Embedding sustainability in food degrees: A Case-study of service-learning as a signature pedagogy for developing food sustainability competencies

Julie L. Dunne
Technological University Dublin, julie.dunne@tudublin.ie

Catherine Barry-Ryan
Technological University Dublin, catherine.barryryan@tudublin.ie

Cormac H. MacMahon
Technological University Dublin, cormac.mcmahon@tudublin.ie

Follow this and additional works at: https://arrow.tudublin.ie/ijap

Embedding sustainability in food degrees: A Case-study of service-learning as a signature pedagogy for developing food sustainability competencies

Julie Dunne [*1], Catherine Barry-Ryan [1], Cormac MacMahon [1]

[1]Technological University Dublin (IRELAND)

Abstract

Food production and consumption are emblematic of challenges to operate within planetary boundaries, whilst providing minimum access for all. They draw on natural and human resources and are de facto drivers of land-use. Moreover, their recognition in the United Nations Sustainable Development Goals has spurred growing awareness of food system fragility reflected in dietary orientation, waste streams and food security. Education is a key lever in transformation for food system resilience. Yet, food sustainability competencies and their signature pedagogies are in their infancy. This paper offers a reflection of their development at TU Dublin's School of Food Science & Environmental Health, which has integrated sustainability in its strategic orientation. Foundations for transformation emerged in 2020 when the School co-created, with its students, a professional development programme to build capacity for integrating sustainability in its education portfolio. Informed by industry, publications and policy frameworks, the programme assimilated inputs from stakeholders across the food system, including enterprise and the public sector, food professionals and sustainability experts. The School joined an Erasmus+ funded initiative to create a model for developing sustainability competences through service learning (NEMOS).

An initial benchmarking was undertaken using a TU Dublin tool that mapped modules to the SDGs and measured sustainability embeddedness using AASHE-STARS. A thematic analysis of staff interviews and student focus groups revealed 70 food sustainability competencies over 9 categories: farm practice; climate change; product development; circular bioeconomy; waste reduction and valorsiation; measurement and reporting; food safety regulation; environmental impact; and sustainable food business. It noted congruence between skills developed through service learning and the epistemological basis for sustainability. Perceived barriers to

transformation included regulation; slow adoption of innovation; supply chain fragility and marketing orientation. Whilst this case is limited to one school's journey, it contributes to an understanding of food-sustainability competency development through service learning.

*corresponding author: julie.dunne@tudublin.ie

Introduction

Food is inherent to nurturing human health and environmental sustainability. Yet, our food systems threaten both (Willett et al., 2019). Recent data underpinning SDG 2 (zero hunger) reveals soaring food prices, stunting in 1.4m children from malnutrition, 10% of the population suffering from hunger, whilst a rise in obesity related diseases. Our industrialised food systems appear to be damaging ecosystems through greenhouse gas (GHG) emissions, land change, eutrophication, biodiversity loss, chemical pollution, and fresh-water depletion. In summary, the food challenge is twofold: how to reduce its environmental impact; whilst continuing to feed a growing population (Garnett, 2013). Given the magnitude of this challenge, there is growing urgency for transformation to more resilient food systems, involving stakeholders from across the food value chain. The SDGs articulate a future of social equity and economic prosperity within planetary boundaries, with education as a catalyst (Sachs et al., 2019). Food system transformation will require quality education (SDG4), with a broadened purpose from an economic focus to one that integrates global citizenship and environmental stewardship, underpinned by values of equity, prudence, comprehensiveness, connectivity, and security. SDG 4.7 mandates higher education to develop competencies for the sustainability paradigm.

Yet, education for food sustainability is in its infancy. There has been a tendency in higher education to conceptualise diverse food system challenges as disconnected issues. Hence, food graduates have been ill-prepared to address system complexity and to interact effectively with knowledge and practice domains outside of their areas of expertise. In response, sustainable food system education (SFSE) has emerged as a new field based on cross-cutting themes of collective action, systems thinking, experiential learning and interdisciplinarity (Valley et al., 2018). Yet, little is understood of graduate competencies required for transformation to more resilient food systems, nor of the signature pedagogies required to develop them. By signature pedagogies, we refer to approaches to learning, teaching and assessment that organise learners and educators around the epistemological foundations of a profession or discipline, as well as accepted methodological approaches to developing professional competencies (Shulman, 2005). One, such pedagogy, service learning, appears to be congruent with SFSE themes. As a form of experiential learning, service learning seeks to engage students in activities that enhance academic learning and a sense of civic responsibility (McIlrath & MacLabhrainn, 2007).

The transformative power of education can assist with addressing the global challenges of economic inequality, cultural dominance, and environmental degradation (Coetzer et al., 2022;

Rocha et al., 2023). As Ireland's first Technological University, TU Dublin envisions a better world through fostering solution-oriented capabilities. Its strategic pillars (People, Planet and Partnership) are rhetorically articulated through the lens of the 2030 Agenda for Sustainable Development (TU Dublin, 2019). Of contextual relevance here, is its ambition to be 'A Powerhouse for Living & Breathing Sustainability' (p.7). Underpinning this ambition is a desire to create new knowledge, to develop timely solutions that address the SDGs, and to develop a new generation of graduates who will lead the sustainability agenda. In acknowledging the benefits inherent in localising the SDGs in learning outcomes, TU Dublin aims to ensure all its programmes include sustainability as a learning outcome. Hence, consistent with idea of constructive alignment, implicit in developing graduate sustainability competencies is the integration of sustainability, reflected in learning outcomes, activities, and assessments. Also implicit is an expectation of constructive alignment between academic modules, programmes, and SDGs. In recognising the intersectionality of food systems with this challenge, TU Dublin's School of Food Science and Environmental Health has embarked on the necessary capacity building for transformation of its research, education, and engagement activities.

The provision of learning experiences to develop graduates with food-specific sustainability competencies is essential to Ireland achieving its ambition of being a Sustainable Food System (SFS) leader (DAFM, 2021). Whilst existing competency frameworks for sustainability (e.g., Wiek et al., 2011, Bianchi et al., 2022) are useful in addressing interdisciplinary aspects to sustainability problem-solving, they are inadequate for detailing food-specific competencies required to develop and implement SFS. Competencies here refer to a "functionally linked complex of knowledge, skills, and attitudes that enable successful task performance" (Wiek et al., 2011, p.204). An intentional focus on competency development in the School's food programmes would orientate educators towards cultivating learning experiences across those programmes to prepare graduates for future professional roles that will address complex food sustainability challenges. The School hosts several educators with expertise in food sustainability, some of whom are members of TU Dublin's Environmental Sustainability and Health Institute (ESHI), and others who focus on teaching sustainability. Nonetheless, the School identified that professional development would be required to meaningfully review its curricula for sustainability embeddedness and alignment to the SDGs.

