE Transition Action

This project was successful in terms of the outcomes for the stakeholders and in demonstrating the possibility of producing value-generative products from an existing waste stream and therefore of satisfying key requirements of CE. In addition, the learning from the project can be used as a developmental step in establishing a potential methodology for solution generation for other waste streams and for other firms or organisations with a desire to transition to CE. As outlined, there has been growing attention to how design as a discipline should change. Within Friedman's challenges [15], sustainability is situated within the global area, which are challenges that are related to complex sociotechnical systems and that must address the major societal issues facing the world, including the UN Sustainable Development Goals (SDGs). To do this, he says, there should be training for designers that allows them to select and specialise in the challenge area they prefer. However, the problem is that design education programmes mostly address the performance challenge, with only a few considering global challenges [15]. There is a clear need for teaching and learning strategies that address head-on the global sustainability challenge but that also remain relevant to the established performance challenge model of education.

5.4. Embedding CE in Education for Sustainable Development

If design as a discipline needs to change to address sustainability, then so too do the structures that generate designers, namely HE. As outlined, it is suggested in the literature that HE provision lacks the adaptiveness and agile qualities to do this effectively., However, one way of overcoming these resistances and generating interest, both academically and institutionally, is to show the disciplinary benefits and potential from integrating sustainability concepts, issues, and case studies into teaching and learning, along with the opportunities to integrate active learning and innovative approaches [12].

It is clear that there is a difficult task of aligning the pragmatic delivery of teaching to the idealistic goals of design education and addressing the challenges that design must respond to. This research project has shown that challenge-based learning can provide both a mechanism for delivery of the required learning and, importantly, provide tangible beneficial results for external collaborative partners and contribute to the less easily quantified student experience. In looking at the design and delivery of this project, the researchers suggest the development of a checklist or framework for delivery of such projects that ensures that the project is situated where the needs of these three areas align.

Challenged-based live briefs in design for sustainability are effective, as demonstrated here, but require comprehensive contextualisation to broaden the emphasis from the narrow product/function solution focus of a traditional design challenge to the key elements of sustainability. Students should be introduced to systems thinking as a concept and be able to view a design problem within the context of a system, i.e., the CE, and to also recognise that they are active participants in this new system. This reflects the ideas of Andrews [23], as outlined before.

In this project, students were able to see and experience the entirety of the manufacturing process, from design studio, to prototyping, to final product manufacture. They were able to interact and ask questions in the factory setting that enabled a holistic understanding both of the design problem and the greater system in which it exists. Students were also able to see how their existing skills, knowledge, and making processes were reflected on an industrial scale. A key point is to enable students to understand and articulate how design decisions made by them affect actions, processes, behaviour, and technical options in other parts of systems. This is a considerable challenge within the already complex and challenging landscape of design education.

A successful project for sustainability with an external partner must satisfy the needs of all stakeholder groups; it should be situated where there is an alignment of interests (Figure 12).

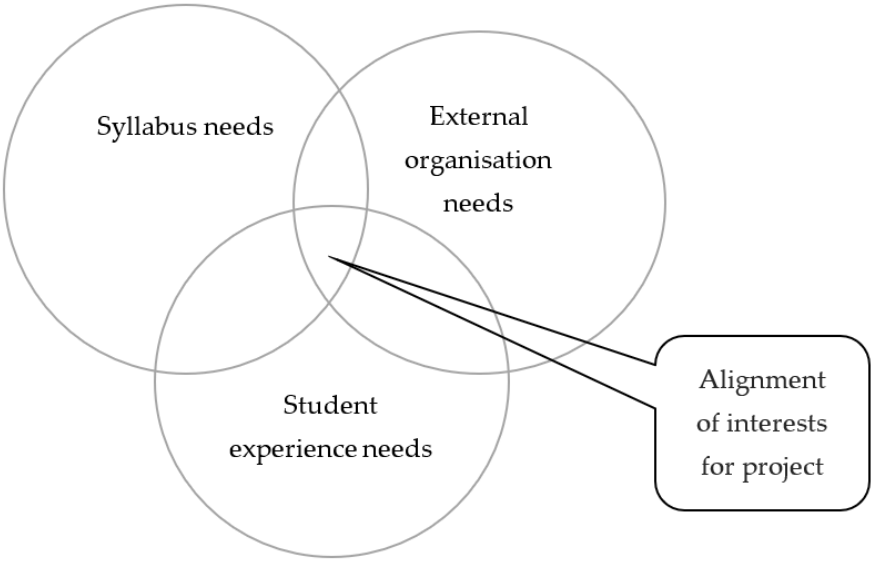

Figure 12. Alignment of interests for successful project.

It was not the aim of this study to provide a comprehensive list of each stakeholder needs, but lessons learned here can contribute to work already done in this area and to proposing further research to determine a guidance framework.

In general terms, there is a need to design the delivery of learning to yield positive results for all stakeholders, for example:

External

a. Direct answers or solutions to defined problems, i.e., Friedman's 'Performance Challenge' [15];
b. Other benefits, such as publicity and visibility;
c. Internal learning derived from collaborative working.

Syllabus

d. Delivering established learning outcomes for the course of study;
e. Addressing the learning required for sustainability, i.e., Friedman's 'Global Challenge' [15];

Student

f. Relevance—perceived and demonstrable;
g. Enjoyment;
h. Success—learning outcomes from the specific project and building skills and knowledge for successful completion of HE courses.

