Research in Engineering Education Symposium &
Australasian Association for Engineering Education Conference
5 – 8 December, 2021 - Perth, WA

# Mapping and Enhancing Sustainability Literacy and Competencies within an Undergraduate Engineering Curriculum

Maryam Lamere[a], Lisa Brodie[a], Abel Nyamapfene[b], Laura Fogg-Rogers[a] and Venkat Bakthavatchaalam[a]
*University of the West of England, Bristol [a], University College London[b], maryam.lamere@uwe.ac.uk*

## ABSTRACT

### CONTEXT
There is growing pressure today to tackle complex sustainability challenges of climate change, resource limitations, extreme poverty, to name a few. As part of this drive, today's engineers are expected to deliver technological solutions that maximise social value while minimising environmental impact. Consequently, engineering graduates must be equipped with the knowledge, skills and attributes needed to work and live in ways that safeguards environmental, social and economic wellbeing, both in the present and for future generations.

### PURPOSE OR GOAL
The objective of the work reported in this paper was two-fold: first, to map out all the sustainability components in the undergraduate mechanical/automotive engineering curricula at the University of the West of England, Bristol (UWE) at the time of the study; second, to use the outcomes of the mapping exercise, and best practice from the sustainability literature, to develop a curriculum that equips its graduates with the sustainability skills and competencies now required of them by employers and society at large.

### APPROACH OR METHODOLOGY/METHODS
The work that we report in this study consisted of a mapping exercise of the undergraduate mechanical/automotive engineering curriculum, followed by curriculum redesign to ensure that the resulting curricula could deliver the required sustainability skills and competencies. Both the mapping exercise and curricula redesign were underpinned by a sustainability framework adapted from the Sustainability Literacy Test for Higher Education institutes by HESI (Higher Education Sustainability Initiative). A survey questionnaire based on the list of topics covered in the Sustainability Literacy Test was developed and sent to Module Leaders of all the 40 modules making up the Mechanical Engineering/Automotive Engineering undergraduate degree programme. Findings from the survey were used to identify sustainability literacy gaps in the curricula. Then, using this mapping together with the sustainability framework, the curricula were redesigned to ensure a throughline coverage of sustainability topics, starting from the first year to the final year of the degree programmes.

### ACTUAL OR ANTICIPATED OUTCOMES
Topics on sustainability are now much more explicit, and accreditation requirements pertaining to sustainability are now more explicitly evidenced. Students are now engaging more with sustainability, as evidenced by the significant increase in the proportion of students tackling topics on sustainability in their final year dissertation. In addition, the number of students interested in pursuing a career in sustainability after graduation has increased over the past 3 years. The outcome of the study has been highly solicited and shared at faculty level within the university. Universities in the South West England and Wales region have also approached the department to learn how Project-Based Learning can be used to integrate sustainability in the engineering curriculum.

### CONCLUSIONS/RECOMMENDATIONS/SUMMARY
Sustainability topics have now been given prominence in the undergraduate degree programme. Sustainability literacies and competencies are now covered alongside other relevant and important topics such as climate change, renewable energy, sustainable development and community engagement.

### KEYWORDS
Curriculum mapping, sustainability literacies and competencies, academic accreditation, curriculum reform.

# Introduction

There is growing pressure today to tackle complex sustainability challenges of climate change, resource limitations, extreme poverty, to name a few. Engineers are faced with the challenge of providing solutions that maximise social value while minimising environmental impact. Bourn and Neal (2008) draws the link between global sustainability issues and engineering illustrating how those issues affect the engineering sector and how the work of engineers has potential to have strong impacts in that context. In fact, it is now an obligation for engineers to consider sustainability, the environment, health, safety and social wellbeing in their work duties (Engineering *Council, 2021)*. A recent study of engineering students from across the USA suggests that they have a strong sense of personal responsibility regarding sustainability issues (Wilson, 2019). This suggests that engineering students increasingly expect and appreciate coverage of sustainability topics in the curriculum.

In 2016, the Department of Engineering Design and Mathematics at the University of the West of England, Bristol (UWE Bristol) redesigned the curriculum of its entire portfolio of undergraduate engineering programmes to ensure that its graduates would be equipped with the skills they need to address the complex challenges facing the 21st. The redesign process was carried out in alignment with the university's education strategy to equip students with the skills they need to make a positive contribution to society, and to contribute to the development of a sustainable global society and knowledge economy (UWE Bristol, 2013 ).

