Co-learning for Sustainable Design: The Case of a Circular Design Collaborative Project in Ireland

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Highlights for

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- Interns are exposed to real-life innovation practices for sustainability.
- Co-learning equips collaborators for real-life sustainable innovation
- Novice designers gained experience for more responsible future practices.
- Industry partners explored ways of transforming their businesses.
- Educators gained insights into real-life challenges faced by industry.

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Abstract

Incorporating concerns of sustainability and circularity into design practice is undoubtedly important for both design research and education. There is a need to equip novice designers with the skills to facilitate a sustainability-focused future, whilst also collaborating with industry to implement these concerns into contemporary design practices. On the one hand, SMMEs and small teams in other sectors (i.e. public) lack the resources and time to improve their knowledge, to explore alternative ways of conducting business and to transform their design practices. Contrarily, novice designers (i.e. design students) can access state-of-the-art knowledge on sustainability and experiment with sustainable design practices throughout their education, yet they lack insights into market realities around implementation. Similarly, design researchers and educators are on the fore-front of developing sustainability-focused design methodology through research, but they often lack exposure to the industry. If the parties were all to work together, however, the sharing of resources, knowledge and experiences become valuable commodities in creating more sustainable design practices.

This paper outlines an on-campus Design for Circular Economy and Sustainability training programme where industry worked with interns and academics to address real-world challenges. The project forms a part of a larger EU collaboration. The programme aimed to create a co-learning environment for novice designers, industry partners and design researcher/educators. Here all stakeholders could exchange their knowledge and insights and learn from each other to explore and experiment with practically implementing sustainability in real-world contexts. This paper briefly introduces the development of the programme and explores how and what co-learning occurred for the different stakeholders. Finally, the paper discusses how the outcomes of this programme subsequently affected the practices of industry partners. The programme offered a unique environment to prepare novice designers for the real world and provided researcher/educators with valuable insights on how to facilitate such a transition. The industry partners utilised this experience and outcomes to review their practices and kick-start the transition towards sustainable businesses.

Keywords: design education, Circular Economy, sustainability, industry collaboration, co-learning, training programme

1. Sustainability in Design (Education)

Design for sustainability education has become more comprehensive over the years, taking into account multi-faceted considerations befitting the complexity of sustainability issues. While the UN (2012) Sustainable Development Goals (SDGs) provide an overview of this complexity through identifying 17 large problem areas, there are numerous ways design, as a practice, can contribute to this challenge. This is achieved through approaches such as social innovation, product services systems, design for Circular Economy, design for transitions, design for behaviour change, etc. The 'Shaping the Future We Want' report recommends that new approaches to curriculum reform need to extend beyond conventional institutions and into lifelong learning models for practitioners, professional bodies and community stakeholders (UNESCO, 2014). This will capitalise on the growing

awareness of, and desire to, integrate sustainability into private businesses in more technical and implementation-driven ways. “Technical ‘know-how’ will not be sufficient. Skills and capacities for whole-systems approaches, critical thinking, and collaborative problem-solving will also be needed for private-sector transformation” (UNESCO, 2014, p. 150). Whilst the integration of sustainability in larger businesses and multinational corporations is underway, the challenge of increasing capacity and training for small, medium and micro enterprises (SMMEs) must still be addressed (ibid).

In a study on the challenges facing design consultancy SMMEs, the barriers to adopting responsible design practices are explored through workshops and in-depth interviews in the UK and Ireland (Stevenson, 2013). While the (lack of) knowledge, understanding and capabilities of addressing more responsible goals are acknowledged as barriers – in parallel to UNESCO, 2014 – there are also other external factors inhibiting design practitioners. These include the clients’ priorities, designer’s (lack of) influence in decision-making, and the designer’s involvement in the implementation of the design outcomes (ibid). In addition to these, for SMMEs in general, there are barriers like time constraints, limited financial resources as well as potential risks involved in implementing sustainable practice (Caldera et al., 2019). There are also opportunities SMMEs perceive in adopting sustainable and/or circular practices, such as a rise in company image/prestige, reduction in costs and increased resilience of the company (Ormazabal et al., 2018). Hence, in an attempt to offset some of the barriers, a collaborative approach should be developed that builds SMMEs’ knowledge and capabilities, as well as overcoming more external factors like lack of time and resources.

There are different levels at which universities can build the relationship between design practice and sustainability. Some of these suggested approaches are: mainstreaming sustainability inherently throughout design education (O’Rafferty et al., 2014; de Eyto et al., 2008), introducing modules focused on incorporating sustainability in design practice (Boks and Diehl, 2006), and acting as intermediaries in industry by utilising the expertise of academics in design for sustainability (Eleonora et al., 2019; Küçüksayraç et al., 2017). Integrating principles of sustainability and its design-related competencies throughout design education is a more holistic approach that can result in deeper learning over an extended period of time. Such integration, however, should involve differing perspectives of academic staff, while at the same time ensuring that core competencies related to design education are still being conveyed to future designers (O’Rafferty et al., 2014). In order to ensure that the issues of sustainability are addressed properly and not just as an additional consideration in design courses, a more hybrid approach should be developed and adopted in education (Boks and Diehl, 2006; O’Rafferty et al., 2014). In addition, continued professional development of academics is necessary to keep up with ongoing changes and advancements around the topic of sustainability (O’Rafferty et al., 2014). Collaboration and knowledge exchange is crucial among different institutions to build educational capacity (McMahon and Bhamra, 2012; O’Rafferty et al., 2014) and between universities and industry to transform business practices (Küçüksayraç et al., 2017). Practice-based learning, where novice designers engage in educational projects in collaboration with industry has advantages for both parties, through facilitating knowledge exchange (Soini et al., 2019) and developing capacity for all involved.

Following this line of thought, this paper presents the development and implementation of an on-campus training programme focusing on design for sustainability and the Circular Economy. The authors aimed to create a co-learning environment for interns, industry partners and educator/researchers through setting learning outcomes for all three parties. In order to assess the programme, the authors conducted group discussions with the interns throughout the programme and interviews with the industry partners a year after the programme ended. The programme in Ireland was the first in a series of training programmes later conducted in Spain, the Netherlands and Sweden, and the data collected throughout the first internship was influential in the development of all subsequent internships. However, this paper presents a thorough reflection and

an in-depth discussion on creating a co-learning environment in Ireland, and the subsequent internships are beyond its scope.