Written as a reflective commentary, this article outlines the developmental pathway of the School to embedding sustainability in food degrees. It begins with a summary of professional

development efforts, in which three thematic areas supporting learning and teaching transformations were explored: (i) the context for sustainable development, (ii) global food sustainability challenges and solutions, and (iii) the application of education for sustainability to SFSE. The paper then provides a benchmarking of the School's degree programmes based on a mapping of modules to the SDGs and their categorisation using criteria outlined by Association for Advancement of Sustainability in Higher Education (AASHE, 2019). In seeking to articulate the necessary reorientation of the School's education portfolio, this paper is underpinned by three research questions (RQs): -

RQ1: how can the capacity of educators of Food Degrees be developed to enable embedding of food system sustainability competencies?

RQ2: what do educators and learners perceive to be the required sustainability competencies that are specific to food sector graduates?

RQ3: how do educators and learners perceive that these competencies can be developed, including through service learning?

To answer these questions, a thematic analysis (Braun & Clark, 2012) of educator interviews and of learner focus-groups was undertaken. An emerging competency framework and an exploration of opportunities for their integration as learning outcomes are presented in this paper. This exercise was replicated across six institutions in an ERASMUS+ project: NEMOS - a new educational model for acquisition of sustainability competences through service-learning. In considering activities that would support learning outcome achievement, service-learning relevance is discussed, with exemplars in the School's programmes. Given a broadening of educational purpose to encompass the sustainability agenda, service learning, with a dual aim of societal commitment (service) and training of professional skills (learning), appears to be congruent with sustainability competency development (Lasen et al., 2015).

Hence, ideas for service-learning activities are explored using Hatcher and Bringle's (1997) four stages of preparation, implementation, reflection, and demonstration. Having contextualised the research questions, the remainder of the paper is structured in three sections. The first addressed capacity building achieved through educator development and curricular benchmarking (RQ1). The second addresses required food sustainability competencies (RQ2) and the last section explores their development through service learning (RQ3).

## Section 1 – Capacity building and Curriculum Mapping

Methodology

Historically, continuing professional development (CPD) has been seen as an essential vehicle for maintaining the professional currency of educators (Brancato, 2003). Yet, until recently, there were few mechanisms, in Ireland, which gave structure, focus and support to educators to avail of relevant professional development opportunities in learning and teaching. The establishment of the National Forum for the Enhancement of Learning and Teaching in Higher Education's professional development framework has been an important catalyst in redressing this situation (Donnelly & Maguire, 2018). Moreover, given the centrality of SDG 4 to enabling achievement of other SDGs, CPD has been recognised globally by higher education as an essential element to facilitating transformation (Schudel et al., 2023). This has manifested in a raft of professional CPD opportunities for educators, often provided through various digital platforms, such as the SDG Academy (Sharma & Bahadur, 2020). The project Sustainable-Food-Curriculum Co-Create was funded through the Irish National Forum for the Enhancement of Teaching and Learning call 'Strategic Alignment of Teaching and Learning Enhancement (SATLE)' 2020. Its objective was to enhance the practice of lecturers in multidisciplinary Food Science education with respect to integrating sustainability through the piloting of a 5 ECTS short CPD course in 'Educating for Food Sustainability'. It sought to address perceptions that most sustainability education initiatives offer resources for learners, but too few for educators.

Hence, the School recognised that a key step in building capacity for Education for Sustainable Development (ESD) is educator professional development, since many educators do not yet have necessary sustainability experience, nor dedicated qualifications. The CPD aimed to provide a foundation in sustainability in the immediate term, and to facilitate transformation in TU Dublin's curriculum in the longer term. It intended to have an immediate impact, through assessments that involved reviewing of module descriptors to include sustainability learning outcomes and assessments. However, as sustainability knowledge is transformative and evolving faster than adaptation facilitated by typical higher education quality enhancement processes, the School also aspired to encourage agile and ongoing review and enhancement for a long-term positive impact. The CPD focused on three related knowledge domains, namely (i) sustainability literacy, (ii) food sector sustainability and (iii) education for sustainability.

Included within the project design was a co-creation process involving educators and learners. The concept was that students from the School would enroll in a new Food Sustainability elective module, which would be co-delivered with the CPD. This would provide the students

opportunities to develop sustainability competences whilst also empowering them to contribute to the reviewing of the TU Dublin curricula. Future students would subsequently benefit through studying the reviewed modules with a stronger sustainability orientation. The student module and CPD were underpinned by curated open education resources (OERs) and three practical workshops. The first workshop facilitated a deep dive into the SDGs, exploring their targets, indicators, and metadata. Figure 1 summarises the second workshop, which provided participants an experiential learning of design thinking processes for problem-solving super-wicked sustainability challenges (Yearworth, 2016).

The third workshop represented the culmination in learning over the duration of the module in which participants were guided, using the nomenclature of the SDG framework, in rewiring learning outcomes, indicative syllabi, learning and teaching methods and assessment strategies to better reflect sustainability components within the School's curriculum. Participants completed a materiality mapping to the relevant SDGs and a comprehensive sustainability lexicon was provided to assist with rewriting learning outcomes. All participants were also required to take the UN Sustainability Literacy Test (Sulitest) and write a reflection based on the (Describe, Interpret, Evaluate, Plan) DIEP framework as an authentic assessment designed to raise awareness of global challenges foster transformative learning for sustainable development (Freeman et al., 2021, 2022).
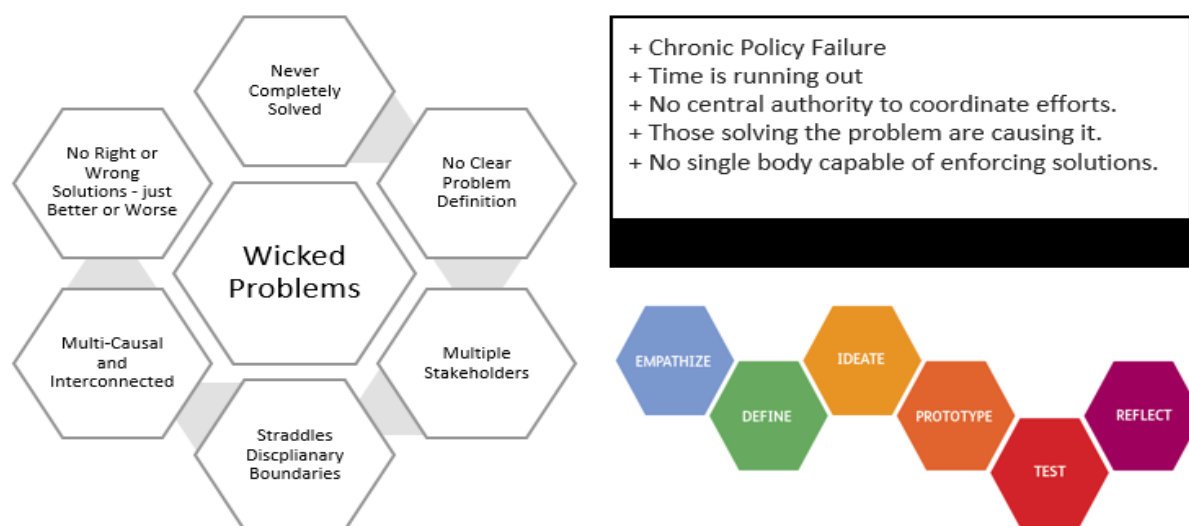
Figure 1: Design Thinking and the Super Wicked Nature of Sustainability Challenges