Recommendations for creating sustainability literate graduates published by the Higher Education Academy (HEA) and the UK Quality Assurance Agency for Higher Education were also consulted. These recommendations emphasise the needs for graduates to: (1) understand what the concept of environmental stewardship means for their discipline and their professional and personal lives; (2) think about issues of social justice, ethics and wellbeing, and how these relate to ecological and economic factors; and (3) develop a future-facing outlook by learning to think about the consequences of actions, and how systems and societies can be adapted to ensure sustainable futures (QAA & HEA, 2014).

This paper discusses the work to incorporate sustainability education within the undergraduate Mechanical and Automotive Engineering programmes at UWE Bristol. This work includes the mapping exercise carried out in 2016 to identify all the sustainability components in the undergraduate mechanical/automotive engineering curricula at the time, the module-level reforms carried out in 2016-17 in response to the mapping exercise, and finally, the root and branch engineering curriculum reform carried out in 2018 in which sustainability education was designed into the curriculum as a central and integral component. The study therefore offers a phased approach to incorporating sustainability education into undergraduate engineering education characterised by introducing sustainability education into the engineering curriculum through incremental changes to course module elements, and gradually building up to a fully integrated programme-level approach. .

# Implementing sustainability education: A review of recent and current approaches

UNESCO defines education for sustainable development (ESD) as the "the acquisition and practice of knowledge, values and skills that ensure balance between the economic, social and environmental aspects of development, and the observance of both individuals and society development and progress in life"(UNESCO, 2008, pp 8). ESD as a dynamic concept intends to empower learners with the necessary skills, attitudes and knowledge to address the global challenges we face, including protecting biodiversity, eliminating poverty, access to safe water and climate change (Shulla et al., 2020; UNESCO, 2019). In 2015, the global community launched 17 Sustainable Development Goals (SDGs) aimed at addressing issues related to poverty, hunger, health, education, energy, work, industry, inequalities, cities, consumption, climate, ocean life, ecosystems, peace, and partnership (UNESCO, 2020). ESD is regarded as both an integral component of SDG 4 on education and a key enabler of all the other SDGs (United Nations, 2018).




https://doi.org/10.52202/066488-0034

According to UNESCO, the goals of ESD are to “empower learners to take informed decisions and responsible actions for environmental integrity, economic viability and a just society, for present and future generations, while respecting cultural diversity” (UNESCO, 2014, pp 12). This requires that learners be equipped with the competencies that allow them to engage constructively and responsibly with today’s world (UNESCO, 2017). However, competencies cannot be taught but must be developed by the learners themselves during action, and based on experience and reflection (UNESCO, 2017; Kolmos, 2021). Consequently, the UK Quality Assurance Agency for Higher Education and the Higher Education Academy, have advised that for ESD to be effective in HE, staff and students should work together collaboratively to develop the core competencies to be able to deal with sustainability issues in their practice (QAA & HEA, 2014). This therefore suggests that with respect to sustainability education, a student-centred, interdisciplinary, team-teaching designed to expose students to multiple perspectives on sustainability related issues is more effective than traditional teaching-centred, siloed approaches. (Hooey et al., 2017; Pompeii et al., 2019). Furthermore, Filho et al. (2020) and Graham (2018) comment on the importance of curriculum in engineering education to shift its’ attention from just imparting academic technical knowledge and towards a broader, complex problem-solving and interdisciplinary approach. Such approaches would thus empower learners with skills for complex problem identification, and to provide engineering-based solutions to societal and sustainable problems.

Like most education innovations, the introduction of sustainability education within the engineering curriculum is typically initiated by individual academics (early adopters) introducing elements of sustainability content within their own course modules. Typical strategies for introducing sustainability content usually include one or more topics within a course module, incorporating sustainability-related assignments and adding readings on sustainability to course module reading lists (Natkin & Kolbe, 2016). This ad hoc, module-level introduction of sustainability education typically leads to change within single and isolated course modules. Holgaard et al.(2010) refer to this strategy as an add-on strategy. It has the advantage that individual academics, as early adopters, can begin to lead change within their school or department, however, it usually leads to non-systemic change (Kolmos et al., 2016). Other strategies include introducing courses focussed on SD, such as ‘sustainability studies’ (Stough et al., 2018), through interweaving sustainability in the curriculum (Bakthavatchaalam et al., 2017), and creating an action-oriented learning, linking theory with practice and inter disciplinary projects (Aleixo et al. 2020).