2.The Irish Context: Education and Practice for Design for Sustainability

Across the Irish HEIs offering design-related undergraduate and postgraduate courses, a quick study reveals that design for circularity and sustainability is implemented in a variety of ways. Some offer discrete modules – i.e. Maynooth University and University of Limerick (UL) – whilst others embed it into related modules – e.g. materials' modules in National College of Art and Design (NCAD) – where the concepts such as eco-materials, lifecycle assessment (LCA) and the Circular Economy (CE) are introduced in the context of another subject. The most common method, however for building knowledge and skills, is to integrate the concepts of sustainability into studio project briefs (NCAD, Institute of Technology Carlow, Maynooth University, TUDublin and UL). Another channel is through standalone projects, with briefs directly focused on sustainability, which are either generated by the lecturers or in partnership with an external collaborator (e.g. industry, NGO, community group etc.). As a result of these methods, the learning is through *doing* and *application*, which arguably leads to more deeply embedded knowledge acquisition. With this increase in understanding around sustainability design lecturers find more and more students choosing to do projects in this space when the opportunity arises (e.g. individual degree projects and external competitions).

The research also highlighted that none of the institutions offers continuing professional development (CPD) courses or modules to the professional design community. Some CPD is offered by the Institute of Designers in Ireland (IDI), the professional body for designers, through their Design Skillnet Programme (Design Enterprise Skillnet, n.d.). These take the form of short courses and workshops offered either free or for a nominal charge. Unfortunately, only a small number of these courses have focused on sustainability or circular design. The IDI, in 2016, introduced *Sustainable Design* as a subcategory under the main category of *Intrinsic Design* in their annual IDI awards (IDI Institute of Designers in Ireland, n.d.). This points to the rising awareness of the imperative to integrate sustainability into professional design projects. An opportunity now exists to capitalise on this growing interest, in both education and practice, to engage with the variety of collaborators and to embed circular economy and sustainability principles into design in valuable ways.

In the consultation paper "Ireland – The Design Island", prepared by the Design & Crafts Council of Ireland (Hennessy and Milton, 2017) for the Department of Jobs, Enterprise and Innovation, the relationship between design education and enterprise was questioned. An educational approach developed in collaboration with enterprise was deemed important to increase the innovative capacity of the design sector as well as other sectors. While bringing the design education agenda in line with national enterprise needs is important, identifying those needs and integrating them into the educational agenda is not the only collaborative action that can happen amongst educational institutions and enterprises. The programme presented in this paper presents a different approach where the agenda of enterprise and design education can be collaboratively reformed through their active participation in the act of designing.

3. Developing a Co-Learning Environment for Sustainable Design

The challenges presented by sustainability and in the SDGs are complex and multifaceted. Transitioning towards, and designing for, a Circular Economy inevitably requires a better understanding amongst stakeholders to discover, analyse and resolve barriers against it, especially for SMMEs with limited resources (Ormazabal et al., 2018), training and/or policy support (Del Río et

al., 2016) and the necessity to ensure financial durability (Biondi et al., 2002). Addressing these challenges through collaborative processes ensure these problems are approached from a multitude of perspectives in ways individuals cannot do on their own (Dekoninck et al., 2016). Similarly, the role of universities is changing as well, going beyond the traditional research and higher education agenda and adopting a more multi-cultural and practical approach to actively participate in technological and socio-cultural innovation (Hyvönen et al., 2017). In the context of design education, this shift involves both researcher/educators undertaking practice-oriented activities aimed at catalysing innovation and the upskilling of students through exposure to real-life innovation processes embedded in the curriculum, to contextualize theoretical knowledge in the world (Leal Filho et al., 2018). Project-based learning with external partners is found especially effective in terms of sustainability education (Faludi and Gilbert, 2019), and examples such as Campus Labs (Vezzoli and Penin, 2006) or Living Labs (Evans et al., 2015; Voytenko et al., 2016) demonstrates the value of collaboration among universities, external partners and public. From this perspective, this training programme was developed with a co-learning approach, acknowledging the gaps in skills, knowledge and experience of educator/researchers, industry partners and interns, and identifying different learning outcomes for each party.

Co-learning is the situation where a group of people attempt the learning of skills and/or knowledge through collaboration (Dillenbourg, 1999). The purpose here is to exchange knowledge, resources and skills that would not be immediately accessible to an individual, and to acquire skills and resources from each other (Chiu, 2000). Co-learning stems from the zone of the proximal development concept introduced by Vygotsky (1978) in the 1930s, which argues that the knowledge and skills development of an individual is through their social interactions with knowledgeable others. The zone mentioned here is between what the learner cannot do at all and what learner can do without any aid, where the learner requires some guidance to successfully undertake a task (Vygotsky, 1978). By undertaking tasks in this zone over time, the learners eventually become capable of undertaking that task independently. The complexity or hardness of that task should be within the zone of proximal development, however, the more complex tasks generate higher learning gains (Wass and Golding, 2014). As this concept suggests, co-learning is only applicable when learners are able to undertake tasks, albeit with the aid of other learners with a different set of skills, knowledge and resources. However, it is argued that learners can learn *more* through collaborative action, and this applies to both the facilitators and the receivers of knowledge (Gokhale, 1995).

3.1. Expected learning outcomes of the programme

Co-learning as an educational approach espouses a (more) horizontal interaction among the collaborators. The term *Collaborators* not only applies to the students or trainees, but also the educators and other parties involved, industry partners in this case. Simply acknowledging the fact that educators do not (cannot) know everything enables a more horizontal reciprocal communication and reaps benefits for both sides (Jacobs et al., 2016). It should be noted that this reciprocity structures itself according to the differences in knowledge, skills and experience, as well as the learning outcomes expected by all the collaborators (Hannon et al., 2005). Furthermore, how well co-learning works is very dependent on constructing shared knowledge and high quality of communication amongst collaborators (Crook, 2010). In the context of the Circular Design training programme in Ireland, the collaborators included design educators, novice designers and industry partners, and their learning goals, as well as their knowledge, skills and experiences, were varied. The programme was developed with the following learning outcomes in mind:

For interns:

- To self-learn, assess and utilise the necessary tools and techniques to design for a circular economy

- To undertake multi-disciplinary group work and tackle the issues of the local context and local industry.
- To experience and develop sustainable solutions with the tools and techniques as they are applied to real-life innovation processes.

