Compilation of Best Practices in Fostering Education for Sustainable Development

PR1.A1

JOIN-RISE

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Co-funded by the European Union

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Table of Contents

1. Introduction

The United Nations' **Transforming Our World: The 2030 Agenda for Sustainable Development** is one of the most ambitious and important global agreements in recent history. In order to achieve the 17 SDGs, it is necessary to educate smart, creative and entrepreneurial individuals that have confidence and critical thinking. Education, specifically, STEM education is essential for the achievement of the SDGs, but universities have struggled to introduce SDGs into their regular courses and degrees especially in STEM subjects due to the lack of both awareness, resources and motivation or incentives to change.

The main objective of **JOIN-RISe** (**Join**t development of **in**novative blended learning in STEM curricula based on SDGs for a resilient, inclusive and sustainable education) is to make higher education STEM students develop into citizens that are critical thinkers and are fully committed to the SDGs. In order to achieve this, it is crucial for there to be changes to current curricula and for the SDGs to be included in the teaching of STEM degrees., lecturers are key players in meeting the project's main objective. Therefore, the aim is also to make STEM lecturers more aware of global challenges and the need to integrate values and ethics into their teaching to help students develop a sustainable mindset and to use science to do good in society.

JOIN-RISe will therefore create a **course specifically for university lecturers** related to how to include SDGs in the teaching of STEM subjects. Students will in turn receive a more holistic education in the STEM discipline by completing the courses that will be created as a result of the project. In addition, Universities and higher education institutions will have a **methodological guideline** at their disposal to adapt the **Certificate of Sustainable Commitment** (CSC) to the **European Qualifications Framework** (EQF) and to the idiosyncrasy of the involved university. This project will also encourage lifelong learning through a **short course** (30 hours) aimed at adult learners. JOIN-RISe will provide a **database of Service-Learning projects** and Bachelor's and Master's final dissertations related to SDGS in STEM which will help students to put their knowledge and social commitment into practice.

But in addition, the JOIN-RISe project aims to revolutionise higher education STEM teaching and learning by designing an **innovative virtual blended SDGs** training environment that has two distinct functions, one specifically targeted at lecturers and the other at students. These, students will be ready to use their knowledge and expertise to contribute to the achievement of the SDGs, through a more inclusive and digital approach. And lecturers' tools to implement them in their subjects.

This document presents the compilation of best practices at the European level in fostering Education for Sustainable Development. In addition, this document identifies (i) the current status of implementation of the SDGs in HE (Higher Education) institutions, (ii) the existing implementation practices and (iii) the main challenges and barriers that HE institutions face when putting them in practice.

It is noted that this document analyses the implementation of the SDGs from the perspective of STEM (science, technology, engineering, and mathematics) disciplines. These disciplines present some commonalities when implementing SDGs in HE. STEM students traditionally have fewer opportunities to tackle the global challenges in their degrees (Chan, 2022), such as poverty (SDG 1), gender equality (SDG 5) or peace, justice and strong institutions (SDG 16). However, as Dasandi and Mikhaylov (2019) point out, SDG 16 is crucial for achieving the other SDGs, given that without good governance and strong institutions, it will not be possible to succeed in the other SDGs. Interestingly, the most common SDGs that are currently taught in HE are climate change (SDG 13), sustainable cities and communities (SDG 11), and quality education (SDG 4) (Leal Filho et al, 2019). The first two of these SDGs find in STEM disciplines the natural environment to be developed within programs, such as Civil Engineering and Natural Sciences, and it is becoming increasingly frequent to find professorships on these areas in technical universities.

The methodology used to develop the document has been the review of different sources, namely, academic and grey literature. Attention has been paid to cover all the SDGs, along with a varied list of resource types, including case studies, lectures, repository and platforms, courses and MOOCs, programs, tool(kit)s and educational guides and strategies. Also, a survey within the teaching community has been conducted. The presented materials are organised into different categories depending

on the material type (video, workshop, guidelines, etc.) and the SDG that it is tackled. Annex I provides a summary of the different sources used in this document.

The document is structured as follows; Section 2 provides a description of the SDGs presented in the context of the STEM disciplines. A description of the different implementation structures and tools is given in Section 3. The current level of implementation of SDGs in the HE institutions is presented in Section 4 and the identified challenges and barriers are discussed in Section 5. Finally, some conclusions are drawn in Section 6.

2.SDGs in Relation to the STEM Disciplines

The work of future professionals from the scientific, technical and engineering fields, and their disposition for critical thinking (Dwyer, 2017) will have significant impacts on our socio-technical and environmental systems (EScGD, 2018). Therefore, meeting the ambitions of the SDGs requires contributions from all STEM disciplines. Speaking at the Global Engineering Congress in 2018, the UN Secretary General confirmed this in his statement, "every one of the goals requires solutions rooted in science, technology and engineering" (Guterres 2018 as cited in UNESCO, 2021). But what are the contributions and responsibilities of the STEM disciplines to the SDGs? This section links the STEM disciplines to relevant SDGs and identifies key issues and challenges for the disciplines in reaching the SDGs. Because of the decentralized nature that literature reports on the relationship between a single STEM discipline and SDG targets, we aggregate according to SDGs and discipline categories (Higher Education Research Institute, 2021). For example, the discipline category 'Computer and Information Sciences' includes the following disciplines: Information management, computer programming, computer science, computer software and media, computer systems networking, date entry & processing and information sciences. It should be noted that the issues and challenges listed under each discipline category are indicative of important relationships between the STEM disciplines and the SDGs but should not be interpreted as an exhaustive list.

The categories 'biological and biomedical sciences' and 'natural resources and conservation' have broad-sweeping relevance for the 17 SDGs. Research in these disciplines has historical ties to the water-food-energy nexus of importance to the SDGs. Together, these life science disciplines can contribute to building integrated assessments of climate change consequences (SDG 13) that include economic, social and ecological dimensions. We discuss these two life sciences categories first.

2.1. Biological and Biomedical Sciences (Dahling et al 2021)

The biological and biomedical sciences make direct or indirect contributions to all 17 SDGs; however, of particular relevance is SDG 3 - ensuring healthy lives and promoting well-being. Contributions to Targets 3.1-3.9 and 3.A-3.D range from developments in drugs and preventative medicine that produce cost-effective treatments and that reduce mortality rates of mothers and newborns to lowering the risk of protracted

shocks like epidemics and pandemics. It further targets reductions in dangerous industrial byproducts such as hazardous chemicals and pollutants. Strategies towards these targets include the recruitment, training and retention of the workforce and strengthening early-warning capacities.

2.2. Natural Resources & Conservation (Gratzer et al 2019)

Many of the contributions of natural resources and conservation relate to the challenge of transitioning to a green economy and green growth (SDG 8), which are especially important for improving human well-being (SDG 3) and social equity (SDG 10), while significantly reducing environmental risks and ecological scarcities (UNEP, 2011). The green economy is one that makes efficient use of resources, is low in carbon and is socially inclusive. Success in transforming agriculture and food systems will depend on progress in other SDGs as enabling conditions for climate action (SDG 13). Relevant SDGs in this transition include sustainable production and consumption (12), food security (2), poverty reduction (1), education (4), gender equity (5), water (6), life on land (15) and energy (7).

2.3. Engineering (Feani, 2021)

In December 2021, the European Federation of Engineering Associations (FEANI) published a position paper stating the role of engineering in achieving the SDGs. FEANI targets four SDGs where its 6 million engineers in 33 countries can make the greatest contribution: Clean Water and Sanitation (SDG 6); Affordable and Clean Energy (SDG 7); Industry, Innovation & Infrastructure (SDG 9) and Sustainable Cities and Communities (SDG 11). A main challenge targeted by the engineering disciplines includes: transitioning to the circular economy in the context of rapidly urbanizing societies. This challenge includes topics of sustainable housing, mobility and logistics as well as green-blue infrastructure. In addition to the sustainability transition, the reliable supply of water and energy supply and infrastructures must be ensured for all. This will require policy frameworks that motivate investment in industry innovation and the provision of high-quality public services.

2.4. Physical Sciences

Chemistry can make a significant contribution to climate change mitigation, but it will require a transition to green and sustainable chemistry. This transition requires:

- greener practices in chemical manufacturing and drug development (SDG 3);

- techniques for drought and crop protection as well as phosphate recovery and innovation in packaging (SDG 2);
- advancements in solar-assisted desalination and heavy metal removal for water resource efficiency (SDG 6);
- improved energy storage (SDG 7);
- retrofitting and upgrading chemical production facilities (SDG 9);
- second generation biofuels, recycling materials and reducing product life cycles (SDG 12) and
- low-carbon emitting chemical production and feedstocks (American Chemical Society, 2022)

These transition challenges are summarized in three design principles for sustainable green chemical industry are 1. maximizing resource efficiency, 2. minimizing hazards and pollution and 3. holistic system design and life-cycle thinking in concert with engineering.