A more coordinated strategy to implementing ESD within the curriculum is to do this at programme level. The focus can be on one or more course programmes offered by an academic unit, typically a department or a faculty. This strategy, which Holgaard et al. (2010) have termed the integration strategy, requires mapping and coordination across the various course modules to ensure integration and streamlining of the sustainability content across the entire course programme(s). Filho et al. (2020) and Brandli et al. (2015) comment that the barriers for implementing ESD include a lack of knowledge, appropriate technology, investment, policies and misconceptions of SD being an add-on, soft concept. Furthermore, Kolmos et al. (2016) comment on the importance of leadership and support from management, e.g. faculty deans, heads of department and programme leaders.

Brosens et al. (2021) have highlighted that traditionally universities have tended to review and update their curricula without the involvement of external stakeholders. However, based on their review of successful curriculum change programmes within engineering across the world, they conclude that programme redesign could benefit from evidence-driven, iterative approaches that actively engage stakeholders in the curriculum development process. (Brosens et al., 2021). This is consistent with the view by Graham (2012), that for successful systemic change in engineering education to be successful, it has to be based on a participatory vision of developing a world class education that incorporates input from a range of stakeholders, including students and academics.

Holgaard et al. (2010) use the term “rebuilding strategy” to refer to this institution-wide, collaborative approach to embedding sustainability education. Given the complexities



https://doi.org/10.52202/066488-0034

associated with collaborative working across and beyond university structures, Hooey et al. (2017) suggest that the introduction of sustainability education should be underpinned by a common institutional sustainability culture that ensures a shared understanding of sustainability amongst all stakeholders.

# The 2016 sustainability mapping exercise

The sustainability mapping was carried out using a survey questionnaire framed on topics covered in the Sustainability Literacy Test for Higher Education institutes by the Higher Education Sustainability Initiative (HESI). The sustainability literacy test is an online multiple choice question assessment intended to evaluate, the minimum level of knowledge in economic, social and environmental responsibility (United Nations, 2015). The United Nations assert that the test is applicable to all, higher education institutions all over the world, and it is relevant to all tertiary level students, including those undertaking degree courses at bachelor, masters and PhD level. The questionnaire was sent out to all the module leaders of the 40 modules making up the Mechanical and Automotive Engineering undergraduate degree programmes. The university ethics procedures were followed, and consent was acquired from participants. The response gathered gave an overview of ESD coverage in the curriculum. The curricula were subsequently redesigned based on the outcome of the study.

### Outcome of the sustainability mapping exercise

The staff survey allowed for gaps to be identified in the curricula. The outcome of the survey was mapped out against the HESI's Sustainability Literacy framework (see Table 1). The survey revealed that only nine of the 55 surveyed topics were covered across all the 40 modules making up the Mechanical and Automotive Engineering undergraduate degree programmes. Discussions held with module leaders after the survey revealed that explicit reference to sustainability was not always made when teaching those topics. Therefore, students did not necessarily perceive that they were learning about sustainability.

The expectation for Higher Education institutions is not to cover all the topics in all programmes, especially as some topics may be relevant to specific fields more than others. Nonetheless, there were relevant and important topics that were not covered in the two undergraduate programmes. This included such topics as climate, biodiversity, the social sphere of sustainable development and community development and involvement.

As expected, coverage of sustainability topics was not uniform, but occurred on an ad hoc, unplanned basis across the programme in line with the individual interests of the academics in a manner consistent with the description by Natkin and Kolbe (2016). There was no coverage of sustainability topics in the first year of the engineering programme, and only three topics were covered in the second year. The remaining six topics were covered at third year and Masters level. Two sustainability topics of critical importance to modern day professional engineering practice – health and safety at work, and climate change and mitigation – were only covered at Masters level. Students graduating with a BEng, and not proceeding to MEng or MSc would therefore graduate without having covered these two critical topics.

# Integrating sustainability into the curriculum

The outcome of the mapping exercise was used to inform the redesign of the curricula and ensure a through-line coverage of sustainability topics, starting from the first year to the final year of the degree programmes. A staged approach was used to integrate ESD in the curriculum.