For industry partners:

- To learn about novel design tools and techniques for sustainability and circular economy as applicable to their businesses.
- To explore sustainable alternatives for conducting their business through the design work carried out by the interns.
- To explore the opportunities and limitations of design for sustainability and circular economy for their businesses, without taking on too much risk.

For design researcher/educators:

- To gather more in-depth knowledge of the real-life challenges faced by the industry.
- To explore ways of incorporating real-life challenges into educational contexts and to prepare novice designers for these challenges ahead.
- To explore novel ways of collaborating with industry to initiate and sustain knowledge exchange and innovative practices for sustainability and circular economy.

3.2. The collaborators of the programme

Ten interns applied and were accepted on the training programme from four different European countries (three interns from Ireland, three from the Netherlands, two from Spain and two from Sweden). While all the interns were in full-time education on design-related programmes, their background, knowledge and skills varied according to the curricula and the disciplinary focus (i.e. architecture, engineering, business) of their home institutions. For example, while some interns had more experience in product design and design processes, others had more knowledge of the business and management aspects of design projects. Similarly, some were inclined more towards material experimentation and engineering practices.

The industry partners were selected and approached according to their interest in and willingness towards business practices for sustainability and Circular Economy, as well as their openness to collaboration and knowledge exchange. Prior experience of researcher/educators with, and the existing network of, external partners were influential in decision-making. As a result, three industry partners with different focuses and different goals in their businesses were selected, and three distinct design briefs were developed in line with their business direction:

- **Material Explorations**: Exploring the potentials of a reclaimed material – used fishing nets – and developing innovative solutions on reusing it along with leathercraft.
  Partner: Mamukko, Kinsale – a craft-producer.
  CE aspect: Exploring ways of recycling contaminated material by utilising existing resources and skills. Focuses on the technical cycle (i.e. contaminated polyethene), through circular approaches like upcycling and second life.
- **Retrofitting**: Designing bespoke, high-end office furniture with a take-back system and reusable products/parts/materials
  Partner: OneOff, Dublin – a bespoke furniture design consultancy.
  CE aspect: Exploring ways of reclaiming, refurbishing and remanufacturing high-end materials within the limitations of an SME. Focuses on both biological (i.e. wood) and technical (i.e. fixtures and accessories) cycles, through circular approaches like extended life, design for disassembly, repurposing
- **Preventing Food Waste**: Reimagine the food waste management in/around Limerick City, and develop solutions for prevention and/or reuse of food waste.

Partner: Southern Region Waste Management Office (SRWMO), Limerick – a local government institution.
CE aspect: Exploring ways of eliminating food waste, utilising any strategies on the biological cycle (i.e. cascading, biochemical extraction and composting).

These design briefs presented three distinctly different scales in terms of sustainability and circular economy. The *material explorations* project focused on the reuse/recycling of a problematic material (fishing nets) discarded in oceans, contaminating the seas and endangering marine life. The purpose of the project was to explore ways of reintroducing this material into SME production processes, thus giving it a second life. The *retrofitting* project focused on the problem of underused, high-end furniture with valuable materials being discarded before their potential lifespan ends and aimed to explore ways of reusing the furniture and/or the materials within the limited organisational capabilities of a design consultancy. The *preventing food waste* project focused on the issue of excessive amounts of food waste produced by citizens and the cultural implications of this. The project aimed to intervene in existing models of discarding food waste and its waste stream to explore ways of preventing food waste in the first place. These projects were developed to align with the external partners' own business agenda, while also responding to the learning goals of the interns particularly by providing real-life challenges in addressing the circular economy.

3.3. The structure of the programme

The programme was structured as a three-month design project moving through four distinct stages: Research, Ideation, Detailing and Finalisation. The interns undertook the design process as multi-cultural and multi-disciplinary teams consisting of members with varied skills and knowledge, and they were expected to self-organise their time and resources to deliver results. However, they were also expected to gain competencies related to general design practice and design for sustainability (Table 1). This required the researcher/educators to provide educational tools to enable self-learning, some of which were scheduled prior to the programme and others were prepared and delivered as per interns' requests. These included:

- Four **masterclasses** focusing on developing sustainability-related, as well as general design-related, competencies by experts in different areas. The below list provides a brief overview of employed masterclasses and their content:
    - *Stakeholders and Material Flows:* Understanding the division of material flows (i.e. technical and biological), building skills in identifying the relevant stakeholders and their levels of engagement in terms of the Circular Economy.
    - *Sustainability in the Broader Context:* Positioning the design solutions in the larger context, exploring the way these solutions interact with existing services and systems and evaluating their impact within this context.
    - *Fab Labs and Circular Design:* Understanding grassroots innovation and the potentials of distributed fabrication for local, circular economies with a focus on fab labs and makerspaces; and exploring their potential for the internship projects.
    - *Presentation and Pitching:* Ways of conveying design solutions properly and with impact. This was especially important for circular design solutions as the interns faced difficulties in conveying their solutions and the CE strategies employed in those strategies.
- Half-day **workshops** and **assignments**, for stages with which the interns had issues in moving forward, lacked skills or simply did not have enough expertise or knowledge.
    - *Data Analysis Workshop:* A hands-on workshop for analysing the data interns gathered from the field in relation to material flows and relevant stakeholders. The analysis involved stakeholder engagement levels, their existing activities and how they can change for various CE strategies.

- *Focused Design Brief:* An assignment to develop a more thorough interpretation of the initial project brief developed according to the analysis of the field data. These focused briefs included various observed intervention points and opportunities for collaboration.
- *Approaches to Sustainable Design:* An exploration of existing methodologies on design for sustainability and the Circular Economy. The interns were expected to select and thoroughly examine several approaches (e.g. localisation, human-centred design, social innovation, PSS, halfway design, open design, etc.) and identify the ones most relevant to their projects.
- *Assessment of Final Design Solutions:* Utilizing the knowledge they gained from the 'Sustainability in the Broader Context' masterclass, the interns were asked to evaluate their design ideas in relation to the Circular Economy strategies and present these evaluations.