Atmospheric sciences and meteorology play a critical role in disaster risk reduction, providing climate services to the agricultural sector and populated areas concerning climate-related risks, e.g. floods, droughts, heatwaves and air pollution that bear health and well-being consequences such as the transmission of insect-borne diseases, death and injury.

The geological and geosciences also contribution to our observation and understanding of earth and its processes. In a letter to the editor published in Nature, it has been claimed that the UN SDG agenda does not adequately address the geophysical processes and environmental feedbacks that impact the SDGs. It claims that the focus on monitoring and reporting at the national level has largely precluded the geosciences from contributing to the SDG debate (Scown, 2020). Improved modelling of ecological feedbacks are showing that anthropogenic CO2 emissions are contributing to global temperature rise that are weakening the ocean's ability to act as a carbon sink (Armstrong et al, 2021). As scientific insights into these knowledge gaps grow, education that couples the geosciences and natural resource management is needed, particularly in relation to climate action (SDG 13). The combination of satellite observation, remote sensing and local information can contribute to greater insight and understanding of the impact of climate change on earth systems. When viewed from an earth (sub)systems

perspective, many interdependencies among the SDGs converge in coastal deltas. For example, the building of hydropower dams to meet renewable energy (SDG 7) targets of upstream nations place the livelihoods, infrastructure and agriculture of downstream nations at risk of salinization and flooding (SDG 6). Education (SDG 4) is advised that 1) adopts systems thinking to link policy making to local actions and their impact on global systems and 2) educates on various geospatial modelling approaches, including ABM, Bayesian networks and geo-data visualization. The geosciences also play an important role in representing our urban socio-technical and ecological systems (SDG 11) as well as providing means for the engagement of a range of actors in policy making (SDG 16).

2.5. Communication & Information Sciences (International Telecommunication Union, 2015)

Our highly connected global society is increasingly dependent on communication and information technologies for the management of infrastructures, for ensuring well-being and equity of individuals and communities but also for helping society deal with the impacts of climate change. ICT is making knowledge and education more accessible to a broader public and is providing platforms for e-governance, expanding opportunities to engage citizens in decision making and connecting the smart city (SDG 11 and SDG 16). ICT makes the monitoring of climate impacts (SDG 13) from the local to the global systems scale possible and will play an essential role in the growing demand for climate services and monitoring of climate mitigation and adaptation interventions. Within the ICT industry, innovations need to lead to a significant reduction in electronic waste and energy consumption and emissions of data storage centers (SDG 12).

In summary, within the STEM disciplines at academic institutions and professional societies there is broad recognition of the interdependency of the SDGs and their targets within the 2030 Agenda. Achieving the SDGs therefore requires movement towards integration among the STEM disciplines. A prominent example is the role that Atmospheric sciences and meteorology can play in providing climate services that support life science disciplines, e.g., in developing both resilient farming and food systems and healthcare systems. The communication and information sciences disciplines play an important role in making this information both accessible and equitable. Consequently, the STEM disciplines must abandon their silo approach and avoiding cherry picking of goals that fit individual or market interests at the cost of transformative impact. These requirements for research and education imply significant

reform within academic institutions. Gratzer et al (2019) raise two points concerning the implementation of reform in education: (1) systems-oriented approaches to teaching that integrate different disciplines and (2) integration of life and social sciences to enable implementation-oriented synthesis of knowledge. The authors emphasize that the STEM disciplines must redefine their 'societal mission' to become change agents. Part of the redefining requires that universities become "living labs for a sustainable future...[and] transform their captivation with competition towards cooperative working attitudes", p. 104.

3. Existing Implementation Structures & Tools

This section describes the existing implementation structures and tools in relation to the education of SDGs in HEs. More precisely, learning objectives and teaching structures are discussed. Then, drivers for the implementation and existing tools and materials to support such implementation are presented.

3.1 Learning Objectives

Teaching HE students SDGs goes beyond enabling them to understand, realise and learn the SDGs. For instance, applied to climate change (SDG 13), learning outcomes should include understanding the scale, urgency, causes, consequences and solutions of climate change; how social norms and practices are driving the climate crisis; and the ability to identify routes to direct involvement in solutions via every discipline (Thew et al, 2021). Therefore, in addition to knowledge and skills[1], students should acquire attitudes, mind-sets, values and behaviours. Tandon and Chakrabarty (2018) note that educators should develop messages that target emotional responses, and are aligned with scientific perspectives.

Accordingly, many authors propose more holistic learning visions, such as the 3H-approach: Head (think), Heart (feel) and Hands (act), where education gravitates around teaching thought, emotion and behaviour (Morrison, 2001). In this line, Rieckmann (2017) suggests the following three learnings objectives; (i) **cognitive learning**, that is, those knowledge and skills required to understands the SDGs, (ii) **socio-emotional learning** that allows students to collaborate, negotiate and communicate, along with self-reflection skills, values and attitudes that allow them to develop themselves, and (iii) **behavioural learning** that includes action competences. Action competences provides the student with the ability, attitudes and values, willingness and opportunity to act (Eames et al, 2013). Six aspects support the development of action competences, that is, experience, reflection, knowledge, visions for a sustainable future, action taking

[1] Knowledge can be transferred from one person to another or it can be self-acquired through observation and study. Skills, however, refer to the ability to apply knowledge to specific situations

for sustainability, and connectedness. Cognitive, socio-emotional and behavioural learning objectives have a clear correspondence with the head-heart-hands approach.

While assessing the students' level of achievement of the cognitive learning objectives seems straightforward, it is not clear how to evaluate the socio-emotional and behavioural learning objectives. In relation to grading a creative process, Hoffman et al (2021) suggest that peer grading or pass/fail systems are more appropriate. Therefore, failure remains as an option as part of a learning process based on reiteration, experimentation and failure.

3.2. Teaching structures

Khalili et al (2015) discuss five different structures to include cleaner production and sustainable development in the academic programs. Generalising to the SDGs, the possible structures are providing exposure to the basic knowledge related SDGs; including fundamental of SDG's concepts in all courses; designing SDG graduate programs; developing concentration/minor in SDG; and promoting research in the areas of SDGs. Oueijan (2018) proposes the two implementation options, namely, separate programs with intensive training and embedded within other subjects.

Embedded material: teaching SDGs without changing the structure of the study program. For instance, Müller (2020) discusses some courses of a bachelor study program in business psychology, where students learn empirical research methods. They propose a three-phase approach, i.e., (1) basic research competences applied to simple/specific sustainable problems, following a hands-on approach, (2) application to more complex problems with strong focus on the research process through coaching, and (3) autonomous and self-determined research on a realistic and transdisciplinary problem. The main challenge they identify in implementing this project- and problem-based learning process is the difficulty in generating relevant research questions, for both, students and educators. The main handicap of teaching concepts about SDGs within the course limits time for the course material, therefore, only if recognised as a strategic learning objective, SDG-related concepts will be properly addressed. If SDGs are embedded within other subjects, it requires the modifications to the Accreditation programs, which is concerned with the skills, knowledge and behaviors STEM students are supposed to acquire by the time they graduate (Oueijan, 2018). Thew et al (2021) highlight the need for strategies that align SDGs teaching provision with governance

structures and working with trade unions and accreditation bodies to enable curriculum reform.

De la Torre et al (2021) propose a master course of Operational Research, i.e., advanced analytical methods, applied to sustainable transportation systems. The students, working in small teams have to analyse a complex decision-making challenge, develop their own methodology and discuss it with the instructor, implement the methodology in code and test it against a set of benchmarks, and analyse the results and obtain insights on the trade-offs between alternative strategies in terms of the different sustainability criteria being considered.

Intensive courses: separate courses with intensive training (dedicated courses) on SDG-related topics. In this line, Braßler and Sprenger (2021) analyse a series of lectures by different sustainability experts accompanied by several tutorials that support students' interdisciplinary learning and teamwork towards an interdisciplinary sustainability product. Hoffman et al (2021) propose a MSc course for students with diverse backgrounds (sustainability sciences, public administration, geography, sustainable business and innovation, etc.) along with policy makers working on circular economy. The students and policy makers meet with policy makers one afternoon and full day design studio, each week, culminating in a weeklong design studio to develop a fictional museum in the year 2050 "Museum of the Linear Economy".

Kirchherr and Piscicelli (2019) propose a course designed to introduce undergraduates to the circular economy, CE, (SDGs 4 and 11). The course was taught over eight modules (90 min each). The first module was intended to ensure that students would understand the guiding principles and aims of the CE concept. The focus of this second module was on eco-design. The third module introduced students to the idea of eco-industrial parks = as a set of businesses that share resources in order to increase profitability and reduce environmental impacts. The fourth module introduced students to the likely macroeconomic impacts of the CE. The fifth module and the sixth module consisted of excursions (e.g. to a global carpet company that produces new carpets by recycling old ones and runs only on renewable energy). For the seventh module, a CE party was organized with different student groups asked to bring circular foods or drinks to this party and to describe and quantify the economic, social, and environmental impact of

the circular business model behind these foods or drinks. Tyagi et al (2021) provides examples of skill development courses.