The first stage, which lasted from 2016 – 2018, consisted in working with existing modules and module leaders, with no radical changes to the overall structure and learning outcomes of the module, in a manner similar to the add-on strategy (Holgaard et al., 2010). The main difference between our approach and the add-on strategy was that, like the integration strategy (Holgaard et al., 2010), our approach was collaborative between interested staff members, and we had a programme-level perspective across all modules being delivered.




https://doi.org/10.52202/066488-0034

Amongst the modules that introduced ESD in stage one were the Design and Project Management modules at Level 1 and 2. We did this by incorporating the EWB-UK's Engineering for People Design Challenge as the assessment brief for the students. In this brief, students develop engineering solutions to real world problem faced by communities around the world. The social, environmental, and economic aspect of ESD were well integrated within the brief.

The next stage, Stage two, took place with a more integrated programme-level approach, as part of the department's major restructuring of its engineering programmes in 2018. A Project-Based Learning approach was adopted at department level, which saw the introduction of dedicated Project Weeks where students worked on the Engineering for People Design Challenge with an international outlook (at Level 1) and on homelessness project with a local focus on the Bristol community (at Level 2).

Stage three followed with an entirely programme based approach, which we called the Integrated Learning Framework. New modules were introduced, and existing traditional modules were restructured to provide through-line coverage of ESD, throughout all levels of the engineering curricula. These modules are: Engineering Practice 1 and 2 (at Level 1 and 2 of the undergraduate degree programme and 'Engineering for Society' (at Level 3 of the undergraduate degree programme and Masters Level)). They use a Project-Based Learning approach giving students the opportunity to work on real-world problems, touching on a wide range of sustainability and ethical issues. Table 2 shows the ESD coverage in the undergraduate Mechanical and Automotive Engineering programmes following the curriculum redesign.

**Table 1: HESI's sustainability topics coverage by module and programme level at UWE (Bristol) Mechanical/Automotive Engineering in 2016**

| Sustainable Development | Module | Level/Year |
|---|---|---|
| *Founding principles* | | |
| Basic definitions | Design and Electromechanical Systems | 2 |
| Pollution | Motorsport Performance, Advanced Powertrain Technologies | 3,M |
| Energy and resource of the planet | Design and Electromechanical Systems, Motorsport Performance, Individual Project, Industrial Applications of Vision and Automation, Advanced Powertrain Technologies | 2,3,M |
| **Social Responsibility (ISO 26000)** | | |
| *Organisational governance* | | |
| values, stakeholder engagement, diagnostic & strategy, accountability & reporting | Business Environment | 3 |
| *Labour practices* | | |
| Health and safety at work | Industrial Applications of Vision and Automation | M |
| *Environment* | | |
| Prevention of pollution | Motorsport Performance, Individual Project, Advanced Powertrain Technologies | 3,M |
| Sustainable resource use | Design and Electromechanical Systems, Business Environment, Motorsport Performance, Industrial Applications of Vision and Automation, Advanced Powertrain Technologies | 2,3,M |
| Climate change mitigation and adaptation | Advanced Powertrain Technologies | M |
| *Consumer issues* | | |
| Sustainable consumption | Individual Project | 3 |

**Table 2: ESD coverage following curriculum redesign of the Mechanical/Automotive Engineering programme at UWE (Bristol), 2021**