In addition, these three stakeholder groups can be viewed as operating collectively within the overall context of sustainability and the global needs that drive the requirement for this subject's teaching and learning. Those needs form the overarching context for a project. The characteristics of a successful project will include

i. Clarity of purpose—sustainability through CE;
ii. Clarity of brief—a description of the problem to be addressed;
iii. Mutual understanding of stakeholder needs;
iv. Openness—to collaborative process and to unexpected outcomes.

A critical foundation to any such challenge-based live brief, as presented here, is the syllabus and course structure within which it is situated. The basis for this will be the programme validation document. In the case of Surface Pattern Design at UWTSD, as outlined before, there are several elements of the structure, aims, and learning outcomes that readily support the use of such learning delivery methods, and, equally, such delivery

formats support well-structured programmes in a holistic way. The design of the project closely aligns with many of the stated aims, in particular

1. '. . . environmental, cultural and professional awareness and a systematic understanding of key aspects of contextual practice';
2. '. . . effective, design industry appropriate communication skills as a foundation for current, emerging and future advances in this field';
3. '. . . experiential learning; through collaboration; and by fostering an innovative mindset';
4. '. . . commercial awareness; design thinking; creative industry liaison; live briefs';
5. '. . . knowledge and skills in the design and production of innovative solutions' [18] (p. 24).

In addition, there is specific mention of sustainability in the learning outcomes key skills specified for the programme. This is because one of the university's strategic priorities is to embed sustainable development through its learning, teaching, curricula, campus, community, and culture [31]: 'Demonstrate an awareness of sustainability, in a design, environmental and ethical context' [18]. The project outlined in this research was situated in the group of modules entitled, 'Changemakers: Creativity and Value Creation', where two stated learning outcomes of this are

- Demonstrate knowledge and critical understanding of innovation, creativity, and enterprising mindset, recognising the values and the contribution creativity makes to the common good;
- Conceive, articulate, and apply creative thinking within a work-based or academic context to develop novel solutions and/or value creation.

These closely and directly map onto the activities undertaken in the research project and specifically address the key principles of CE (value generation, systems thinking) and further those of the activities needed to transition to CE working: creativity and innovation.

A project exercise as undertaken here can also be shown to address many of the aims and objectives of the QAA Enterprise and Entrepreneurship guidance as identified before. The student engagement project was particularly focused on the challenge of value creation from a waste resource, and the students showed, by their response, that they were able to apply competencies they already possessed in meeting that challenge (creative and technical). Moreover, there was evidence that other competencies were developed and confidence gained. Student feedback demonstrated that the project had helped them to understand commercial production, but, importantly, many had greater belief in their capability to succinctly present their ideas and work to clients and in listening and responding to client feedback (See Table 1). These skills were not the core focus of the project but represent valuable transferable skills applicable across many situations and add to the portfolio of skills that enable entrepreneurship (in whatever form). The project also demonstrated to the students that they already had skills acquired through their previous learning that were noticed and valued by the external partner organisation, for example, the ability to create a colour swatch palette. This external recognition of skills, knowledge, and abilities is important in demonstrating to students the validity of the learning as part of their course and their developing confidence both within their chosen field and as individuals. Similarly, the opportunity in this example of the students having their work shown as part of Clerkenwell Design Week in the showroom of a high-profile brand such as Orangebox demonstrated that they and their work were valid and fully belonged in the professional commercial realm.

6. Conclusions

This paper discusses the results of one collaboration between HE and industry as a method to explore a CE opportunity by using waste materials to develop new product. However, it is not difficult to envision the potential for benefits beyond the immediate results of such a project, to amplify and leverage positive outcomes, and for this to drive

concrete progress toward CE and sustainability. Indeed, it can be considered critical that, if addressing such a 'wicked problem' as implementing CE to achieve sustainability, such projects are used in a constructivist sense to make positive and defined progress towards that goal. Examples include learning gained in the project becoming established as part of the knowledge base in the partner organisation and for project outcomes forming the basis of further work in an iterative process.

The scope of this project did not extend to an assessment of any embedded permanent change at the partner organisation, Orangebox. Anecdotally, to date, no direct changes have been implemented within the company as a direct result of taking part in this educational project. As a barrier to CE implementation, it would be important to understand why this is the case, and this should be the subject of further research, with the findings used to refine the proto-model outlined here. It is not only important that new and emerging designers (the students) achieve and gain knowledge from such teaching and learning exercises but also that established designers (and the organisations where they practice) do, too. The speedier our collective progress towards sustainability, the easier our task is since the longer we take, related problems, such as climate change, become ever worse. For that reason, the more active participants (designers) there are who understand and have the skills to address the challenge, the better.

The on-going iterative process as a method of incremental progress towards CE implementation is something that can be embraced within the HE engagement model presented above. Challenge-based design briefs can be developed that reference and build on those that went before. For example, as outlined previously, financial sustainability is of critical importance in any decision made within a commercial firm, and it is this realm that is likely to hold sway. Financial risk management in terms of the provision of confident financial parameters detailing the investment required, marginal production costs, and revenue generation would reduce the unknowns and provide a firmer basis for the adoption of CE-oriented products and design decisions. HE institutions educate accountants and business students, too. Consequently, developing further collaborative projects with a focus on financial sustainability could be an option for Orangebox in the future. After that, advertising, marketing, and brand management may be targeted. All could build on previous learning, each enabling progress to real and tangible CE implementation.

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