Entire programs: E.g., Nowotny et al (2018) propose a general curriculum for an education program on sustainable energy systems (SDGs 4 and 7). The program would involve three core teaching modules, including the basic sciences module, the applied sciences module and the module related to energy conversion systems. They also elaborate on the concept of a textbook suitable for an interdisciplinary program.

Transdisciplinary projects: Final course and graduation projects provide an interesting alternative to lecture-based sustainability lessons at the university level (Pires et al, 2020). Hernández-Barco et al (2020) propose service-learning in the context of a Final Degree Dissertation in the degree in Environmental Sciences at the University of Extremadura (Spain). Service-learning is an active education method in which the students apply their knowledge to improve real-life situations. Therefore, the students experience how they become competent by contributing to society (Tejedor et al, 2019). Hernández-Barco et al (2020) conclude that the method allows acquiring transversal competences of primary relevance when teaching SDGs.

Project-based competitions can also be included under this group, such as the one hosted by Ocean Wise (see Oceanwise Innovator Lab) for youth aged 13-30, including university students, student clubs, high school students, youth-led organizations and startups. Participants are given the task of coming up with innovative material (tiktok video, app, technology to capture ocean plastics) to raise awareness of ocean issues and pollution.

3.3. Drivers

The implementation of SGDs in HE institutions is a complex process that involves a number of drivers. On the one hand, internal drivers (see Fig. 1), such as visionary leaders that promote cooperation and collaborative efforts; connectors, that is, existing networks that reach across the university to include a critical mass of campus actors. Chaleta et al (2021) highlight the need for the involvement of the various sectors of the institution for more coordinated and interdisciplinary work; coordinator units; teachers and students. HE institutions should actively involve students to commit to and support SDGs (Leal Filho et al, 2019). Ferrer-Balas et al (2008) also mention the role of "lone

wolves" or "innovators" who work with no support from their institution or in parallel to the established channels. On the other hand, the external drivers, including the pressure from other universities, sources of funding and employment availability.

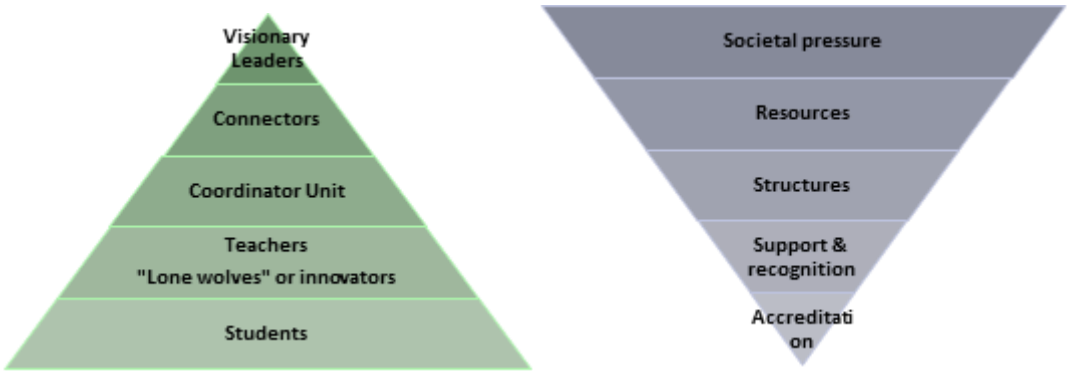

Fig. 1 *Drivers of the SDGs implementation in HE institutions (on the left, actors, and on the right, transformation triggers and requirements).*

Pérez-Foguet and Lazzarini (2019) note that in order to foster lasting academic engagement, permanent structures of universities should actively encourage and support the integration of SDGs principles into their different functions, by not only formally acknowledging SDGs commitment but also effectively implementing it throughout the system. Indeed, based on analysis of the curricula of 5 schools the University of Iceland, Jóhannsdóttir (2021) concludes that the key of a successful implementation of the SDGs into the practice and policy of a university is based on how determined the authorities of the university are.

3.4. Tools & Materials

There are some education-oriented platforms that provide courses, tutorials, podcasts, analytical and other tools, and the expertise on topics related to SDG achievement, catalogued according to SDG. For example, UN SDG, the United Nations initiative that aims to bring relevant and curated learning solutions on sustainable development topics to individuals and organizations have created the platform www.unsdglearn.org, bringing together multilateral organizations and sustainable development partners from universities, civil society, academia and the private sector.

Open Educational Resources, OER, including MOOCs: MOOCs, massive open online courses provide learning opportunities where diverse audiences can learn at their own pace and access the knowledge they need. Within this group, the SDG Academy is highlighted, which provides a collection of online courses catalogued according to SDG, sdgacademy.org. All the material is available for educational purposes. For instance, the course Climate Action: Solutions for a Changing Planet, with links to EdX MOOC which provides a full (10 week) course of 7 modules. It is also interesting EUSTEPs initiative. EUSTEPs' goal is to support the assessment and reduction of the environmental impact of EU HEIs through an experiential approach based on an innovative application of the Ecological Footprint. They will release a MOOC by August 2022. So far, they provide teaching materials, case studies, examples, conference posters and ecological footprint calculators (eusteps.eu). Besides, the Open Learning Campus (olc.worldbank.org/wbg-academy) is a collection of MOOCs, webinars and online courses dealing with different aspects of development provided by the World Bank Group. Examples of recorded lectures are ITSD2021 and sdgacademylibrary.mediaspace.kaltura.com.

It is worth noting the Biomimicry toolkit, toolbox.biomimicry.org, an online toolbox that can be used to introduce students to the concepts of biomimicry, i.e., to find solutions to technical problems through studying solutions found in nature. The toolkit, used in connection with engineering design, help students appreciate nature, biodiversity and sustainability if they can closely look at initiatives nature uses to solve engineering problems.

Serious games: Other tools supporting the educational efforts include serious games. Whalen et al (2018) note that serious games utilize two stages of learning, that is, active experimentation and concrete experience, which are not usually addressed by common teaching methods. They are also useful for reaching high Bloom´s cognitive levels and stimulate critical thinking. The emotional implication of the learning players stimulates critical thinking from an ethical perspective which is an important learning objective, though difficult to implement otherwise (De la Torre et al, 2021). To maximize learners' experience, an introduction to the main concepts is required before playing with serious games and reflexion after playing. In fact, different initial background results in unequal experiences and interpretations of the games. Examples of serious games can be found in Bekebrede et al (2021) on the topic of resilience (SDG 11), Whalen et al (2018) on the topic of material criticality and circular economy (SDGs 9, 11 and 12), the

Games4Sustainability platform, https://games4sustainability.org with more than 100 games arranged by the SDGs for teaching, learning and practicing the SDGs.

Simulation tools: Such as the SDG Impact Assessment Tool (sdgimpactassessmenttool.org). This online tool visualises the results from a self-assessment of how an activity, organisation or innovation affect the SDGs. It aims to stimulate the user to acquire a better understanding of the complexity of sustainable development and the different aspects of the SDGs. Simulation-based learning is at least as effective as case studies and even more effective than traditional lectures (De la Torre et al, 2021).

Non-educational resources: There are other resources that are initially not education oriented, however, they can support creation of course content and acquisition of a new sensitivity towards SDGs and deeper knowledge on topics such as gender equality (related to SDGs 4, 5 and 10), e.g., mik.pte.hu/women-engineer; consumer and industry trends (related to SDGs 3 and 11), e.g., www.euromonitor.com; biodiversity (related to SDGs 6-8, 10, 11 and 13-17), e.g., knowledge4policy.ec.europa.eu/biodiversity_en and biodiversity.europa.eu; business and economy (related to SDGs 8, 9, 11 and 12), e.g., sdgcompass.org that provides guidance for companies on how they can align their strategies as well as measure and manage their contribution to the realization of the SDGs. The United Nations Population Fund, UNFPA's website, provides resources to support case studies (e.g., https://www.unfpa.org/resources/unfpa-2020-greenhouse-gas-ghg-inventory-management-plan), along with information in the areas of sexual and reproductive health, young people, human rights and gender equality and population matters such as ageing, census, climate change, demographic dividend, migration, urbanization and population trends, of relevance for SDGs 1-6 and 16.

4. Current Level of Implementation of SDGs in European Higher Education Institutions

This section discusses the current level of implementation of SDGs in the HE institutions. Initially some tools created to guide the implementation and assess the effectiveness of the implementation are discussed. Then, several European universities are presented and their current level of implementation analysed. They are the University of Burgos (Spain), Trinity College Dublin (Ireland), University of Pecs (Hungary) and Delft University of Technology (Netherlands).

4.1 Methods to guide implementation and assess the effectiveness of the implementation

SDSN Australia/Pacific (2017) provides general tools and guidance for universities to implement the SDGs in their institutions. They can be adapted to different contexts and needs, including guidance on mapping, engaging with university stakeholders and senior management, building the business case, relationship management and reporting. Universities can use the following steps to start and deepen their engagement with the SDGs; (1) mapping what they are already doing, (2) building internal capacity and ownership of the SDGs, (3) identifying priorities, opportunities and gaps, (4) integrating, implementing and embedding the SDGs within university strategies, policies and Plans and (5) monitoring, evaluating and communicating their actions on the SDGs.