Results and Discussion

The CPD and student Food Sustainability modules were designed, developed, and delivered as a collaboration between the TU Dublin's Learning Teaching and Assessment team, a university sustainability expert, and the School of Food Science and Environmental Health, framing sustainability in learning, teaching and assessment and allowing for the broadest possible exposure across the three knowledge domains of the CPD programme.

Education for Sustainable Development (ESD) requires several considerations. The content for sustainable development must be rooted in the knowledge disciplines and consider how technology and other advances can influence sustainable development solutions. However, sustainable development is complex, requiring systems and transdisciplinary approaches that allow knowledge to emerge between established fields, providing space for alternative perspectives, innovative ideas, and solutions to be created (QAA, 2014). The difficulty is that sustainability requires appreciation of system complexity, far beyond that historically taught in traditional disciplinary focused programmes. Solutions to complex sustainability challenges will not derive from traditional disciplinary-focused problem-solving but, rather, require innovative interdisciplinary approaches that foster food-specific competencies and a wider set of future-oriented skills, as well as for students to reflect critically and question their worldviews. To be meaningful, ESD must be influenced by the viewpoints of all stakeholders, including business and enterprise, regulatory and state bodies, local communities, and social partners. Hence, ESD encourages learners and educators to collaborate widely to affect change. The ethos of the professional development initiative is based on sector focused multi-disciplinary collaboration, with a strong focus on academic-enterprise co-creation of curriculum, leading to co-creation of knowledge for sustainable development, and integrating UNESCO's learning outcomes for the SDGs (Rieckmann, 2017).

The module learning outcomes are shown in Table 1. The assessment strategy was primarily reflective in nature, to capture participants' development. Participants recorded a reflective journal, detailing their developmental journey through various webinars, workshops, online activities and learning resources. Additionally, three face-to-face workshops required participants to develop and submit creative artefacts. The mode of delivery was blended. Curriculum delivery included peer-lectures from staff participating on the module, lectures from experts from across the university, as well as non-academic experts who were invited to deliver key industry-related elements. Speaker profiles are provided in Table 2.

Table 1: The learning outcomes of the Educating for Food Sustainability module

	Learning Outcomes:
	On Completion of this module, the learner will be able to
1	Demonstrate high-levels of sustainability literacy - knowledge, skills, and mindsets to become deeply committed to building a sustainable future
2	Demonstrate high-levels of sustainability literacy - knowledge, skills, and mindsets to become deeply committed to building a sustainable future as related to the Food sector
3	Critically appraise sustainability-related exemplars of curriculum design, pedagogical approaches and assessment strategies that inform design of transformative learning 'interventions' to create cognitive, affective, and behavioural learning opportunities.
4	Apply design-thinking to food systems, premised on collaborative experimentation that integrates stakeholders as co-creators of food sustainability knowledge.
5	Co-create an evidence-based framework to support the design, implementation, impact-measure, and durability of learning 'interventions' in food-related disciplines for achievement of the SDGs.
6	Explore questions about the purpose of higher education in building embedded pathways though curricular, co-curricular and informal curriculum for life-long sustainability.

Table 2: Guest Speaker Series

Topic	Speaker
Sustainability Literacy	Member of Ireland's National Regional Expert Committee for sustainability literacy.
Indicators of Sustainable Living	Senior lecturer on TU Dublin's MSc in Sustainable Development
Food Production and Climate Change	Environmental Health and Food Science Lecturer at TU Dublin
Urban Food Initiatives	Environmental Planning Lecturer at TU Dublin
Sustainable Challenges in Irish Agriculture	Enterprise Ireland expert on supporting SME agriculture and Professor of Dairy at University College Dublin
Decarbonising Ireland's Energy	Expert form Ireland's Wind Energy Association with PhD in sustainable energy planning.
Food Sustainability Accreditation – Origin Green	Expert from Bord Bia sustainability programme - the only one in the world which operates at a national level, and which includes farmers and primary producers, processors and retailers working together to create a better future for all involved.
Waste Valorisation	Senior lecturer in Food Product Development at TU Dublin
Sustainable Diets	Senior Lecturer in Dietetics at TU Dublin
Corporate Sustainability	Head of Sustainability from Dawn Meats

The open education resources (OERs) used to support module delivery were curated from several sources, including: the UN Food and Agriculture Organisation (FAO), the UN Global Compact (UINGC), the international panel on climate change (IPCC), ESD guidelines (e.g. Government of Ireland, 2023), the SDG Academy, UN CC Learn, the World Economic Forum (WEF) as well as seminal sustainability reports, such as *Our Common Future* (Brundtland, 1987), and the *FABLE* report (FABLE, 2020). Given that module delivery occurred during the COVID-19 pandemic, many of guest-lectures delivered their lectures online as webinars, which were recorded and edited into OERs for on-demand consumption. These resources are available under creative commons (CC) license from TU Dublin's SDG Literacy community of practice, an active community of educators and learners with a shared interest in advancing education for sustainable development (Behan et al., 2022).

Guest-speakers were invited to deliver masterclasses on different topics, including the impact of climate change on food production, decarbonising Ireland's energy, sustainable diets, the UN food systems dashboard, corporate sustainability, food waste valorisation, the circular bioeconomy, the EU green deal, urban food initiatives, food sustainability accreditation and indicators of sustainable living. The student voice was captured through co-creation workshops and reflective exercises. All participants in the modules were asked to complete a reflection-in-action, which was designed to document learning transformation. Workshops were facilitated online using MS TEAMS breakout rooms. The CPD culminated in a workshop focused on evaluating the embeddedness of sustainability within individual module descriptors by applying the AASHE-STARS criteria for sustainability-focused and sustainability-inclusive courses.