| **Sustainable Development** | Level (2016) | Level (2021) | **Social Responsibility (ISO 26000)** | Level (2016) | Level (2021) |
|---|---|---|---|---|---|
| *Founding principles* | | | *Labour practices* | | |
| 1. Basic definitions | | **1** | 1. Employer and employee relationships | | **2,3,M** |
| 2. Governance | 2 | | 2. Condition of work and social protection | | **3,M** |
| 3. Demography (age pyramid, urbanisation) | | | 3. Social dialogue | | **1,3,M** |
| *Environment* | | | 4. Health and safety at work | M | **2,3,M** |
| 1. Biodiversity | | **1,3,M** | 5. Human development and training in the workplace | | **2,3,M** |
| 2. Climate | | **1,3,M** | *Environment* | | |
| 3. Pollution | 3,M | **1,3,M** | 1. Prevention of pollution | 3,M | **1,3,M** |
| 4. Energy and resource of the planet | 2,3,M | **1,2,3, M** | 2. Sustainable resource use | 2,3,M | **1,2,3, M** |
| *Social* | | | 3. Climate change mitigation and adaptation | M | **1,M** |
| 1. Fundamental human rights | | **1,3,M** | 4. Protection of the environment biodiversity and restoration of habitats | | **1,3,M** |
| 2. Health and basic human needs | | **1,3,M** | *Fair operation practices* | | |
| 3. Inequality and poverty | | **1,3,M** | 1. Anti-corruption | | |
| 4. Wellbeing and social progress | | **1,3,M** | 2. Responsible political involvement | | **3,M** |
| 5. Cultural diversity and heritage preservation | | **1,3,M** | 3. Fair competition | | |
| *Economy* | | | 4. Promoting social responsibility in the value chain | | **1,3,M** |
| 1. Economic growth and development | | **1, 3,M** | 5. Respect for property rights | | |
| 2. Global finance | | | *Consumer issues* | | |
| 3. Green economy | | **1,3,M** | 1. Fair marketing, factual and unbiased information, and fair contractual practices | | **1,3,M** |
| 4. Tax havens and corruption | | | 2. Protecting consumers' health and safety | | **1,2,3, M** |
| 5. Underground economy | | | 3. Sustainable consumption | 3 | **1,3,M** |
| 6. Prosperity indicators | | | 4. Consumer service, support, dispute resolution | | |
| **Social Responsibility (ISO 26000)** | | | 5 Consumer data protection and privacy | | **1,3,M** |
| *Organisational governance* | | | 6. Access to essential services | | **1,3,M** |
| 1. Values, stakeholder engagement, diagnostic & strategy, accountability & reporting | 2,3 | **1,2,3, M** | 7. Education and awareness | | **1,3,M** |
| *Human rights* | | | *Community development and involvement* | | |
| 1. Due diligence | | **1,3,M** | 1. Community involvement | | **1,3,M** |
| 3. Avoidance of complicity | | **1,3,M** | 2. Education and culture | | **1,3,M** |
| 4. Resolving grievances | | | 3. Employment creation and skills development | | **1,3,M** |
| 5. Discrimination and vulnerable groups | | **1,3,M** | 4. Technology development and access | | **1,3,M** |
| 6. Civil and political rights | | **1,3,M** | 5. Wealth and income creation | | **1,3,M** |
| 7. Economic, social and cultural rights | | **1,3,M** | 6. Health | | **1,3,M** |
| 8. Fundamental rights at work | | | 7. Social investment | | **1,3,M** |





https://doi.org/10.52202/066488-0034

The integration of ESD throughout the curriculum was supported at institutional level. As highlighted in UWE Bristol's 2020 and 2030 strategy documents, ESD is at the forefront of the university teaching and operational agenda. A faculty wide Knowledge Exchange for Sustainability Education (KESE) was created to support staff by providing a platform of knowledge sharing. In terms of training and support for academic staff during the Integrated Learning Framework transition, Departmental Staff Away days were used to hold sustainability workshops for staff. In Stage one of the initial phase of the mapping exercise, a lack of common understanding amongst staff on what ESD is was noted, what it should include, and whether it is necessary for student engineers to learn about it. Over the years, alongside the staged approach, there has been more acceptance of ESD as an essential part of the engineering curriculum amongst staff and students. Another challenge and limitation of the approach was the allocation of teaching workload for ESD integration. In the initial phases, a small number of committed academics had to put a lot of time, effort and dedication in to push through with ESD integration. There is now wider support by module leaders and tutors, who all feel capable of delivering some aspects of ESD, which eases the workload.

## Outcomes of integrating ESD into the curriculum

Following the staged approach to integrating ESD into the curriculum, a wide range of ESD topics are now covered in the Mechanical and Automotive Engineering undergraduate programmes. ESD topics are now covered coherently across all levels from Year 1 all the way to Year 3 and Masters level. A through-line of core sustainability topics are now systematically covered across compulsory modules right through the degree programmes, thereby ensuring that no student misses any of the core topics. The Mechanical and Automotive Engineering programmes offered by the Department of Engineering Design and Mathematics were assessed and accredited by the Institution of Mechanical Engineering (IMechE) in December 2020. In their academic accreditation visit report following the visit (IMechE, 2020), the Accreditation Panel commended how the Department had embedded ethics and sustainability throughout the programmes so as to offer good coverage of legal, sustainability and societal factors in a manner that was beneficial to all students on the programmes, and how they had aligned this with the UK Specification for Professional Engineers.