Sánchez-Carracedo et al (2021) propose several tools that enable a diagnosis of the degree of integration of sustainability competencies in HE. For instance, the Engineering Sustainability Map that facilitates the definition and distribution of engineering sustainable development-related learning outcomes within the curriculum, and the Sustainability Presence Map of the degree, based on the sustainability learning outcomes that are developed in the subjects. Also, questionnaires for students enable quantitatively measuring the perception of students about their own learning in sustainability. Ferrer-Balas et al (2008) propose the FLA method to assess and reflect on the implementation status and process from the point of view of the organizational structures. FLA stands for Framework, i.e., changes in culture, institutional structure and technology, Level of change required and Actors involved.

The level of implementation of the SGDs within the academic curricula has been analysed for four universities in Europe, that is, University of Burgos (Spain), Trinity College Dublin (Ireland), University of Pecs (Hungary) and Delft University of Technology (Netherlands). First, the existing institutional strategy to integrate the SDGs within their curriculum is presented. The existence of coordination units within the faculty and other structured links with external world are identified. Examples are also provided of embedded courses, intensive courses, entire programs and transdisciplinary projects in these universities. Finally, attention is paid to dedicated recognition, support, or resources for teachers to realise the change and for students through accreditation criteria.

4.2 Implementation level of University of Burgos (Spain)

The University of Burgos (UBU) is a public university whose mission is based on the provision of comprehensive, quality teaching, close to the student, focused on internationalisation and which, in just 25 years, has become a benchmark in Spanish university research and knowledge transfer to the business world. It has been distinguished by Spanish Ministry of Education as a Campus of International Excellence (CEI).

Currently, its educational offer is made up of 24 bachelor's degrees, 5 of which are also taught online and 3 are bilingual in English and Spanish, 8 double degrees, 26 master's degrees, 3 of which are online and 6 blended, 11 doctoral programmes and 20 UB-specific degrees. This educational offer is focused, as a priority, on facilitating the employability of its graduates, through the establishment of internship agreements with the business and industrial fabric of the region.

The University of Burgos is a public, open and plural institution, made up of people whose goal is the generation and transmission of knowledge at the service of improving the society of the geographical environment in which it is located.

Institutional strategy

Universities, as a fundamental part of today's society, play a key role in the transmission and training of the values of the 2030 Agenda for Sustainable Development to both students and society in general.

The commitment achieved and the complete evaluation of the actions taken by the University of Burgos to fulfil this Agenda are included in the Social Responsibility Report 2021, recently approved (17th March 2022) by the UBU Social Council (direct access to the full text).

The experience in the commitment to achieving the SDGs is described on a specific web page that the University has opened on its transparency portal. Here the actions are grouped according to the Goal to which they contribute, showing the great effort and the large number of actions carried out in practically all the SDGs.

In the area of Cooperation and Solidarity Action, there is also a website, from which complete information on the programmes developed or in progress can be accessed.

The UBU is currently developing the Plan for the integration of Sustainability-ODS in the University's Bachelor's and Master's Degrees.

Coordination units within the faculty & structured links with external world

Providing knowledge, innovations and solutions on the SDGs:

- "The SDGs in the City of Burgos" project, assessing the implementation of the SDGs in the city and the strategies to be followed.
- University Cooperation Grants Programme for the development of UBU staff.
- Project "Women and Migration Another Look", for the creation of a citizen model of active participation in the field of gender and migration.
- "Educational communities in action for fair trade and responsible consumption" project, which promotes the integration of fair trade and responsible consumption in the work, training and awareness of the university community of the University of Burgos and the educational community of primary schools in the city of Burgos.
- Fair Trade: Since 2015 we have been a University for Fair Trade (University Week for Fair Trade) and we participate in the Burgos, City for Fair Trade initiative, together with its City Council and other organisations in the city (University for Fair Trade).
- "Good Practice Guide for ethical procurement of services and goods, promoting sustainability", which shows how to incorporate social, ethical and environmental criteria in contract award procedures.

- Climate action: We lead the ACCUE project, adaptation to climate change in Spanish universities (see here). From Green Office -UBUVerde, we carry out training and awareness-raising activities with workshops, environmental excursions and environmental volunteer work.

Adopt and implement the SDGs in the governance and culture of the institution itself:

- Institutional approval of UBU's commitment to the 2030 Agenda.
- Portal for monitoring our actions on the SDGs.
- Specialised courses for staff and students to build internal capacity and ownership of the SDGs.
- UBU-Refuge Programme: shelter for beneficiaries of international protection, in collaboration with local, provincial and regional institutions.
- Postgraduate scholarship Women for Africa Foundation, co-funded by the State Pact against Gender Violence for postgraduate courses.
- Networking: We are members of the Spanish Sustainable Solutions Network (REDS-SDSN) and the UN Global Compact.
- Healthy Campus Classroom: We are part of the Spanish Network of Healthy Universities (REUS), with strategic lines of health promotion with the Healthy Campus Classroom and the University Health Care Service (SUAS).
- "Guide of good practices for the transition, access and reception of students with specific educational support needs", useful for families, students, technical support staff and teachers.
- Project 360 REWIN - Erasmus Plus Resilient immigrant Women interventions for Inclusion, to develop skills and competences among students and university lecturers to improve the care we offer to victims of gender-based violence and, specifically, to violence against migrant women.
- Entrepreneurial Ecosystem Project - AECID. to promote the development and empowerment of adolescents and young workers in Potosí, Bolivia.

All this institutional effort has been recognised by the Times Higher Education ranking, placing us in position 150/1115 in the implementation of the SDGs, with a rating of 100% in "Education for the SDGs".

Examples of embedded courses, intensive courses, entire programs and transdisciplinary projects

The most relevant actions and projects related to the implementation of the SDGs are presented below:

Training for those responsible for the implementation of the 2030 Agenda:

- Diploma in Sustainable Development: Cross-cutting subjects for all Bachelor's and Master's Degrees.
- Service-Learning and Volunteering Programmes
- PPACID Programme: Grants for final degree projects in developing countries

Recognition, support, resources for teacher and students

Currently UBU does not have any accreditation for teachers who implement the SDGs in their subjects. Nor does it exist for students.

4.3 Implementation level of Trinity College Dublin (Ireland)

Trinity College is situated in the centre of Dublin and was founded in 1592. It is ranked 1st in Ireland, and 104th in the world (QS University Rankings 2018). It offers over 600 course options, a deposit library with over 6 million volumes, and researchers who attract €70million annually in external funding. Trinity students receive a world-class education at a leading university for both teaching and research.

Three Faculties offer a range of studying opportunities in over 400 undergraduate courses as well as postgraduate taught and research options in the Arts, Humanities, Engineering, Science, Human, Social and Health Sciences.

Institutional strategy

The University is committed to sustainable development. A Vice President for Biodiversity and Climate Action was appointed for the first time in 2021.

Goal number 5 of Trinity's Strategic Plan for 2020-2025 is as follows: 'We will shape our organisation and focus research around the challenge of achieving a sustainable and healthy planet'. It is a commitment to sustainability on a global scale. Bringing different perspectives together, Trinity College is committed to finding ways in which as many members of the university as possible can contribute to furthering the UN Sustainable

Development Goals (SDGs) and to prepare its students to lead their lives as responsible global citizens. Objectives within Goal no. 5 include:

- commit to strong ethical leadership;
- create a UN Sustainable Development Goal Hub using our research data to monitor research in all fields linked to the UN SDGs;
- have set targets for the significant reduction of our carbon footprint;
- provide leadership in sustainability through improvements in energy use, reduction in waste including single use plastics, promoting areas such as sustainable transport and biodiversity, and ensuring all new buildings are based on sustainability principles;
- support and conduct civically-engaged research thereby increasing the number of research outputs connected to UN SDGs by 20% by 2025;
- promote civically-engaged research across the university and host public engagement events relating to the UN SDGs, highlighting to the wider public and policy makers the impact of our work;
- build the teaching programmes and research projects of the CHARM-EU alliance around the grand challenge of 'Reconciling Humanity with the Planet'.

Trinity also commits to embedding the skills of independent thought and action throughout our curricula and promoting the values of pluralism, social justice and environmental sustainability.

There are a number of initiatives aiming at boosting sustainability thinking and action, such as:

- Green Campus Committee. The Green Campus Committee meets monthly to act on Trinity's sustainability initiatives and is a collaboration between students and staff. Bring ideas and suggestions for real change to this meeting – anyone can attend. It is part of Trinity's Green Campus Programme which has worked in several projects including replacing polystyrene cups with cardboard cups, various recycling programs, composting, biodiversity campaigns, etc.
- Student Societies. Joining an environmentally-themed society such as EnviroSoc, Botanical Soc, Vegan Soc, TCD Young Greens, Zoo Soc or the Joly Geological Society.
- Sustainability Guides. They have created a number of guides to share helpful information about how to reduce your impact on the natural world - learn how to get around Dublin/Ireland using public transport, reduce waste and minimize your energy consumption.