- A comprehensive list of available **open educational resources** (*see* Bakırlıoğlu et al., 2019). The resources were categorised according to their usefulness at different design process stages.[1]

Table 1. Circular Design Training programme structure in relation to skill development

	General Design Practice Competencies	**Sustainable / Circular Design Competencies**	**Programme Content**
Research	Understanding the capabilities of industry partners & stakeholders	Assessing the potential of these capabilities for sustainability	- *Masterclass*: Stakeholders and Material Flows - *Open Educational Resources* for data collection - Data Analysis *Workshop*
	Scoping the project, through research outcomes	Defining limitations and opportunities for sustainability (i.e. sustainability criteria)	- *Deliverable*: Focused Design Brief - *Presentation*: Research outcomes to the industry partners
Group Discussion 1			
Ideation	Deciding on how to tackle the design problem	Developing a practical approach to sustainability	- *Deliverable*: Approaches to Sustainable Design - *Open Educational Resources* for idea-generation - *Mock-ups* - *Meetings* with industry partners
	Generating ideas and assessing them		
Group Discussion 2			
Detailing	Selecting design solution ideas for further development	Assessing ideas according to sustainability criteria and clients' capabilities	- *Presentation*: Design ideas to industry partners
	Further developing the design solution	Understanding the implications of the design solution for sustainability	- *Masterclass*: Sustainability in the Broader Context
		Ensuring the design details are in line with sustainability criteria	- *Deliverable*: Assessment of Final Design Solutions
Group Discussion 3			
Finalisation	Using a digital fabrication lab and workshop equipment	Exploring potential sustainable production tools and techniques	- Health and safety *training* - *Masterclass*: Fab Labs and Circular Design

[1] As part of the L4IDS project, an online Open Educational Resources (OER) Database was developed. The OERs can be found in this database: http://circulardesigneurope.eu/oer

	Developing design communication material	Conveying sustainability issues and sustainable design solution effectively and in a relatable way	- *Masterclass*: Presentation and Pitching - *Presentation*: Finalised design solution to industry partners and supervisors
Group Discussion 4			

As can be seen in Table 1, a group discussion was conducted at the end of each stage to gather interns' feedback on the different stages, deliverables, masterclasses, workshops, and relationships with external partners. These group discussions aimed to provide the researcher/educators with insights on improving the remainder of the programme and its subsequent applications, in terms of educational tools, external partners, design briefs and the co-learning environment.

In addition to these tools, some of the meetings with the industry partners were scheduled prior to the project start, to ensure a minimum level of exposure among them, the interns and researcher/educators (Table 2). The first of these meetings comprised the researcher/educator visiting the external partners in order to frame the challenge for the brief and the potential outcomes developed by the intern teams, as well as ensuring that these outcomes would be appropriate for the partners' business direction. In addition to these scheduled meetings, both the interns and the external partners were encouraged to arrange further meetings to sustain the knowledge exchange among them throughout the programme. Table 2 presents the purpose of these meetings, which included site visits, general updates about the design project and other knowledge acquisition opportunities that arose (e.g. conference on the topic).

Table 2. Meetings between industry partners, interns and researcher/educators according to the programme structure

	Scheduled industry partner meetings	*Further meetings arranged between interns and industry partners*		
		Mamukko, Kinsale	*OneOff, Dublin*	*SRWMO, Limerick*
Preparation	**Researcher/educators** for initial brief development			
Research	**Researcher/educators** and **interns** for kick-off and introductions **Researcher/educators** and **interns** for research outcomes presentations	**Interns** for workplace visits **Interns** bi-weekly virtual meetings	**Interns** for workplace visits	**Interns** for workplace visits
Ideation	**Interns** for preparing detailed design briefs **Researcher/educators** and **interns** for the presentation of design ideas	**Interns** bi-weekly virtual meetings	**Interns** for providing feedback on design ideas	**Interns** about additional resources
Detailing	**Interns** for design detailing feedback	**Interns** bi-weekly virtual meetings		**Interns** about attendance to a Start-up competition Conference attendance with **interns**

Finalisation	**Researcher/educators** and **interns** for final presentations	**Interns** bi-weekly virtual meetings	**Interns** for copyright issues around the project

Throughout the programme, the interns were allocated a space in the design department studio as their base of operation to carry out the project, and they utilised the university resources according to their project needs. These included the school's workshop facilities and the affiliated fabrication facility (i.e. Fab Lab Limerick), as well as the library and another laboratory facility for material experimentation. The researcher/educators identified two days a week as their on-site visit days, and they communicated via a Slack channel for the remainder of the time.

3.4. Gathering feedback and the assessment of the programme

This programme was loosely structured to allow for self-learning and meaningful collaboration. This allowed the interns to gain experience in the real-life innovation process and provided insights on ways of overcoming them. The industry partners shared their insights and know-how through their practices, while also exploring the opportunities for their potential future practices as envisioned by the interns. Finally, the researcher/educators had the chance to explore incorporating real-life challenges into a training programme and gather valuable insights on teaching design for sustainability and circular economy by collaborating with industry.

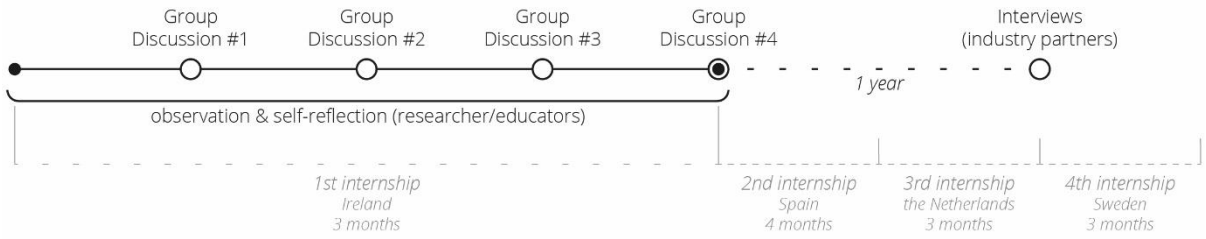


Figure 1. Sources of data for the evaluation of Circular Design training programme

Figure 1 summarises the forms of data gathering throughout and after the training programme. While group discussions were conducted with the interns at the end of each phase, detailed observations were maintained by educator/researchers and reflected upon throughout the programme. To ensure the reliability of the data collected through group discussions and researcher/educators' observations, a colleague of the authors regularly attended various activities in intervals (approximately every two weeks) and provided insights on the process. In addition to the data collected throughout the internship, interviews were conducted with the collaborating industry partners to question the lasting impact of this programme on their practices one year after the internship's conclusion. The interviews were conducted with the representatives of the industry partners who were actively involved in the internship process, and each one lasted approximately 45 minutes.