Student interest in sustainability has increased over the past five years as evidenced by the steady increase in students taking sustainability topics in final year projects and dissertations. Whilst this increase may be consistent with increasing awareness of sustainability by students world-wide, particularly by engineering students, in recent years, student informal feedback suggests that there is a growing appreciation for the inclusion of ESD in the curriculum. Furthermore, at the end of the five-year curriculum redesign process, students were surveyed through module feedback surveys, and it was found that the project-based learning approach was viewed very positively. Students commented that they enjoyed working on 'real-world projects' where they can make a difference locally or globally.

Our novel, staged integration of ESD into the engineering curriculum has also caught the interest of other universities, with several making enquiries, and some visiting us to learn how we went about the process. Disseminating our ESD practice has become an integral part of our remit, and colleagues within the department have presented invited talks on ESD integration at several universities, including the Universities of Bath and Swansea, and the French Ingenium network.

However, findings from this study indicate that students were more inclined towards sustainability topics that were relevant to their subject discipline. For instance, Aerospace Engineering students tended to prefer topics relevant to Aerospace Engineering. A survey of USA engineering students by Wilson (2019) also indicates a link between students' study discipline and their predilection for certain sustainability topics. The main recommendation from this study is that for sustainability education to be effective, the content coverage should be aligned, or better still, integrated, with the topics that form part of the students' disciplinary studies.



https://doi.org/10.52202/066488-0034

## Concluding Remarks and Future Work

Whilst there is a multiplicity of approaches to integrating sustainability in higher education curricula, it is apparent that most higher education institutions are yet to fully integrate ESD into their curricula. For instance, a recent study of UK higher education institutions suggests that only a handful of institutions have implemented ESD into their curricula in a manner that ensures that ESD is an integral and systemic part of their curriculum (Fiselier et al., 2018).

At this time of Climate and Ecological Emergency, it is therefore pressing that engineering curricula throughout the world consider how best engineering can contribute to adaptation, resilience, and mitigation of environmental issues. This study, therefore, presents a phased strategic approach to integrating education for sustainable development into existing engineering curricula. We hope that other higher education engineering institutions will follow suit to produce engineering professionals capable of operating within a fast changing global environmental crisis. Documented best practice recommendations about this phased and programmatic approach to ESD is therefore something that other engineering educators can learn from, and in that regard, is an important contribution to the sustainability education literature.

## References


Aleixo, A. M., Azeiteiro, U. M., & Leal, S. (2020). Are the sustainable development goals being implemented in the Portuguese higher education formative offer? *International Journal of Sustainability in Higher Education, 21*(2), 336-352.

Bakthavatchaalam, V. P., Lakshmanan, D., Chellam, N., & Prasath, K. (2017). *Effectiveness of Digital Lectures in Increasing Subject Knowledge and Sustainable Development Goals: A Pilot Study*. Paper presented at the TECH 2017 Vizag, India.

Brandli, L. L., Leal Filho, W., Frandoloso, M. A. L., Korf, E. P., & Daris, D. (2015). The Environmental Sustainability of Brazilian Universities: Barriers and Pre-conditions. In W. Leal Filho, U. M. Azeiteiro, S. Caeiro, & F. Alves (Eds.), *Integrating Sustainability Thinking in Science and Engineering Curricula: Innovative Approaches, Methods and Tools* (pp. 63-74). Cham: Springer International Publishing.

Brosens, L., Raes, A., Octavia, J. R., & Emmanouil, M. (2021). *Designerly ways of transforming design education: A review of design curricula reforms worldwide*. Paper presented at the 23rd International Conference on Engineering and Product Design Education (E&PDE 2021), Herning, Denmark.

Engineering Council. (2021). Guidance on Sustainability. Retrieved from https://www.engc.org.uk/sustainability

Filho, W. L., Brandli, L. L., Lange, S. A., Rayman-Bacchus, L., & Platje, J. (2020). COVID-19 and the UN sustainable development goals: threat to solidarity or an opportunity? *Sustainability, 12*(13), 5343.