- Green Maps. Explore the Green Maps of Trinity, they will show where to recycle; where to fill up water bottles; where to find vegetarian restaurants/cafes and eco-friendly shops; where there are innovative energy retrofits on campus, rainwater harvesting and green roofs.
- Students Union. The SU and GSU each have a student Environmental Officer who can connect students into events, activities and groups around environmental issues.

Coordination units within the faculty & structured links with external world

Trinity established a Staff Sustainability Network and a Student Sustainability Network in 2017. The Staff Sustainability Network has been created to offer staff the support, awareness, skills and tools they need to foster sustainability in their respective departments. The Staff Sustainability Network meets monthly throughout the year to discuss staff ideas and concerns regarding issues of sustainability. This group disseminates information to peer staff members, helping to drive better environmental habits and raise environmental consciousness among staff and faculty. The Student Sustainability Network was designed to raise the awareness of the environmental impact we have on the world. The network has been created to offer students the support, awareness, skills and tools they need to foster sustainability in their respective departments. Students and staff receive an electronic copy of the Staff or Student Sustainability Guide (geared individually towards staff and student populations) each year, which provides links to resources to enable our campus population to live and work more sustainably.

Examples of embedded courses, intensive courses, entire programs and transdisciplinary projects

The courses related to SDGs already in place are detailed in Appendix II.

4.4 Implementation level of University of Pecs (Hungary)

The University of Pécs, is the largest higher education institution in the South Transdanubian region of Hungary. It has 10 faculties spanning the fields of science, engineering, humanities, cultural sciences, law, economics, and medicine and more than 20,000 students including 4,500 international students. In addition, it has over 1400 lecturers and researchers.

Institutional strategy

The University of Pécs is committed to the smooth transition to a more sustainable environment and campus. It has set a series of goals for what it would like to achieve by 2020, 2030 and 2050 under the Green University initiative (https://zoldegyetem.pte.hu/en) which is not limited to just improving the natural environment and reducing carbon footprint but also covers numerous other social aspects of the SDGs (e.g., gender equality). The University of Pécs was ranked 42nd (from 956 participating universities) according to the UI GreenMetric World University Rankings in 2021 (https://greenmetric.ui.ac.id/). The same green metric shows that the University of Pécs was the highest rating HEI in Hungary and ranked 25th among universities in Europe. However, there is no specific strategy that is directly related to teaching SDGs at the university.

Coordination units within the faculty & structured links with external world

The Faculty of Engineering and Information Technology actively promotes, recruits and supports female students in all disciplines at the university through the Women in Engineering initiative https://en.mernoknok.hu/.

Additional coordination between different departments of the faculty (transdisciplinary) mainly take place through transdisciplinary courses and also research teams. Several research teams collaborate in topics which are directly linked to the SDGs, for example, Smart City Technologies Research Team; Modern, Ecological Systems of Water Management and Green Surfaces Research Team; Medical Engineering Research Team; Energy Design Building Technology Research Team.

The faculty actively participates in the Solar Decathlon Design Challenge and Solar Decathlon Build Challenges, where the aim is for 'students to create efficient, affordable buildings powered by renewables, while promoting student innovation, STEM education and workforce development opportunities in the building industry' (https://www.solardecathlon.gov/about.html). This is financially supported by the faculty's external business partners.

Another student group at the faculty is the Pécs Chapter of the Engineers without Borders (UK) which is a multidisciplinary group that encourages a lifelong commitment to globally responsible engineering (https://www.ewb-uk.org/inspire/chapters/). The

Pécs chapter regularly participates in online events hosted by EWB chapters in the UK as well as promoting sustainability at local secondary schools through presentations.

One other initiative, is the "Design your own eco-house – International competition" which is a cooperation between the University of Pécs and the local secondary technical school. The competition is open to all technical secondary schools in Hungary and as well as partner schools in the surrounding countries (Romania, Serbia, Slovakia). Architectural technicians working in the field of eco-architecture can learn about current issues in eco-construction, the use of traditional building materials, the possibilities of using renewable energies, and water management in a more sustainable way. The main aim is to educate future architects, to prepare students to think ecologically and to shape the built environment of the future (https://mik.pte.hu/tervezz-te-is-okohazat-verseny).

Examples of embedded courses, intensive courses, entire programs and transdisciplinary projects

The University of Pécs has embedded SDGs through all the structures mentioned in Section 3.2.

- Embedded courses: An example of embedded courses is English for Sustainable Design which incorporates different aspects of sustainable design into a course offered to learners of English as a second language who are also interested in sustainability. To pass the course, students have to present to the class a sustainable design of their own home that incorporates different aspects from the SDGs, e.g., clean energy, clean water and sanitation, life on land, life below water, responsible consumption and production and zero hunger.

- Intensive Courses: Sustainability in Structures is a lecture and project-based course for MSc level students from a variety of disciplines. There are lectures on different aspects of sustainability and students also must work together to produce a design that takes into consideration life cycle costs, embodied energy, and the circular economy. In 2021, as part of this course, an intensive design week was organised between the University of Pécs, Dortmund University of Applied Sciences and Arts, and Metropolitan State University of Denver, where students had to collaborate on the design of a sustainable fire watch tower.

- Entire programs: The faculty trains undergraduate environmental engineers who deal with environmental protection and management. In addition, the Institute of Smart Technologies is currently organising a two-year postgraduate programme 'Sustainable Systems in the Built Environment' in collaboration with Metropolitan State University, Denver, which is planned to be launched in September 2023.

- Transdisciplinary projects: The faculty actively participates in the Solar Decathlon Design Challenge and Solar Decathlon Build Challenges, where the aim is for 'students to create efficient, affordable buildings powered by renewables, while promoting student innovation, STEM education and workforce development opportunities in the building industry' (https://www.solardecathlon.gov/about.html).

In addition, undergraduate students from any discipline are invited to participate in the Engineers without Borders, Engineering for People Design Challenge. This transdisciplinary project 'is embedded in the curriculum and gives university students the opportunity to learn and practice the ethical, environmental, social and cultural aspects of engineering design. Students work on real-world problems without real-world pressures and risks. This gives them the skills, knowledge and experience needed to address global and local issues' (https://www.ewb-uk.org/upskill/design-challenges/). At Pécs, students work together with students from the University of Brunel in this collaborative project.

Recognition, support, resources for teacher and students

The Solar Decathlon competition gets significant financial support from the faculty and also from numerous sponsors in the business community often in return for promotion of their products. Students also get special allowances to catch up on those courses they missed due to taking part in the solar decathlon, e.g., extra examination period, extension on deadlines for submission of assignments.

The Engineers without Borders UK organisation actively supports teachers though workshops, an online forum and suggested activities to assist with the project based learning aspects of the Engineering Design Challenge.

There are several courses in environmental protection which are compulsory courses for engineers and architects, which are taught by the department of environmental engineering. The faculty also teaches a BSc level environmental engineering programme, which obviously incorporates many aspects of SDGs, e.g. biodiversity, water, energy, waste reduction, etc. In addition, there are several courses that focus more specifically on SDGs, e.g., Introduction to Sustainability, Circular Economy, however, these are optional courses and a significant proportion of students often drop out when they face time constraints to focus on their compulsory courses.

4.5 Implementation level of Delft University of Technology (Netherlands)

Delft University of Technology (TU Delft) is the oldest and largest public technical university of the Netherlands. Its university population includes 27,270 students, 2,999 PhD candidates and 6,347 personnel members. The TU Delft is ranked by QS World University Rankings 2nd worldwide in the fields of architecture and the built environment and civil and structural engineering and is among the top 10 engineering and technology universities worldwide. In terms of SDG Ratings, the university has a gold rating for Environmental impact and a silver rating for social impact. The university is composed of 8 faculties teaching 16 Bachelors programmes, 33 Masters programmes and numerous post-graduate programmes. In addition, the university has more than 3 million enrolments across a broad range of massive open online courses (MOOCs).

Institutional strategy

The TU Delft has taken significant concrete steps in shaping a sustainable society by applying these principles to its campus as a living lab for sustainability. Since 2020, the university has constructed the ECHO teaching building, establishing a cooperation between the Sustainable Operations Coordinator and the Green TU student organization to promote more sustainable and less consumptive behaviours among students. Green Teams at each faculty to advise the faculty board on the transition to more sustainability in the curriculum and in operational practices. In the same year, the Hive opened as a central knowledge sharing location for staff and students to meet and exhibit sustainable products.