The AASHE-STARS (2019) technical manual provides a methodology for measuring university contributions to the SDGs. It classifies modules into three categories: 'Sustainability-focused' modules must contain significant content with an explicit reference to sustainability or focus on a major sustainability challenge; Although 'Sustainability-inclusive' modules do not have to have an explicit focus on sustainability, they must incorporate a sustainability component to indicate requisite learning; 'Non-sustainable' modules represent those that are neither sustainability-focused nor sustainability-inclusive. To assist educators with the categorisation process, TU Dublin applied a natural language processing (NLP) technique, referred to as Term Frequency-Inverse Document Frequency (TF-IDF), to a lexicon of root keywords extracted from the 169 targets and 247 indicators describing the SDGs, as a means of scoring their relative sustainability importance to each SDG (Lemarchand et al., 2022; 2023).

A weighting, or sustainability importance (SI), for each root keyword to each SDG was scored, based on the calculation shown in the below Equation 1.

$$\text{SI Score} = \frac{\text{Number of Times the Keyword appears in the t arg ets and indicators}}{\text{Number of SDGs in which the keyword appears}} \tag{1}$$

Searching for these keywords within module descriptors then provided a basis for scoring the sustainability importance (SI) of modules to the SDGs. A statistical parsing of these SI scores then provided the basis for categorising modules to AASHE-STARS criteria. A detailed analysis of the modules in the Food degree programmes was disseminated to programme teams for consideration. Whilst acknowledging that the computational technique was prone to systematic error, it nevertheless provided useful guidance for educators to consider how the narration of their courses, using module descriptors, could be adapted to better reflect the SDGs. Guided by the SDSN's SDG keywords, students and staff mapped selected module learning outcomes, indicative syllabi, assessments and learning resources to the SDGs, manually simulating the NLP technique. The analysis also identified opportunities for enhancing the sustainability importance score of each module. Each breakout room contained a mix of staff and students who were familiar with the respective modules for evaluation. A second workshop was run to evaluate the GHG impact of module delivery, using the SusTEACH model (Caird et al., 2015). Finally, the third workshop, focused on the application of design thinking. It required students to adopt different personas in understanding user needs for a sustainability product, thereby replicating the problem-solving process typically required to solve complex sustainability problems, with characteristics outlined in Figure 1.

The assessment strategy for the Food Sector sustainability modules was based on three elements. First, participants were required to write a reflection of their personal development during the module, as well as on their experiences of an UN supported online multiple-choice question style sustainability literacy test or Sulitest, for short (MacMahon, 2020). Second, participants were required to co-create artefacts during the workshops. Third, academic staff were required to review and modify one of their module descriptors to embed sustainability learning outcomes. An example of a modified module descriptor is shown in Figure 2, with sustainability elements integrated in **bold** text (Dunne, 2021).

Using TU Dublin's computational technique to evaluate sustainability embeddedness before and after the changes were made to the learning outcomes, a noticeable impact could be discerned from modifying the learning outcomes, with both the sustainability importance (SI)

score and AASH-STARS categorisation of the module changing. Table 3 highlights the improvement in the module's SI score and upgrade of the module's AASHE-STARS classification, due to the textual modifications to the module descriptor (Dunne, 2021).

Module Overview:	
The module aims to enable students to employ analytical techniques to food analysis to generate high quality analytical data.	
This subject deals with principles of chemical analysis and the application of analytical methods to food, including the use of advanced instrumentation. An emphasis will be placed on extraction and analysis of nutraceutical components, including structure identification, **and the role in circular bioeconomy. An emphasis will also be placed on the role of green chemistry in food analysis.** Laboratory work involves the application of analytical methods to food, including the use of advanced instrumentation.	
Learning Outcomes (LO):	
On Completion of this module, the learner will be able to	
1	Describe the basic terminology of chemical analysis and explain the decision process for choice of methods, and use of validated methods.
2	Describe the principles of sampling.
3	Explain the uses of traditional sample preparation techniques **as well as potential for greener solvents for extraction of bioactives.**
4	Describe aspects of laboratory Quality documentation for analytical methods
5	Describe applications of chemical techniques in food analysis, **and the role of green chemistry in analytical methods.**
6	Describe applications of instrumental techniques including rapid methods in food analysis.
7	Discuss **global challenges** in the context of food chemistry and analysis: **food fraud and the impact of climate change on food chemical contaminants.**
8	Develop enhanced numeracy through in-class and in-practical calculations, including identification and reduction of variance.
9	Develop enhanced laboratory skills to perform high quality food analyses for a range of food constituents.
10	Develop enhanced research and scientific writing skills to report on food analysis experiments.

Figure 2: A module descriptor reviewed to embed sustainability competencies

Table 3: Application of TU Dublin's Computational Modified Module Descriptor

	SI Score	AASHE-STARS Category	SDG Mapping
Before Modification	19.4	Sustainability Inclusive	SDG 2
After Modification	33.4	Sustainability Focused	SDG 2

Although educators and learners were each enrolled on different versions of the programme, the underlying ethos was on co-learning, as partners equally vested in a transformative learning process for an embryonic but rapidly evolving field of study. Indeed, the most prevalent theme evident from the reflective writings of participants in the programme was transformation, as indicated by sample extracts provided below.

"Sustainability will underpin my thinking, teaching plans and educational remit for both undergraduate and postgraduate students."

"The most significant change in my perspective and attitude towards sustainability and food is the definite plan to incorporate the learning outcomes in my future course development."

"I have some good ideas about how I can transform one of my modules in food chemistry to include sustainability ... throughout the timeframe of the module".

In conclusion, I feel that aspects of this module have been truly transformative for me and have opened my eyes to several sustainability challenges that we face ... and approaches being undertaken to address them".

The foundation provided by the Educating for Food Sustainability CPD programme became the catalyst for the School of Food Science & Environmental Health to engage with the EU Erasmus+ NEMOS project (NEMOS, 2022) and to contribute in a more impactful manner to the strategic scoping and implementation of the project. The NEMOS project is focused on developing a competency-based food sustainability profile and enabling its implementation through service learning within the degree programmes of collaborating universities.

Section 2 – Developing a Food Sustainability Profile (FSP)

Methodology

As part of a consortium of European universities, TU Dublin commenced the EU Erasmus+ project 'NEMOS A new educational model for acquisition of sustainability competences through service-learning' in 2022. Significant work on completing the first objective has been completed: defining a food sustainability profile through a community building methodology.