The qualitative data was analysed using content analysis and in relation to the expected learning outcomes for different collaborators. The paper does not claim statistical robustness, nor does it present any quantitative data. The purpose here is to present a detailed account of the programme and a critical reflection on the programme through qualitative data collection and analysis of the case, which we believe other educators in the area of design for sustainability and circular economy will benefit from and build on for their own curriculum development. The analysis revealed various

aspects regarding the co-learning approach adopted, industry-HEI collaborations and transitioning towards alternative ways of doing business. To note, the outcomes of this assessment also revealed practical implications with regards to the implementation of such a programme and affected the subsequent implementations of the programme in Spain, the Netherlands and Sweden; however, these are beyond the scope of this paper. The next section outlines the analysis of the group discussions with the interns, interviews conducted with industry partners a year after the programme ended, and the researcher/educators' self-reflection to identify the strengths and shortcomings of this training programme in relation to the identified learning outcomes.

4. Learning Outcomes Revisited

4.1. Self-learning and multi-disciplinary collaboration

The groups of interns tackled a variety of challenges throughout the project, some of which were presented to them in their project briefs and others they discovered throughout the project as they delved deeper. These involved industry collaborators' capabilities and limitations, as well as potentially new stakeholders, and target audiences. The whole programme was configured to support the development of practical and project-specific approaches to the design problem at hand, through identifying the 'general design practice' and 'design for sustainability' competencies the interns were expected to acquire. Self-learning was an important aspect of this skills acquisition process, as the interns needed to develop ways of renewing themselves to take on unforeseen challenges sustainability might present throughout their future careers. As presented in Table 1 in the previous section, the educator/researchers created a list of competencies and included several tools and structured learning sessions throughout the training programme. Faced with wide-ranging and abundant knowledge – some they were introduced to through more structured sessions and others they had to explore for themselves – all the interns agreed on the difficulty of sifting through this knowledge to (1) truly comprehend and (2) assess its usefulness for the project at hand. However, they also agreed on the rewarding outcome of this process: (1) a sense of accomplishment and (2) having a better understanding of sustainability.

Structured learning sessions, like masterclasses and workshops, were important to deliver core knowledge to the interns. For all these sessions, the interns emphasised how these sessions enabled them to look for and acquire further knowledge and assess the applicability to their design projects. The first masterclass on material flows and the third masterclass on sustainability in the broader context were mentioned as the most influential in grounding interns' decision-making processes. This was also observed by the researcher/educators throughout intern meetings, as they kept referring to these two sessions to explain their design decisions as well as to make sense of the *online educational resources* they reviewed and incorporated.

The fourth masterclass was not directly related to sustainability and circular economy; however, it was arranged at the request of the interns mid-programme. The interns recognised their shortcomings in conveying their ideas and decisions to others, including the researcher/educators and the industry partners. While at first they tried to improve their presentations through self-reflection and feedback from the researcher/educators, they recognised that they had a fundamental shortcoming and felt the need to acquire this competence through a proper session. In group discussions, most of the interns identified the need for conveying ideas properly and in a visually engaging manner if any circular design solution is to be adopted in real-life.

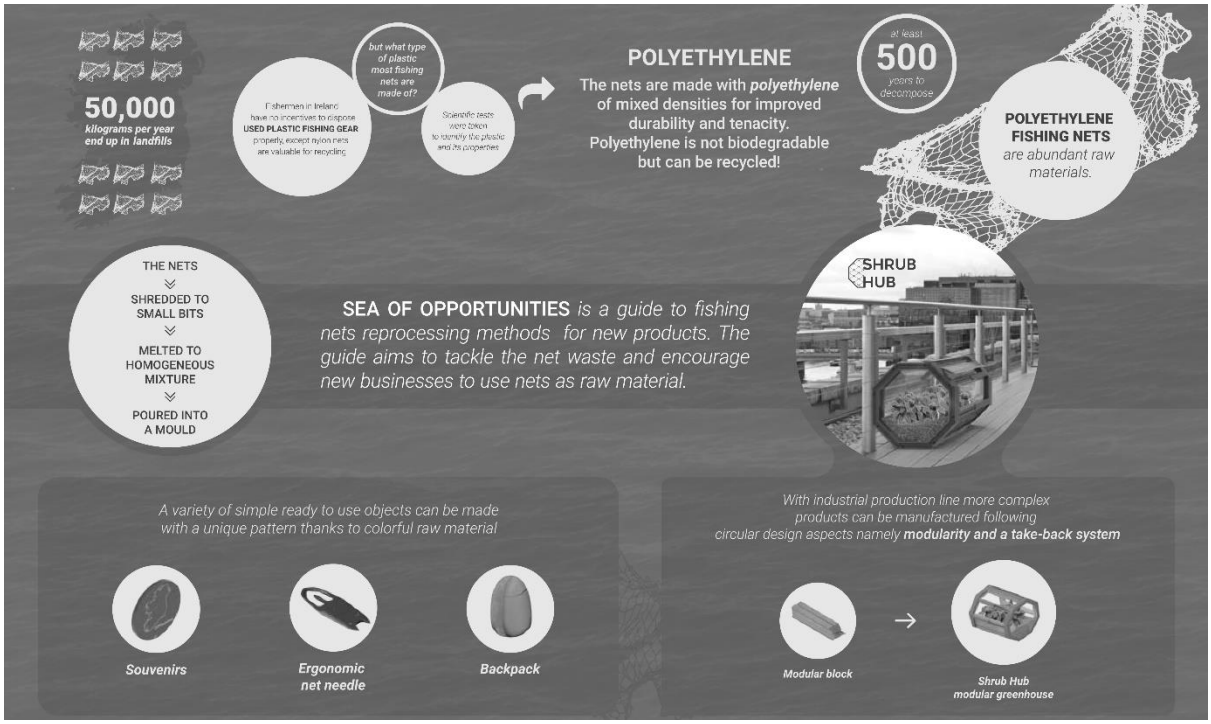


Figure 2. One of the final poster for material exploration of used fishing nets project, showcasing various opportunities for diversifying the industry partner's portfolio.