More recently, The TU Delft has made a noteworthy commitment to SDG 13- Climate Action with its Climate Action Programme. This 10-year programme is a 22 million euro investment in research, education and the sustainability of the campus. The investment

includes the funding of 17 tenure track assistant professors, the development of courses for professionals and a Climate Action minor and to develop a Climate Action Hub for debate with global and national leaders and industry partners on climate action. A campus sustainability coordinator has been appointed to develop a sustainability vision and programme for the campus. According to the vision, the university commits to operating in a completely sustainable manner by 2030, meaning "all activities on and from the campus will then be carbon neutral, circular, climate adaptive and contributing to the quality of life for its users and for nature". As a monitoring tool, the university will monitor its carbon footprint starting with the Dashboard 2020 Baseline , to calculate the CO2 footprint for various campus operations including electricity use, water consumption, catering, waste production and business/commuting travel. The CO2 roadmap of the campus can be read here: Direct access to the full text.

Coordination units within the faculty & structured links with external world

Within the Climate Action Programme, a three-levelled roadmap is being developed to implement education for sustainability university-wide. These level include: 1) the base layer- fundamentals of sustainability, 2) discipline-specific sustainability and 3) interdisciplinary sustainability – interfaculty and interuniversity courses – serving overarching themes.

Next to this, the multiple faculties of the TU Delft engages in transdisciplinary research and education on the societal challenges of health and resilience within centers and initiatives with academic institutions throughout the Netherlands. The 4TU Center for Resilience Engineering hosted by the federation of Dutch technical universities hosts an open access community platform for urban resilience resources. Within the Convergence programme, stimulates collaboration of TU Delft with to other academic institutions within the Rotterdam area on 5 strategic topics of importance for achieving the SDGs:

1. Resilient Delta
2. Health and Technology
3. AI, data and digitalization
4. Pandemic and disaster preparedness
5. Healthy start

Examples of embedded courses, intensive courses, entire programs and transdisciplinary projects

Entire programmes: The new MSc programme Metropolitan Analysis, Design and Engineering (MADE) is a joint degree programme between Delft University of Technology and Wageningen University & Research, in close cooperation with the Amsterdam Institute for Advanced Metropolitan Solutions (AMS). Working closely with the City of Amsterdam, MADE applies urban living labs to jointly develop solutions for the practical challenges facing major cities. In a similar vein, Convergence plans to develop one or more School(s) of Convergence with the aim of transdisciplinary teaching spanning from early education to life-long learning courses.

The Joint Interdisciplinary Programme (JIP) is 10-week interdisciplinary Master course at TU Delft, which is embedded in the curriculum. In it, students work full-time in groups of five on a challenge identified by industry for a total of 10 weeks. The course aims to develop student skills in working across disciplines and from a challenge-driven perspective.

Minor degree: As a part of convergence among regional universities Leiden Medical, Delft University of Technology and Erasmus University, there is an SDG minor in development called ‘ in the Decade of Action’. It is a mixed classroom concept where students work in groups together with public and private organizations to connect the SDGs to strategy policies and business strategies.
The TU Delft Faculty of Architecture and the Built Environment hosts MOOCs teaching about the SDGs. These courses are: “Healthy aging in 6 steps” (SDG3- Good health and well-being) and Rethink the city: New approaches to global and local urban challenges (SDG11-Sustainable cities and communities). TU Delft also hosts MOOCs of the Amsterdam Institute, “Sustainable urban development: Discover advanced metropolitan solutions” (SDG11-Sustainable cities and communities); and “Co-creating sustainable cities” (SDG11-Sustainable cities and communities).

In 2022, the Faculty of Civil Engineering and Geosciences upscaled the topic of Environmental Engineering of the Civil Engineering programme from a track to a fully independent MSc programme focussing on water management and technology and mitigation of soil and air pollution. The Faculty of Architecture and the Built Environment

has long led the TU Delft in interdisciplinary education on the topic of sustainability. The annual summer school “Planning and Design of the Just City” is imbedded in the SDGs.

Recognition, support, resources for teacher and students

The Dutch Ministry of Education, Culture and Science (OCW) wants open science and with it open education to become standard practice. Open Educational Resources (OER) support educators in their work to imbed the SDGs in their teaching by supporting the exchange of creative commons licensed, high quality educational materials. The SURF.nl platform OCW supports the digital transition to open science and education including the provision of various online platforms for hosting OER.

TU Delft Library Services provides support to teachers and faculties across the university to build community of online open science and education. Examples of OER communities led by TU Delft include: 4TU. Ethics and 4TU. RE Urban Resilience, With interdisciplinary education of key importance to imbed SDGs in STEM education, the TU Delft Teaching Academy forms a network for an by lecturers aiming to collaboratively enhance engineering education across faculty boundaries.

5. Identified Implementation Challenges

This section discussed the implementation challenges identified in the literature and in the universities studied.

5.1 Implementation challenges identified in the literature

Enabling critical thinking. Although acquiring critical thinking is very often presented in the HE curricula, it is not clear that HEs have the adequate structures implemented to achieve it. Indeed, Thomas (2009) highlights the need for a pedagogical transformation that make student think critically. It is also important that learners develop a systems thinking. This would enable them to critically reflect on the trade-off of each decision in a complex and interconnected world. Serious games and simulation-based learning offer students systems-thinking perspective (De la Torre et al, 2021).

Dealing with complexity of real life. Pedagogical approaches should enable learners to engage with, and respond to, SDGs as "real-world" problems, such as through experiential learning (Thew et al, 2021). In this line, Maruna (2019) proposes some guidelines for teaching SDGs that include the partnerships with institutions and communities, links with scientific research work, and practice orientation.

Embedding Intra-, inter- transdisciplinarity. Embedding interdisciplinarity is crucial to ensuring that our response to the challenges addressed by SDGs make use of all of the expertise HEs have to offer and promotes knowledge exchange and integration for students and staff (Thew et al, 2021). This aspect goes hand in hand with the next implementation challenge, the collaboration across sectors and disciplines.

Collaboration across sectors and disciplines & network. HE institutions should guarantee partnerships between the sectors and stakeholders that are necessary for the transformation of our society (Tandon and Chakrabarty, 2018). Pires et al (2020) notes that trans-departmental strategies need to be implemented. Thew et al (2021) highlight the need for partnering with industry, government and third sector organisations to enable context-specific education.

Internationalization: Sustainability is a global issue. Tandon and Chakrabarty (2018) highlight the importance of international collaboration beyond the own university. A way of addressing this issue is to involve learners in international projects. In this manner, the learners in developed countries can understand developing countries' context and issues whereas the learners in developing countries can understand developed countries' approaches and reality. Student and staff mobility is an important tools for achieving the SDGs through internationalization (Nogueiro et al, 2022).

Teaching teachers. An important hindrance of integrating SDGs principles is that academics mostly have a strong disciplinary expertise (Pérez-Foguet and Lazzarini, 2019). For instance, within the context of SDG16, Oueijan (2018) highlights that educators are not prepared (in general) to teach peace, they should detach themselves from their own ideological confines.

Stimulating individual actors. From their analysis of 7 universities in Spain, India, USA, Japan and Sweden, Ferrer-Balas et al (2008) conclude that the main barrier to implement SDGs is the lack of incentive structure to promote changes at the individual level. They point out to the limited freedom of individual faculty members, the poor incentive structure, for instance through salaries, promotions, and granting of tenure, and the lack of desire to change.

5.2 Implementation challenges identified in the analyzed universities

In Annex III, Figures 1-4 below show main findings of teaching interests and institutional barriers to integrating teaching materials urban resilience. We use findings from this survey as a proxy to examine key interests and institutional barriers to the adoption of existing educational materials in HE teaching based on responses from 37 educators of TU Delft. The most respondents (8) stated an interest in resources teaching the general principles about resilience followed by design guidelines for resilient infrastructure. Disciplinary topics such as ethics, governance and measuring resilience, in total, were marked as priorities by 4 respondents. The vast majority of respondents preferred resources that could be taught within 45 minutes or less rather than a full lecture or longer. “Awareness”, “resource to innovate in education”, “lack of reward system” and “potential copyright issues” were the 4 most cited reasons to not adopt existing educational resources from other educators on societal challenges. Despite these challenges, all but 2 respondents marked that they would indeed recommend the

uptake of Open Educational Resources in teaching to course coordinators in their department or faculty.

Annex IV provides the results of the survey conducted to the teaching staff at the University of Pecs about introducing SDGs into the teaching. The survey showed that a large proportion of teachers who completed the survey are interested in integrating different aspects of the SDGs into their teaching. Because the survey was conducted at a faculty of technology and engineering, those SDGs that are related to technical aspects of the SGDs, (e.g., SDG 9, SDG11, SDG12, SDG13) were given higher priority for inclusion than those related to biological, social, or economic aspects. Quality education also featured highly which is also to be expected.

A large proportion of those surveyed have already partially introduced SDGs into their teaching, however, some obstacles were identified including accessing quality external teaching materials in English but more so in Hungarian. Teachers stated that introducing sustainability at the undergraduate level can have a large impact on integrating sustainability issues into the curricula, as well as open access to resources to promote interdisciplinarity, and that the integration should be layered with differentiation linked to the learning pathway.