The methodology for defining the food sustainability profile was developed collaboratively by the NEMOS partner institutions. Research Ethics approval was granted for NEMOS to conduct Surveys, Focus Groups, and Interviews. A purposive sampling strategy identified lecturers and students who could participate meaningfully in the FSP development process. All participants were provided with information on the project, including its potential benefits and the commitments associated with their participant. All participants consented to participate in the research. A question schedule developed by the NEMOS project was used for all qualitative interviews and focus groups. Focus groups were conducted online by TU Dublin NEMOS leads, who were members of academic staff in the School of Food Science & Environmental Health. Both interviews and focus groups were recorded, and key points were summarised, followed by an overall analysis of themes arising from staff and students. An interview with the TU Dublin Students Learning with Communities (service learning) lead was also conducted. Recordings were transcribed and summarised into 8 key themes. Five interviews with external stakeholders were also carried out by a TU Dublin NEMOS lead and NEMOS Fellows. Key points were summarised to various extents depending in the interviewer and were reported. All the data from these interviews were drawn into a single summarised report. Surveys were completed by TU Dublin students (N=39), staff (N=21) and the data was analysed.

TU Dublin's computational approach to evaluating sustainability embeddedness within the curriculum and curricular alignment to the SDGs was also applied to an analysis of the School's BSc in Food Innovation programme, as part of an initial benchmarking to assist with scoping the sustainability profile for food degrees. The analysis of the four stages of the TU Dublin BSc Food Innovation shows no stage where the category of sustainability-focused modules is highest (Table 4). When sustainability focused and inclusive modules are combined, Stage 4 has the highest level of sustainability, with Stage 2 the lowest.

Table 4: BSc Food Innovation with year and the % of modules in each AASHE category

Stage	AASHE-STARS Category	Number of Modules	%
1	No Sustainability Element	4	33
	Sustainability Inclusive	5	42
	Sustainability Focused	3	25
2	No Sustainability Element	8	66
	Sustainability Inclusive	2	17
	Sustainability Focused	2	17
3	No Sustainability Element	3	25
	Sustainability Inclusive	7	58
	Sustainability Focused	1	8
4	No Sustainability Element	2	17
	Sustainability Inclusive	7	54
	Sustainability Focused	3	25

However, these results are favourable (with a significantly higher proportion of sustainability focused and inclusive modules) when compared with other TU Dublin programmes. Across the wider TU Dublin curriculum portfolio, the incidences of sustainability-focused and sustainability-inclusive modules average 5%, and 13% respectively, indicating that the School's education portfolio is rooted in a strong sustainability orientation.

Results and Discussion

Informed by this benchmarking exercise, the qualitative research through interviews, surveys and focus groups with stakeholders (as outlined in the methodology) identified common barriers to food sector sustainability, including economic, supply chain constraints, labour, knowledge, awareness, investment, government, human nature, climate change, environmental, social sustainability, unregulated capitalism, low adoption of innovation, and food safety. Key food related sustainability concepts that will be useful in informing the development of a sustainability profile and for the review of food degrees to embed sustainability learning outcomes were identified and are shown in Table 5. In summary, 76 food-specific competencies were identified across 10 competency categories.

Table 5: Food Sustainability Themes and Competencies

Theme	AgriFood Sustainability Competency/Learning outcome
Farming Practices	1. GMO foods – require less water, less nutrients 2. Sustainable methods, i.e. free range, Hydroponics 3. Upkeep of land, improving organic matter and quality 4. Biodiversity 5. Availability of stock seeds 6. Improving farm activity, pollinating insects, use of pesticides 7. Reduce reliance on chemical fertiliser and pesticides 8. Soil analysis, and include worm activity, organic matter, soil structure 9. Carbon and carbon sink 10. Reduce antibiotics. Food sustainability and health relationship.
Climate Change	11. Climate change aspects 12. Erratic/destructive weather 13. Changes in pathogen/toxin biology 14. Human population movements 15. Pollution 16. Biodiversity loss/change 17. Curbing methane and other GHG emissions. 18. Food security
Environmental	19. Carbon footprinting of the lifecycles of common food production 20. Use of new power sources, e.g., hydrogen, wind, wave 21. Emissions reduction 22. Life cycle assessment 23. Laboratory design, solvent reduction in food chemical analysis 24. Reusable laboratory materials 25. Reuse tools and materials for less wastage 26. Energy management in food processing and distribution. 27. Capacity for measuring sustainability and environmental quality 28. Biodiversity
Food Product Development	29. Sustainability in NPD 30. Sustainability of food packaging 31. Changing public opinions, diets, perspectives, fears. 32. Healthy and nutritious food (reformulation, reduced sugar, salt, etc) 33. Reduce focus on animal foods – less energy and feed, water, shelter 34. Utilise crops that are in season 35. Alternative products ie flexitarian 36. Food processing sustainable innovation 37. Food ingredients sustainability 38. Supply chain reliability
Agrifood Circular Bioeconomy	39. Use of food and other waste (manure, cardboard) to generate biogas and biodiesel and offer back as renewable energy (Green Generation). 40. Reduction in waste & removal costs 41. Offsetting fossil fuel usage 42. Side streams circulated back e.g. as fertiliser 43. Organic fertiliser reducing other fertilisers 44. Use of enzymes for bioremediation and valorisation

	45. Bioeconomy principles to achieve sustainability
Waste Reduction and Valorisation	46. Reducing water waste 47. Food waste for animal feed 48. Eliminating / reducing food waste 49. Packaging recycling
Measuring and Benchmarking	50. BRC Food safety standard V9 will include sustainability 51. Auditing skills 52. Capacity for measuring farm sustainability and environmental
Food Safety and Regulatory Affairs	53. Traceability, food safety, regulation, and compliance 54. Sustainable packaging and food safety 55. Food Safety and Climate change adaptation 56. Benchmarking systems for sustainability targets
Sustainable and Ethical Food Business	57. Measurement of sustainability in the food industry 58. Marketing – responsible marketing, consumer, transparency 59. Sustainable Certification e.g. Bord Bia Origin Green 60. Adulteration and sustainability. Labelling. 61. Gender equality and food. Not well known or understood. 62. Social issues, equality, climate justice, unfair wages, fair trade. 63. Balance sustainability and business viability 64. Negotiating with suppliers and customers 65. Innovation brokerage for sustainability 66. Ethical ingredients, supply chain, labour 67. Innovations in procedures, equipment 68. Plans for surplus food grown 69. Commercial requirements, ethical credentials, sustainable governance 70. Bioeconomy as a driver of sustainability and new markets

The qualitative research also revealed that educators in the School are interested in food sustainability and that most have some sustainability elements included within their modules. Nonetheless, a need for further professional development within their food related discipline area, in general sustainability, and in pedagogies to embed sustainability were identified. Meanwhile, the learner focus groups revealed a need for specific knowledge and training in sustainability issues as a necessary part of their professional education. Most learners indicated an interest in sustainable development projects or activities. The interest in participating in service learning was high across all those surveyed and interviewed. Specific guidance on integrating sustainability through service learning was provided by the university service-learning lead. The next section provides a brief introduction to the School's plans to adopt service learning as a signature pedagogy for developing the food sustainability competencies identified by the qualitative research undertaken. It offers both a theoretical framework and practical examples of implementation.