The researcher/educators observed that the disciplinary differences among the interns affected their initial understanding of circular design, and how these differences evolved to become more comprehensive and critical in nature as part of the collaborative learning process. This was particularly visible in the outcomes of the programme. The design briefs were on three different scales (i.e. materials, PSS and local service), however, the results addressed multiple scales including material/product aspects, product-service systems, existing infrastructure, alternative business models and transitioning towards them. For example, the material explorations brief with Mamukko was configured around ways of reusing fishing nets and the main aspect of it was experimenting with this reclaimed material and reintroducing it into Mamukko's own production processes. The outcomes of this project highlighted several opportunities for Mamukko to alter its business model, diversify their portfolio, and introduce novel fabrication methods into the business (Figure 2). The team devised incremental steps for transitioning towards these business models, identifying the needs and preferences of potential stakeholders, and assessed the applicability of these solutions in real-life.

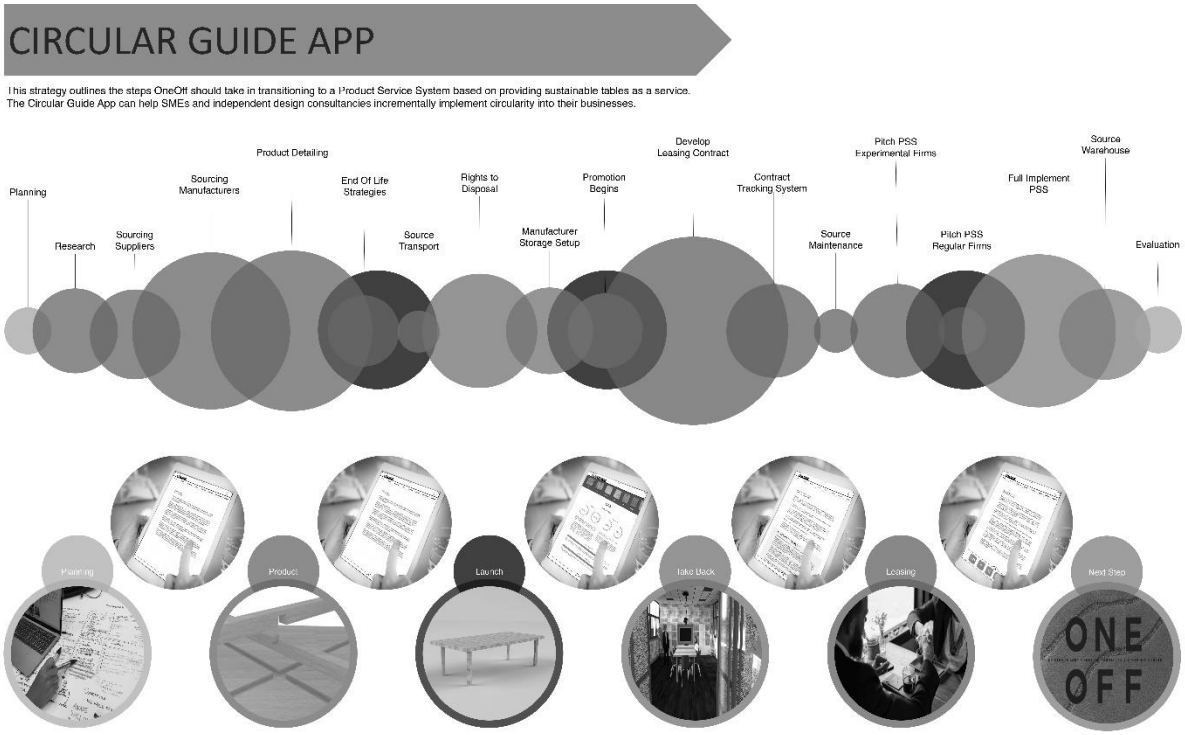


Figure 3. One of the final posters for the retrofitting brief, showing the structure of the 'Circular Guide App' designed by the interns. It is structured around steps for OneOff to transition towards a PSS business model.

Similarly with OneOff, the outcomes presented multiple methods of dealing with the materials and product parts at end-of-life of high-end bespoke commercial furniture. By exploring circularity from the start of the process, the OneOff design team explored material impacts, stakeholder behaviour as well as legislative requirements and logistical and financial implications of take-back and reuse strategies (Figure 3). The SRWMO outputs centred around an open-source design for public food 'drop-spots' that encouraged university students to share their excess food and by this, positively change consumption behaviour (Figure 4). Again the proposed outcome addressed several levels of circular intervention and dealt with multiple stakeholders e.g. students, commercial food providers, fab labs as producers and local authorities.