Most teachers are willing to devote from 45 minutes to several hours to teaching sustainability issues in their courses, however, also a large proportion thought there should be a separate course focusing on sustainability.

It can be concluded that there is a real demand from teachers to integrate SGDs into their teaching and many teachers have already done this in their field of specialization. To ensure more comprehensive coverage of the SDGs it may be important to include aspects of those SDGs that are not generally covered at a technology faculty such as those dealing with inequality, poverty, good health and peace, justice, and institutions which could be done by applying a multidisciplinary approach. Teachers also need ready access to good quality materials that are easy to adapt to fit their situation.

The survey shows there is a demand for tools, materials, and methodology in education that is more conducive to a change of mind-sets and values. These tools could also contribute to increasing the interdisciplinarity in teaching concepts of SDGs.

6. Conclusions

Clear progress in the field has been made within the last ten years (Ferrer-Balas et al, 2010); Education for Sustainable Development, 2012, Thomas et al, 2012) Despite these efforts, the existing literature presents frameworks and recommendations at a very conceptual level, with little attention paid to the effective implementation of the frameworks. Some works discuss implementation barriers and suggest ideas to overcome them; however, little evidence of their successful implementation has been found.

Several recommendations for implementation are formulated based on the reviewed literature:

1. SDG relations to STEM disciplines.

Main contributions to achieving the SDGs and targets outlined in the 2030 Agenda have been identified by professional societies spanning the STEM disciplines (see Section 2). These societies together with academia have the capacity to identify white spots where scientific insights are needed for transformative action but should resist cherry-picking SDGs for self-benefit. The STEM disciplines must therefore redefine their societal mission, becoming living labs for sustainability and transforming competitive inclinations into cooperative working attitudes towards interdisciplinary collaboration. Academic institutions, and education in particular, play a crucial role in bridging the disciplines for an integral approach to reaching the SDGs. But, this emerging role necessitates education reform based on the adoption of system-oriented approaches and integration of the life sciences, social sciences and the arts.

2. Implementation structures and tools.

Taking action on education reform involves adopting new learning objectives and teaching structures. To supplement the acquisition of knowledge and skills, messaging should target emotional responses to share the attitudes, mindsets and values of students in the STEM disciplines. While this can be facilitated by holistic learning visions of cognitive, socio-emotional and behavioural learning and the development of action competences, evaluating such creative processes remains challenging.

New learning objectives can be housed in the following teaching structures: (1) exposure to basic SDG knowledge, (2) including SDG fundamentals in all courses, (3) designing SDG graduate programs, (4) developing SDG concentrations or minors and (5) promoting research in SDG areas. SDG materials can be embedded in the structure of existing programs though this requires modifications to the Accreditation programs. Next to this, intensive courses, entire programs and transdisciplinary projects can be set up where SDG-related topics are explored through interdisciplinary learning and teamwork. While embedding the SDGs in STEM education throughout the system, it can be significantly facilitated or hampered by the ambition of the governing bodies within the HE institution.

New learning objectives must be linked to teaching structures through teaching tools and materials. One best practice is the use of existing resources such as open educational resources (including MOOCs) to fill in and customize an SDG for STEM education in the desired format of the client, whether it be a university, a study programme or an individual lecturer. While there are a number of MOOCs covering SDG-related topics, it is important to note that for imbedding in existing courses and curriculum, the format of teaching materials must fit the use case to ensure coherency in content and learning objectives. For this reason, open education resources in smaller formats such as snippets of MOOCs, serious games, simulation tools and non-educational resources can serve as useful teaching materials in suitable formats with high integrative and deep learnign value.

Some final considerations also worth mentioning are that special attention must be paid to the education of lecturers. It is also important to implement a diagnostic tool to measure the degree of integration of sustainability competencies in higher education, with the aim of guaranteeing the acquisition of these competences by graduate students. The teaching tools and materials themselves should be easy to use, implement and export to different areas of study.

3. Current Implementation of SDGs in HE Institutions.

An analysis of the participating HE institutions of the JOIN-RISe project provides an indication of the current level of implementation of SDGs in HE institutions focused on the STEM disciplines. It can be claimed that HE institutions are aligning their institutional strategy with the SDGs and in some cases are offering their campuses as living labs, for

example, to accelerate the energy transition. Numerous bottom up initiatives are also present across campuses promoting and institutionalizing sustainability thinking and action such as Green Campus committees and student societies. Dedicated inter-faculty research collaborations such as TU Delft's Climate Action Programme and auxiliary transdisciplinary research such as the Solar Challenge highlight some of the long-term commitments of HE institutions to the SDGs. In the domain of teaching structures, integration of the SDGs is dominated by intensive courses, entire programmes and transdisciplinary projects, where embedment of SDGs in existing STEM courses and curricula lag behind. Examples where embedment has been achieved lean heavily towards disciplines that are by nature interdisciplinary such as urbanism and the health sciences.

Two main barriers to SDG implementation can, thus, be concluded from the study. First, the embedment of SDGs in traditionally siloed disciplines remains a persistent barrier. Second, a lack of incentive structure throughout the HE institution system serves as a barrier to education reform.

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Annex I. Summary of investigated sources

	Source	SDG		Material description		Content type			Educational tools/formats suggested	
	Link/ Reference	Main	Other (explicitly) related	Keywords for search	Goal of the material	Provides content, information	Applications	Operationalization	Format	Brief description
Governance & Infrastructure	Games 4Sustainability platform[2],	All SDGs		sustainability, teaching	To provide serious games for teaching, learning and practicing the SDGs	Information			Tools	More than 100 games and simulations arranged by the SDGs
	Ferrer-Balas, at al (2008).	All SDGs		HE, sustainability, case study	To identify the key aspects of transformation of HE towards sustainability (at an institutional level) and the drivers and barriers in the transformation.		Comparison of 7 universities: UPC (Spain), TERI University (India), Carnegie Mellon University (USA), IR3S (i/University of Tokyo,Kyoto University, Hokkaido University, Osaka University and Ibaraki University), Linkoping University (Sweden)	FLA method to assess/reflect on the implementation status and process: **F**ramework (related to changes in culture, institutional structure & technology), **L**evel of change	n.a.	

[2] https://games4sustainability.org, accessed on 09 February 2022

	Müller et al. (2020).	All SDGs	Project-based learning, Transformative learning, HE, SDGs, Project-based learning, laboratories	To propose alternative routes for teaching SDGs without the need to change the structure of their study program	Case study: Bachelor study program in business psychology	Method required and Actors course	Courses on empirical research methods. Three phases: (1) basic research competences applied to simple/specific sustainable problems. Hands-on approach, (2) Application to more complex problems with strong focus on the research process. Coaching, (3) autonomous and self-determined research on a realistic and transdisciplinar problem.

	Marun a, (2019).	11	SDG 11 targets 11.1-6 and 11.a-c	SDGs, higher education	Build thematic and methodological (incl. GIS) knowledge for planning work. Curriculum was evaluated based on UNESCO SDG11 Los and professional planning requirements	Information on programme content		evaluation of content for accreditation	Full programme	18 courses plus internship and thesis (project)
	Hoffman et al (2021). .	9		Mixed learning, futuring, sustainability	Facilitating a meaningful exchange between students and policy makers by engagement in futuring in a mixed classroom setting		investigates how futuring methods can be applied in an educational setting to learn about wicked problems.		Course	Course of either 5 or 7.5 ECTS, 22 international students 12 policy makers meeting with policy makers one afternoon and full day design studio, each week. Culminating in weeklong design studio culminating in fictional museum in year 2050 "Museum of the Linear Economy"

	Bekebrede et al (2021). .	11	9	urban resilience, infrastructure	After playing the game, the participants: - Understand different perspectives of resilience and how they influence key performance indicators and decision making - Experience the impact of disasters on the environment of the system - Experience the consequences of different measures on disasters - Experience the consequences of different measures on other systems (counter intuitive effects): a. effect of measure during implementation and under normal conditions, b. effect of measure to protect one disaster on effects when another disaster happens - Experience how to organize disaster prevention and mitigation.	information	fictional city setting can be customized to a real city.	facilitator manual and game rules included	Game	4-person card game that is downloadable under a creative commons license in both print-and-play and blank formats (for customization). Game rules, facilitator manual and research background document also provided

Dasandi, & Mikhaylov, (2019).	16	All SDGs	Peace, justice, strong institutions, higher education	To convince that AI is important to achieve SDG16		Recommendations		
Oueijan, (2018).	16	-	Peace, justice, strong institutions, higher education	To discuss if peace education should be introduced in the educational programs as separate program or embedded in the subject content of all the courses		Recommendations	Full programme	Peace education is “a philosophy and a process involving skills, including listening, reflection, problem-solving, cooperation and conflict resolution". Implementation options: (1) separate programs with intensive training, (2) embedded within other subjects with modifications to the Accreditation engineering programs, which is concerned with the skills, knowledge and behaviors engineering students are supposed to acquire by the time they graduate. (3) educators are offered peace education workshops and training sessions.
Tandon, Chakrabarty, (2018).	17		accountability, higher education	Group of Experts in SDGs and Higher Education share experiences and recommendations.		Examples		Recommendations for integration: (a) Seek for opportunities for cross-discipline and cross-sector collaboration, (b) Develop messages that target emotional responses, and are aligned with scientific perspectives, (c) Establish hubs housed by institutions of HE to coordinate initiatives