Section 3 – Service Learning as a Signature Pedagogy for SFSE

Signature Pedagogies – Theoretical Underpinning

Signature pedagogies are 'types of teaching that organise the fundamental ways in which future practitioners are educated" (Shulman, 2005,). This final section focuses on one such pedagogical approach, namely service learning, exploring its potential contribution to the development of food sustainability competencies. Whilst there are many examples of signature pedagogy developments for the archetype professions, such as medicine, law, or engineering, they are less evident in the scientific disciplines (Harris, 2012). An analysis of food science education using Shulman's (2005) three dimensions of signature pedagogies reveals: -

> **Surface Structure:** Shulman refers to 'surface structure' as the 'operational acts of teaching and learning' (p. 54). In a food science context, this can involve traditional lectures, sharing of digital resources on a Virtual Learning Environment (VLE), small group tutorials, field trips, debates, case-studies, and laboratory exercises.

> **Deep Structure:** Shulman refers to 'deep structure' as the 'operation a set of assumptions about how best to impart a body of knowledge and know how' (p. 55). In a food science context, this is reflected in heavy emphasis on laboratory work and formal curriculum as articulated in textbooks and seminal scientific articles, as well as various techniques for to enhancing problem-solving abilities and critical thinking.

> **Implicit Structure:** Shulman refers to 'implicit structure' as a moral dimension that comprises a set of commitments to professional values' (p. 55). In food science, it is primarily reflected in the 'hidden curriculum', e.g., behavior of educators and learners that foster a combination of professionalism and rigorous methodological approaches.

In seeking to strengthen the sustainability orientation food science education, Valley et al. (2018) highlight key themes coded in learning outcomes of emergent SFSE, namely collective action, systems thinking, experiential learning and interdisciplinary learning, that could complement the food specific sustainability competencies identified earlier in this paper. In the context of collective action, exemplars of development of civic engagement and agency are evident in the literature (e.g., Hilimire et al., 2014; Niewolny et al., 2012. In context of developing systems thinking, there is also accumulating body of education literature (e.g., Borman et al., 2022; Spiker at al., 2021,) supporting the interconnectedness of global food challenges. Given the transformative nature of sustainability learning, there is a growing

acceptance of the need for experiential learning, inspired by Dewey (1938) and Kolb (1984), which can support learning through connecting action with reflection (e.g., Ahmed et al., 2018). Interdisciplinarity appears to be particularly important in the context of synthesising perspective across food systems through interacting with a diverse set of stakeholders (Hartle et al., 2017).

Service Learning

Hatcher and Bringle (1997) define service learning as a 'type of experiential education in which students participate in service in the community and reflect on their involvement to gain further understanding of course content and its relationship to social needs and an enhanced sense of civic responsibility. The pedagogy is underpinned by the notion of facilitating learners to make connections between the service experience and module content. Whilst service learning appears similar to other experiential learning methods, such as volunteering or internship, it differentiates itself by focusing on enhancing students' understanding of their disciplinary knowledge through service experience and reflection on that experience, thereby connecting classroom theory with real-world problems (Salam et al., 2019).

As sustainability becomes more important in higher education, a greater emphasis on social responsibility and civic collaboration places service learning at the forefront of pedagogical importance. In the context of educating for more resilient food systems, service learning is, thus, a likely signature pedagogy for developing both food-specific sustainability competencies as well thematic competencies identified in SFSE. Multiple benefits to service learning are cited. The active nature of the learning assists the development of critical thinking, problem-solving, social awareness, and sense of civic responsibility (Barth et al., 2014). Molderez et al. (2018) highlight how it assists with more holistic development, supporting character buiolding, personal growth and a sustainability orientation. Additionally, service learning promotes creativity, innovation, and ability to work collaboratively (Toncar et al., 2006).

The core challenge in the design of service learning is in linking the learning experience with learning outcomes. In food programmes, outcomes relate to food-specific competencies (Table 4) and to the thematic competencies of SFSE. The benefits to adopting service learning were sufficiently persuasive to the School to pursue its integration. However, the School also recognises that effective learning needs to be supported by careful guidance for experience and reflection. Hence, in contributing to the NEMOS project, it has adopted a TU Dublin developed guide for the reflective assessment of the service-learning experience and piloted it with service-learning projects on its BSc in Food Innovation. The guidance includes reflective

assessment trigger questions, a rubric for assessing service learning, an adaptation of the *What? So what? And Now What?* model of reflection (Rolfe, 2014), reflective writing structure and vocabulary support, and recommended reading for educators. Rolfe's framework uses Borton's (1970) developmental model, to stimulate reflection from novice to advanced levels. First, the learner reflects on the situation. Second, the learner is encouraged to construct personal knowledge about the situation. Third, the learner considers ways of improving the situation and reflects on the consequences of his/her actions. In 2022-2023, the BSc in Food Innovation Final Year research project module, with sustainability and service-learning components, was implemented with two non-profit Irish organisations, namely Dublin Zoo and the Food Safety Authority of Ireland. These activities will be evaluated using the NEMOS tools. In preparation for programmatic review, the School team has embedded sustainability at programme and module levels. Table 6 lists the revised modules, which will include service-learning.