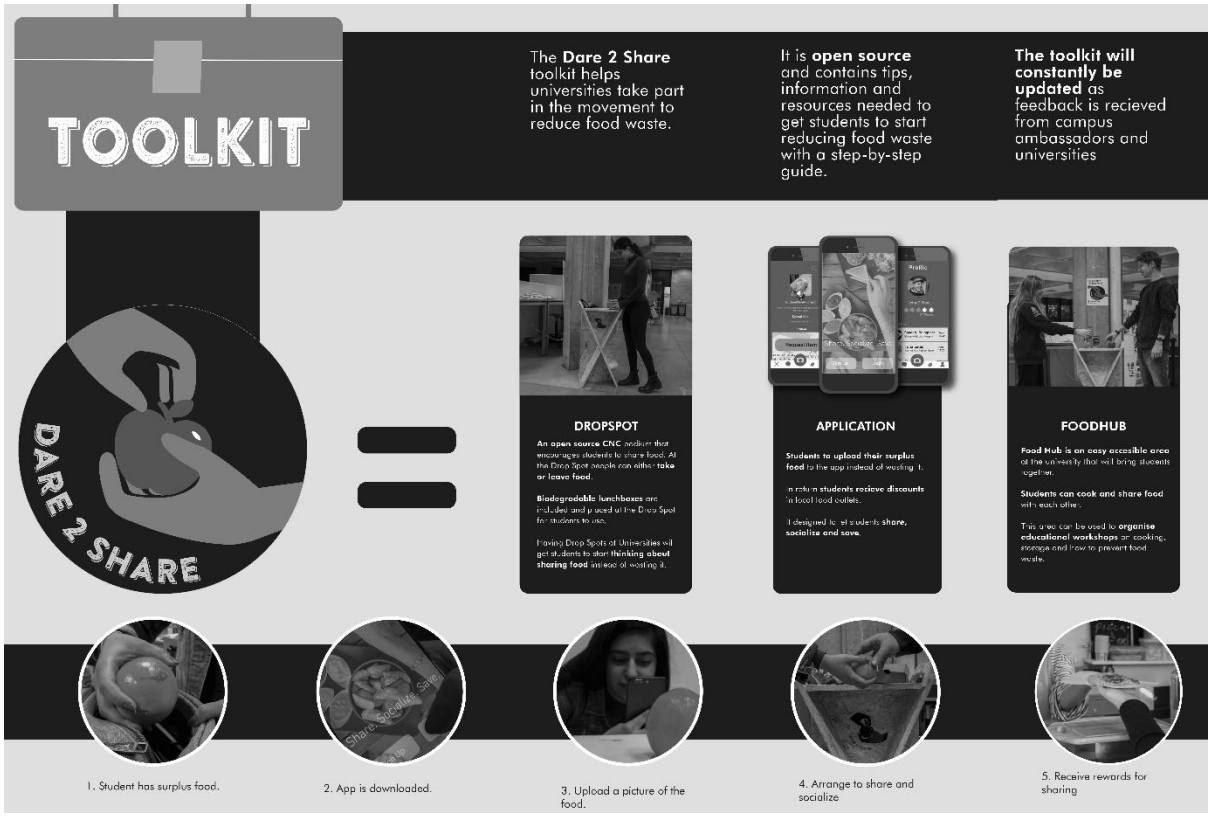


Figure 4. One of the briefs for the food waste brief. The project focuses on campuses and the solution includes open-source, locally fabricated 'drop spots' and an application to locate the shared food on a map.

Clearly building circularity into business requires a diversity of solutions as one single solution will not address the complex challenges of sustainability. This more holistic and systems-level approach to design was the outcome of collaborative learning among interns with different backgrounds and competencies, building on top of each other's knowledge and skills.

4.2. First-time addressing real-life challenges: Industry exposure

This project was the first time the interns worked in collaboration with industry partners, which presented many challenges in terms of communication and mutual understanding. This challenge presented itself in various ways according to the different backgrounds of the industry partners. For example, Mamukko representatives were two leather craftsmen who swapped one kind of material (i.e. leather) with another reclaimed material (i.e. reclaimed sails). They utilised their hands-on experience in leathercraft and expanded their technique to accommodate different materials, but they rarely acquired completely new crafting skills from different areas. This required both the interns and the Mamukko representatives to form a common language to convey design solutions and their applicability. Similarly, SRWMO representative had years of experience in public sector and waste management processes, and the interns needed to find common ground through which to properly convey their ideas.

That said, the interviews with industry partners revealed that there were differences in what they expected from this project. This affected the ways they collaborated with the interns and the role they assumed within the collaboration. These roles can be summarised as follows:

1. **Collaborating Partners:** Although Mamukko had the expertise in leathercraft and related design and production capacities, the challenge they were exploring with the interns (i.e. fishing nets, plastics reuse and recycling) required additional capacity building which they

were hoping to get through collaborating with UL. Hence, they assumed the role of collaborating partners with the interns, as well as the researcher/educators, and became more actively involved compared to other industry partners.

2. **Mentor:** SRWMO had a lot of expertise on food waste having previously worked on several projects in the area and so was aware of the many real-life challenges of consumer behaviour change. Working with novice designers, the representative in SRWMO assumed a mentor role, trying to inform interns and expand their knowledge around the food waste and behaviour change issues. SRWMO was more interested in the exploration of the topic by the interns and had no preconceived outcome in mind.
3. **Client:** OneOff's role shifted throughout the process. They began as a collaborator working closely with the intern team to develop a new business model for their design consultancy firm. But this role changed to that of a client, where OneOff was providing feedback in the confines of their own focus on designing products and the interns were reconciling their work based on said feedback at specific stages.

The way these roles were adopted by industry partners indicates the importance of facilitating knowledge exchange through such programmes. Through these roles, the interns were able to experience and/or observe different kinds of professional relationships and develop their own voices as well as improving their communication skills.

4.3. Small steps toward alternative ways of doing business

As mentioned before, the scales of the projects in the design briefs were varied. The material exploration brief was mostly focused on ways of reusing old fishing nets with the (current and/or future) capabilities of Mamukko. The retrofitting brief explored designing a bespoke furniture take-back system for OneOff, through which they can recapture the valuable materials in their designs. The food waste brief was about initiating behavioural change on a local or regional level; however, it did not inherently have a physical product design aspect embedded. Throughout the programme, however, these focuses expanded to address various challenges at different scales (Figure 5).

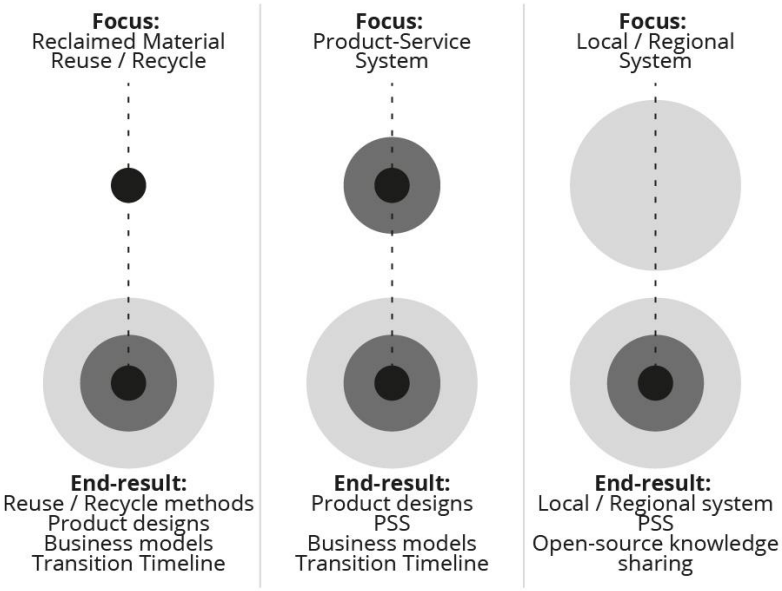


Figure 5. Project scales according to the design briefs (up) and the outcomes of projects (down) in the Circular Design training programme

The shift between scales of operation could be attributed to the initial focus of identifying stakeholders and material flows (see the first masterclass in Table 1). Interns were immediately

faced with the role of various stakeholders in recapturing embedded value, and their design solutions would need to consider all stakeholders' involvement. We observed that this perspective became more important throughout the programme with industry exposure, as the industry partners became more interested in the ways they can implement these design solutions as part of their businesses. This led the interns to develop design solutions, as well as business models, around those solutions, while at the same time suggesting solutions for how the industry partners can, in time, transition into those businesses. This was an unexpected outcome for the researchers, as well as the industry partners. Presenting how industry partners can influence their stakeholders and what steps they may need to take over time was one of the most interesting outcomes of this programme.