Fiselier, E. S., Longhurst, J. W. S., & Gough, G. K. (2018). Exploring the current position of ESD in UK higher education institutions. *International Journal of Sustainability in Higher Education, 19*(2), 393-412. doi:10.1108/IJSHE-06-2017-0084

Graham, R. (2012). *Achieving excellence in engineering education: The ingredients of successful change*. Retrieved from https://www.raeng.org.uk/publications/reports/achieving-excellence-in-engineering-education

Graham, R. (2018). *The global state-of-the-art in engineering education*. Cambridge, MA: MIT.

Holgaard, J. E., Graaff, E. d., & Kolmos, A. (2010). *Sustainability in the practice, mindset and heart of engineering*. Paper presented at the ESRSCP-EMSU Conference, Delft, The Netherlands. https://vbn.aau.dk/da/publications/sustainability-in-the-practise-mindset-and-heart-of-engineering

Hooey, C., Mason, A., & Triplett, J. (2017). Beyond greening: Challenges to adopting sustainability in institutions of higher education. *The Midwest Quarterly, 58*(3), 280.

IMechE (2020). [Academic Accreditation Visit Report - University of the West of England].






https://doi.org/10.52202/066488-0034

Kolmos, A. (2021). Engineering Education for the Future. In UNESCO (Ed.), *Engineering for Sustainable Development* (pp. 121-128). PARIS: UNESCO.

Kolmos, A., Hadgraft, R. G., & Holgaard, J. E. (2016). Response strategies for curriculum change in engineering. *International Journal of Technology and Design Education, 26*(3), 391-411.

Natkin, L. W., & Kolbe, T. (2016). Enhancing sustainability curricula through faculty learning communities. *International Journal of Sustainability in Higher Education*.

Pompeii, B., Chiu, Y.-W., Neill, D., Braun, D., Fiegel, G., Oulton, R., . . . Singh, K. (2019). Identifying and Overcoming Barriers to Integrating Sustainability across the Curriculum at a Teaching-Oriented University. *Sustainability, 11*(9), 2652. Retrieved from https://www.mdpi.com/2071-1050/11/9/2652

QAA & HEA. (2014). *Education for sustainable development: guidance for UK higher education providers*. Retrieved from Gloucester, UK:

Shulla, K., Filho, W. L., Lardjane, S., Sommer, J. H., & Borgemeister, C. (2020). Sustainable development education in the context of the 2030 Agenda for sustainable development. *International Journal of Sustainable Development & World Ecology, 27*(5), 458-468.

Stough, T., Ceulemans, K., Lambrechts, W., & Cappuyns, V. (2018). Assessing sustainability in higher education curricula: A critical reflection on validity issues. *Journal of Cleaner Production, 172*, 4456-4466. doi:https://doi.org/10.1016/j.jclepro.2017.02.017

UNESCO. (2008). *Regional Guiding Framework of Education for Sustainable Development in the Arab Region*. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000161944.locale=en

UNESCO. (2014). *UNESCO roadmap for implementing the Global Action Programme on Education for Sustainable Development*. Retrieved from https://unesdoc.unesco.org/notice?id=p::usmarcdef_0000230514

UNESCO. (2017). *Education for Sustainable Development Goals: Learning Objectives*. Retrieved from http://unesdoc.unesco.org/images/0024/002474/247444e.pdf

UNESCO. (2019). *Framework for the Implementation of Education for Sustainable Development (ESD) Beyond 2019*. Retrieved from PARIS: https://unesdoc.unesco.org/ark:/48223/pf0000370215

UNESCO. (2020). *Education for Sustainable Development: A Roadmap*. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000374802

United Nations. (2015). *17 Sustainable Development Goals 17 Partnerships*. Retrieved from https://sustainabledevelopment.un.org/content/documents/211617%20Goals%2017%20Partnerships.pdf

United Nations. (2018). *UN General Assembly Resolution 72/222*. Retrieved from https://undocs.org/A/RES/72/222

UWE Bristol. (2013). UWE Bristol 2020 Strategy. In U. Bristol (Ed.). Bristol.

Wilson, D. (2019). Exploring the Intersection between Engineering and Sustainability Education. *Sustainability, 11*(11), 3134 (3116 pp.). doi:10.3390/su11113134

## Copyright statement