Table 6: The core subjects chosen from the BSc Food Innovation for piloting the acquisition of food sustainability competences through service learning in TU Dublin

Module Code	Module Title	ECTS	NQF Level
TFMB 2001	Food Microbiology	5	6
CHEM 2027	Natural Organic Chemistry	5	6
TFQM 2001	Quality and Hygiene Systems	5	6
TFCD 2004	Food and Pharma Instrumentation	5	6
TFFP2004	Food Ingredients and Consumer Foods	5	6
CHEM3022	Food & Beverage Chemistry & Analysis	5	7
TFFS3003	Training & Auditing	5	7
WKPL3010	Industrial Placement	24	7
TFHS3002	Occupational Safety Management for the Food Industry	5	7
TFPJ4003	Project/Dissertation	15	8
FSFS4001	Beverage Regulatory Affairs	5	8

Conclusions

The provision of educator CPD has been an important pre-requisite to realising TU Dublin's strategic intent to embed sustainability in a meaningful way. TU Dublin's capacity for review and enhancement, through the lens of the SDGs, particularly for integration of sustainability learning outcomes in food programmes, has been upgraded through the provision of the CPD. First, educators in the School have developed their literacy of the social, environmental, and economic dimensions to sustainability. Second, they gained an understanding interconnected

issues concerning food systems. Third, they developed a collective capability to enhance sustainability components in their own curriculum and make explicit mappings of modules to the SDGs, reflected in sustainability importance (SI) scores of their modules. Hence, the CPD has provided a basis for curricular transformation. An important aspect to the CPD has been the development of capacity to engage nimbly with enterprise. Sustainability knowledge, which is transformative in nature, mandates a CPD provision that encourages ongoing review and positive impact on the food sector. In the co-create process, the Food Sustainability student module has provided opportunities for TU Dublin students to develop sustainability leadership capabilities until curricular integration of sustainability is formally enshrined.

In tandem with educator professional development, the NEMOS project has facilitated the identification of 70 food sustainability competencies over 9 categories (Table 2) that can be interwoven with the transversal skills of GreenComp (Bianchi et al., 2022). In tandem with educator professional development, NEMOS has facilitated an in-depth curriculum analysis of the BSc in Food Innovation programme for sustainability embeddedness and SDG mapping. Hence, the School team is well positioned, through review and enhancement, to embed specific food related sustainability learning outcomes, and to design aligned learning activities and assessments. Sustainability components have been drafted into (i) programme aims (ii) graduate attributes and (iii) programme learning outcomes in the form of edits to existing attributes as well as new, sustainability focused attributes. All modules have been reviewed through the lens of sustainability and the module descriptors updated, whilst several modules were identified for piloting of service learning. Changes to the curriculum will be formalised through TU Dublin's quality enhancement processes. Service-learning pilots will be evaluated using NEMOS developed tools. Whilst the developmental journey of the School implies that this paper is a work-in-progress, there are already noticeable impacts on learners. Students from the BSc Food Innovation have, for example, participated in the TU Dublin SciFest event. They disseminated their final-year project work to secondary school students and highlighted sustainability aspects to their research. It is intended, as the School's developmental journey continues, that the capacity of its graduates to contribute to Ireland becoming a leader in SFSE will be enhanced.

Acknowledgements

References

AASHE (2019). *Stars Technical Manual Version 2.1*. Philadelphia, PA: American Association for the Advancement of Sustainability in Higher Education.

Ahmed, S., Byker Shanks, C., Lewis, M., Leitch, A., Spencer, C., Smith, E. M., & Hess, D. (2018). Meeting the food waste challenge in higher education. I*nternational Journal of Sustainability in Higher Education*, *19*(6), 1075-1094.

Barth, M., Adomßent, M., Fischer, D., Richter, S., & Rieckmann, M. (2014). Learning to change universities from within: a service-learning perspective on promoting sustainable consumption in higher education. *Journal of Cleaner production*, 62, 72-81.

Behan P, Ferns S, Foley S, Freeman O, Gabaudan O, McAlpine A, MacMahon C, & Walsh L. (2022). Using the Community of Practice model to shape approaches to Education for Sustainable Development across disciplines in a Technological University context: A Roundtable Podcast. Polytechnic Summit, Darmstadt, July 2022. https://doi.org/10.21427/RJN2-E451

Bianchi, G., Pisiotis, U., & Cabrera Giraldez, M. (2022). *GreenComp: The European sustainability competence framework* (No. JRC128040). Joint Research Centre (Seville site).

Borman, G.D., de Boef, W.S., Dirks, F., Gonzalez, Y.S., Subedi, A., Thijssen, M.H., & van Berkum, S. (2022). Putting food systems thinking into practice: Integrating agricultural sectors into a multi-level analytical framework. *Global Food Security*, *32*, 100591.

Borton T (1970). *Reach, Touch and Teach*. New York, NY: McGraw-Hill.

Brancato, V. C. (2003). Professional development in higher education. *New directions for adult and continuing education*, 98, 59-66.

Braun, V., & Clarke, V. (2012). *Thematic analysis*. American Psychological Association.

Brundtland, G. H. (1987). Our common future - Call for action. *Environmental Conservation*, *14*(4), 291-294.

Caird, S., Lane, A., Swithenby, E., Roy, R., & Potter, S. (2015). Design of higher education teaching models and carbon impacts. *International Journal of Sustainability in Higher Education*, *16*(1), 96-111.

Coetzer, J., Morales, L., & MacMahon, C. (2022). Rethinking higher education models: towards a new education paradigm for the UN 2030 agenda for sustainable development. In Re-imagining higher education through equity, inclusion and sustainability (RISE). *Proceedings of the 2nd. EUt+ International Conference on Equality, Diversity and Inclusion, Technical University of Sofia, Sozopol, Bulgaria, 1-3 September*.

DAFM (2021). *Food Vision 2030 – A World Leader in Sustainable Food Systems*. Government of Ireland. Available online at: https://www.gov.ie/en/policy/b2a3c-food-vision-2030-a-world-leader-in-sustainable-food-systems/ (Accessed February 12, 2023).

Dewey, J. (1938). Experience and education. New York: Macmillan.

Donnelly, R., & Maguire, T. (2018). Supporting Teaching and Learning Transformations through the National Professional Development Framework: Establishing and Recognising an Inclusive Community of Practice for all who teach in Irish Higher Education. *AISHE*, *10*(1).

Dunne, J. (2021). Food Analysis Module Descriptor with SDGs Embedded. Reusable Resources. Available online at: https://arrow.tudublin.ie/totalarcresreu/1

FABLE (2020). *Pathways to Sustainable Land-Use and Food Systems*. 2020 Report of the FABLE Consortium. Laxenburg and Paris: International Institute for Applied Systems Analysis (IIASA) and Sustainable Development Solutions Network (SDSN). https://doi.org/10.22022/ESM/12-2020.16896

Freeman, O., Duffy, D., McAlpine, A., Nolan Dr, C., McMahon, C., & Walsh, L. (2021). Exploring the impact of authentic assessment on sustainability literacy through reflective and action-oriented tasks: A roundtable podcast. *Irish Journal of Academic Practice*, *9*(2), 7.

Freeman, O., Walsh, L., McMahon, C., & McAlpine, A. (2022). *Grassroot Power of Communities of Practice–The Case of SDG Literacy*. Presented at the International Conference on Sustainable Development, 20th September 2022.