During the interviews with industry partners one year after the conclusion of the programme, the effects of these comprehensive outcomes were noticed. Mamukko was exploring ways of expanding their focus, as they were presented with more concrete steps of altering their business, one of which being identification of stakeholders with whom they needed to engage. OneOff was aware of the ways they can influence their stakeholders and clients to buy-in to more sustainable alternatives, and the challenges they need to overcome to transition towards such a take-back system as an SMME. SRWMO adopted the strategy of directly addressing different target audiences (e.g. university students) to combat the issue of food waste and was exploring the ways of implementing solutions accordingly. It should be noted that this was a three-month programme and the outcomes were comprehensive in addressing many aspects around the briefs, however, they weren't finalised solutions ready for implementation. All three industry partners identified this as a limitation of the programme and expressed their belief that a longer programme would have resulted in more detailed and ready-to-implement results.

4.4. Bringing theory into practice: Notes on facilitating co-learning for sustainability

The researcher/educators acted as facilitators of this programme, the process of which required creating a balance between structuring certain activities and allowing room for creativity and innovation. All the parties involved – interns, industry partners and educators – had different learning outcomes in mind, and for our authors, it was a learning-by-doing activity to explore a new way to collaborate with industry and a new way to incorporate real-life sustainability challenges into design education.

At the beginning of the programme, both the interns and the industry partners were informed about the nature of this arrangement: This was not just an educational project, rather, it was a design project where there is a client with a real-life challenge and a team of novice designers addressing it. The educators acted as the mediators, ensuring proper communication between both sides and aiding the interns where necessary. We (the researcher/educators) did not deliver any structured lectures ourselves, rather arranged training sessions with external experts, or led the interns through relevant resources. As an outcome, we observed the kinds of real-life challenges the industry partners faced, and how interns addressed those challenges.

We also observed the impact of multi-cultural groups of interns tackling the challenges of local industry partners. The challenges were deeply related to the Irish context in terms of existing infrastructure and resources, as well as the socio-economical aspects of the Irish industry and users. The Irish interns were familiar with these challenges and could translate these to their non-Irish fellows. On the other hand, other interns provided different perspectives, knowledge and opportunities which inspired the development of unconventional solutions. The researcher/educators also gained insights from this multi-cultural collaboration, having a better understanding of the real-life challenges faced throughout innovation processes and potential new ways by which they could be approached. However, we still don't fully understand the challenges

facing industry in balancing daily business with integrating larger strategic change. This project provided a glimpse into this complex process, but by continuing to work with the industry partners we can gain a broader understanding and be part of effecting change.

5. Conclusions

Incorporating sustainability into design education is a key step in equipping the next generation of designers with the appropriate skills and knowledge to address the complex challenges of sustainability. However, the impact of third level design education can extend beyond the theoretical exploration of the issues around, and approaches to, circular design and incorporate the real-life challenges of transitioning towards sustainable ways of doing business. There is a real opportunity explored by this project, to build capacity amongst a variety of stakeholders in the move towards a sustainable future. Collaborating with SMMEs provides a window into the real-life challenges preventing sustainable innovation. Higher education institutions can, in turn, provide a reduced-risk environment for experimenting with sustainable business alternatives. The programme was designed as a co-learning activity for novice designers, industry partners and educators with these aims in mind and the outcomes clearly indicate that a productive co-learning environment was cultivated throughout the project process, both in terms of addressing real-life challenges to circularity and facilitating productive exchanges of knowledge.

The project outcomes demonstrate that novice designers gained a perspective into the practicalities of adopting sustainable design solutions with the limited resources of SMMEs. From an educational perspective, the co-learning environment provided not only skills related to design practice and sustainability, but also an opportunity to further practice and improve these newly acquired capabilities. The multi-cultural composition of the teams and the varying disciplinary backgrounds of the team members improved the impact of this co-learning environment, which was also visible in the project outcomes. Furthermore, the scopes of the projects changed and expanded during the process, as the outcomes of all three design briefs addressed three scales (i.e. product, service and system).

In terms of collaboration with industry, the partners gained insights into how, and in what way they can transform their businesses and service offerings. Several real-life challenges identified before or during the programme were addressed, exceeding the impact and expectations of all industry partners. All the project outcomes clearly addressed various levels of design intervention (i.e. products, services and systems) and presented opportunities beyond self-contained design solutions and for transitioning into sustainable, circular businesses.

Finally, the educators gained a better understanding of real-life challenges and explored different opportunities for collaborating with industry, all of which can be integrated into subsequent projects/modules/courses. The benefit of translating the theory of sustainability into real situations cannot be underestimated as we move from theoretical notions to practical action in addressing some of the larger global sustainability challenges. This type of collaboration also provides a path for research to extend beyond the academy and into the real-world, leading to tangible impacts for SMMEs. This project has showcased the potential benefits of this new kind of collaboration between industry and HEIs, not only through creating a workforce more attuned to real-life challenges of sustainability but also through immediate impact of the designed outcomes.

Considering the industry partners' comments on the timeframe of the programme and the readiness of the outcomes, we identified some possible directions for future studies on industry-HEI collaboration for sustainability and the circular economy. The co-learning process can be deepened by placing the 'expert' interns in the SMEs upon the completion of the training and encourage both the interns and the industry partners to explore the real-world implications of the developed ideas

further. Similarly, a follow-up 'consultancy' service can be offered by the interns and researcher/educators to the industry partners for integrating sustainable and circular practices into their businesses. These efforts can also be supported through seeking external funding for SMEs to bring the proposed ideas from the internship to realisation.

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