Garnett, T. (2013). Food sustainability: problems, perspectives, and solutions. *Proceedings of the nutrition society*, *72*(1), 29-39.

Government of Ireland (2023). *ESD to 2030: Second National Strategy on Education for Sustainable Development*. Available online at: https://www.gov.ie/en/publication/02952d-national-strategy-on-education-for-sustainable-development-in-irelan/ (Accessed February 18, 2023)/

Harris, C. (2012). Expanding political science's signature pedagogy: The case for service learning. *European Political Science*, *11*, 175-185.

Hartle, J.C., Cole, S., Trepman, P., Chrisinger, B.W., & Gardner, C.D. (2017). Interdisciplinary food-related academic programs: A 2015 snapshot of the United States landscape. *Journal of agriculture, food systems, and community development*, *7*(4), 35.

Hatcher, J.A., & Bringle, R.G. (1997). Reflection: Bridging the gap between service and learning. *College teaching*, *45*(4), 153-158.

Hilimire, K., Gillon, S., McLaughlin, B.C., Dowd-Uribe, B., & Monsen, K.L. (2014). Food for thought: Developing curricula for sustainable food systems education programs. *Agroecology and Sustainable Food Systems*, *38*(6), 722-743.

Hollis, F.H., & Eren, F. (2016). Implementation of real-world experiential learning in a food science course using a food industry-integrated approach. *Journal of Food Science Education*, *15*(4), 109-119.

Kolb, D. A. (1984). Experiential learning: Experience as the source of learning and development. Englewood Cliffs, N.J: Prentice-Hall.

Lasen, M., Tomas, L., & Hill, A. (2015). Potential of service-learning to promote sustainability competencies in pre-service teachers: A case study. *Teaching Education*, *26*(4), 341-365.

Lemarchand, P., McKeever, M., MacMahon, C., & Owende, P. (2022). A computational approach to evaluating curricular alignment to the united nations sustainable development goals. *Frontiers in Sustainability*, *74*. https://doi.org/10.3389/frsus.2022.909676

Lemarchand P., MacMahon C., McKeever M., & Owende P. (2023). An evaluation of a computational technique for measuring the embeddedness of sustainability in the curriculum aligned to AASHE-STARS and the United Nations Sustainable

Development Goals. *Frontiers in Sustainability*. 4:997509. https://doi.org/10.3389/frsus.2023.997509

MacMahon, C. (2020). Using the UN Sustainability Literacy Test. Technology Tools for Teaching in Higher Education. The Practical Handbook Series.

McIlrath, L., & MacLabhrainn, I. (Eds.). (2007). *Higher education and civic engagement: International perspectives*. London: Ashgate Publishing Ltd.

NEMOS (n.d.). A new educational model for acquisition of sustainability competences through service-learning. Available online at: https://www.nemosproject.com/

Molderez, I., & Fonseca, E. (2018). The efficacy of real-world experiences and service learning for fostering competences for sustainable development in higher education. Journal of cleaner production, *172*, 4397-4410.

Niewolny, K., Grossman, J., Byker, C., Helms, J., Clark, S., Cotton, J., & Jacobsen, K. (2012). Sustainable agriculture education and civic engagement: The significance of community-university partnerships in the new agricultural paradigm. *Journal of Agriculture, Food Systems, and Community Development*, 2, 27–42.

QAA (2014). Education for sustainable Development: Guidelines for UK Higher Education Providers. Higher Education Academy and UK QAA.

Rieckmann, M. (2017). Education for sustainable development goals: Learning objectives. UNESCO publishing.

Rocha, O., Kamphambale, D., MacMahon, C., Coetzer, J. H., & Morales, L. (2023). The Power of Education in a Globalised World: Challenging Geoeconomic Inequalities. *Peace Review*, *35*(4), 708-723.

Rolfe, G. (2014). Rethinking reflective education: What would Dewey have done? *Nurse Education Today*, *34*(8), 1179-1183.

Sachs, J.D., Schmidt-Traub, G., Mazzucato, M., Messner, D., Nakicenovic, N., & Rockström, J. (2019). Six transformations to achieve the sustainable development goals. *Nature sustainability*, *2*(9), 805-814.

Salam, M., Awang Iskandar, D., Ibrahim, D., & Farooq, M. (2019). Service learning in higher education: A systematic literature review. *Asia Pacific Education Review*, *20*, 573-593.

Sharma, N., & Bahadur, C. (2020). OOCs for Sustainable Development: SDG Academy Lessons for motivations learning completion and impact. *International Review of Research in Open and Distance Learning*, *10*(5).

Schudel, I., Down, L., McKeown, R., Baumann, S., Petersen, A., & Urenje, S. (2023). *Supporting Education for Sustainable Development through an Online Global Forum for Teacher Educators*. At school in the world: Developing globally engaged teachers.

Shulman, L. S. (2005). Signature pedagogies in the professions. *Daedalus*, *134*(3), 52-59.

Spiker, M., Hege, A., Giddens, J., Cummings, J., Steinmetz, J., Tagtow, A., & Sauer, K. (2021). Leveraging Online Learning to Promote Systems Thinking for Sustainable Food Systems Training in Dietetics Education. *Frontiers in Nutrition*, *8*, 623336.

Toncar, M., Reid, J., Burns, D., Anderson, C., & Nguyen, H. (2006). Uniform assessment of the benefits of service learning: The development, evaluation, and implementation of the seleb scale. *The Journal of Marketing Theory and Practice, 14*(3), 223–238.

TU Dublin (2019). *Realising Infinite Possibilities. Strategic Intent 2030*. Technological University Dublin. Available online at: https://www.tudublin.ie/media/website/explore/about-the-university/equality-and-diversity/TU-Dublin-Strategic-Intent-2030.pdf (accessed January, 16, 2023).

UN (2015). *Transforming Our World: The 2030 Agenda for Sustainable Development*. Seventieth Session of the General Assembly Resolution A/RES/70/1. UN, New York.

Valley, W., Wittman, H., Jordan, N., Ahmed, S., & Galt, R. (2018). An emerging signature pedagogy for sustainable food systems education. *Renewable Agriculture and Food Systems*, *33*(5), 467-480.

Wiek, A., Withycombe, L., & Redman, C.L. (2011). Key competencies in sustainability: a reference framework for academic program development. S*ustainability Science*, *6*(2), 203-218.

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., & Murray, C.J. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet*, *393*(10170), 447-492.

Yearworth, M. (2016). Sustainability as a 'Super-Wicked' Problem: Opportunities and Limits for Engineering Methodology. *Intelligent Buildings International*, *8*(10), 37-47.

Irish Journal of Academic Practice