	SDSN Australia/Pacific (2017): f	All SDGs	SDGs, higher education	This Guide provides general tools and guidance for universities to implement the SDGs in their institutions. They can be adapted to different contexts and needs, including guidance on mapping, engaging with university stakeholders and senior management, building the business case, relationship management and reporting.	Provides a step-by-step guide to help universities engage with the SDGs and in particular develop an institution-wide framework for supporting SDG implementation. develop an institution-wide framework for supporting SDG implementation.	Offers practical guidance and tools to assist universities to engage with the SDGs, including how to map existing activities, how to engage with stakeholders, and how to report on SDG contributions		Guide	Case studies, developed by different universities, with regard to the Sustainable Development
Human Development	Pérez-Foguet, &; Lazzarini (2019)	4.6	SDGs, higher education, STEM	This work analyses the extent to which a professional development programme, aimed at engaging and empowering faculty, has positive effects at integrating sustainable human development principles into existing courses of engineering; specifically, in new teaching modules in a subject of basic engineering science, implemented in regular courses of the first year of an engineering degree programme.	Information on programme content		Real case	n.a.	Case studied

	Noguei ro et al (2022)	4, 5, 8	SDGs, gender equality	The purpose of this research is to identify, among the 17 SDGs, those that could be more relevant in the context of mobility projects in higher education within the Erasmus+ Programme and how these projects contribute to these identified SDGs.	Information on programme content		n.a.	
	Sánche z-Carrac edo et al (2021)	4	Education for sustainability; Education for sustainable development; Education for sustainable development goals; Engineering sustainability map; Sustainability assessment; Sustainability presence map	Tools developed within the framework of the project EDINSOST2- SDG, aimed at embedding and assessing the Education for Sustainable Development (ESD) in Engineering curricula.	Tools that enable a diagnosis of the degree of integration of sustainability competencies in higher education		Tools	The first tool, the Engineering Sustainability Map, facilitates the definition and distribution of ESD-related learning outcomes within the curriculum. The second tool the Sustainability Presence Map of the degree, based on the sustainability learning outcomes that are developed in the subjects. The third tool, the questionnaire for students, enables us to quantitatively measure the perception of students about their own learning in sustainability.
	Tyagi et al (2021)	10.4	Reduced Inequalities, Education	Skill Development Courses,	Information	Examples	Courses	Examples of Skill Development Courses

	Braßler &, Spreng er (2021)	4		higher education for sustainable development (HESD); project-based learning; tutor training; interdisciplina ry learning; interdisciplina ry; sustainability knowledge; sustainability attitudes; sustainability behaviours	Study with an interdisciplinary approach to HESD and investigate its efficacy regarding students' development of sustainability knowledge, attitudes, and behaviours at a university in Germany.	Information	Case study	Course	The approach of the study applies a series of lectures by different sustainability experts accompanied by several tutorials that support students' interdisciplinary learning and teamwork towards an interdisciplinary sustainability product.
	https:/ /www. unsdgl earn.or g	All SDGs	All SDGs	SDGS, courses	The Platform includes courses, tutorials, podcasts, analytical and other tools, and the expertise on topics related to SDG achievement, catalogued according to SDG. All material available for educational purposes.	Information		Catalogue of tutorials, podcast, analytical and other tools	Collection of online courses catalogued according to SDG. All material available for educational purposes.

	https://mik.pte.hu/women-engineer; https://www.youtube.com/watch?v=x0P_ANttZTU; www.mernoknok.hu	5	4, 10	women in engineering, be present, pte mik	Using PR and social media to promote female participation in STEM subjects through the 'Women in engineering is the new normal' Increase enrolment of female secondary school students through community building and support initiatives of existing HE students	Support marketing work	website, blog and YouTube videos	
	https://www.euromonitor.com	3	11	trends	Using fresh consumer and industry trends, and papers about SDGs from this online platform	Information	tool	teachers can use it, to present the up to date world-trends, students can use it as a research resource
	Moscardo, (2017). .	3	11	mindful visitors, interpretation, heritage interpretation	„interpretation is trying to produce mindful visitors; visitors who are active, interested, questioning and capable of reassessing the way they view the world. Repetition, on the other hand,	Information	tool	could be an offer literature for heritage studies

					has been found to be related to decreased visitor attention, which can be seen as an indicator of mindlessness. It is likely that mindfulness and mindlessness are valuable concepts in understanding how visitors respond to interpretation at built heritage sites."				
	Pálsdóttir, and (2021),	1	All SDGs	Sustainable development goals; curriculum; university; higher education; strategy	This research provides an overview of the UN SDGs in the curriculum of the five schools at the University of Iceland and an overview of individual SDGs for the university, to identify the main challenges and opportunities for improvement	Information	Case Study		n.a.	Case studied
	Chaleta ,et al (2021) .	8	All SDGs	higher education; sustainable development; sustainable development goals; undergraduate courses;	Analysis of the mapping of Sustainable Development Goals in the curricular units of the undergraduate courses of the School of Social Sciences at the University of Évora.	Information	Case Study		n.a.	Case study

				social sciences						
	Hernández-Barco, et al (2020).	1,8,13	All SDGs	Service-Learning methodology; environmental sciences; higher education; Sustainable Development Goals; rubric	Analysis of the application of a Service-Learning (SL) methodology in the context of a Final Degree Dissertation (FDD) in the degree in Environmental Sciences at the University of Extremadura (Spain).	Information	Case study		n.a.	Case study

	https://sdgimpactassessmenttool.org/	All SDGs		SDGs, tool	The SDG Impact Assessment Tool is a free, online, learning tool that visualises the results from a self-assessment of how an activity, organisation or innovation affect the SDGs. It aims to stimulate the user to get a better understanding of the complexity of sustainable development and the different aspects of the SDGs.	Self-assessment		Tool to a self-assessment of how an activity, organisation or innovation affect the SDGs.	Simulation
	https://youtu.be/nMXCV2X_mAw	4	11,12,13,15	video	I Seminario Internacional Integrated Teaching in Specific Didactics: Potentialities and Challenges of Transdisciplinary Integration for the Resolution of the Contemporary Social Problems (2021, 8 al 12 de noviembre. Virtual Event) Ángel Alsina Pastells: Integrating mathematical and sustainability competences.	Information	Case study	Lecture	Case study

	https://sdgcompass.org	8	8, 9, 11, 12	SDGs and economy, SDGs and companies	provides guidance for companies on how they can align their strategies as well as measure and manage their contribution to the realization of the SDGs	guideline		guideline, how you can align the SDGs in your strategies	tools, training material	Inventory with filter of Business Indicators and of Business tools - these tools you can discover participating institutions, community commitments, checkpoints and apply them to build your own strategy. Compass guide in your language, which you can use as complete training material, or you can improve by it yours
	www.unfpa.org	All SDGs	1,2,3,4, 5,6, 16	up-to-date data and programme information	to inform and make the people sensitive about the 3th worlds problem. UNFPA is the United Nations sexual and reproductive health agency. Launches and implements programmes collects aid and donation, collects and organises information on the subject in a thematic way	Information	Resources to support case study. E.g., https://www.unfpa.org/resources/unfpa-2020-greenhouse-gas-ghg-inventory-management-plan		Tools	Their topics are: SEXUAL & REPRODUCTIVE HEALTH (Family planning, HIV & AIDS, Maternal health, Midwifery, Obstetric fistula, Sexual & reproductive health) YOUNG PEOPLE (Adolescent pregnancy, Child marriage, Comprehensive sexuality education, Youth leadership & participation) HUMAN RIGHTS & GENDER EQUALITY (Engaging men & boys, Female genital mutilation, Gender-based violence, Gender equality, Human rights, Gender-biased sex selection) POPULATION MATTERS (Ageing, Census, Climate change, Demographic dividend, Migration, Urbanization, Population trends)

	Whalen, et al (2018).	12		serious games, higher education, sustainability	To explore how learning about Circular Economy may be facilitated through the use of a specific serious game		Case study	Tool	Serious board game called "In the Loop". Designed to raise awareness about material criticality and Circular Economy. It is presented in the context of the course, assisted by lecturers and the students have to write a reflexion essay afterwards
Resource Use	De la Torre, et al (2021) .	12	9, 11	Higher education, sustainability	Revision of the main trends and challenges related to teaching circular economy and sustainable energy in higher education degrees, and the role of simulation and serious games as a learning tool.	information	case study	course	Master course of Operational Research (i.e., advanced analytical methods) applied to sustainable transportation systems. Students work in small teams. They have to (i) analyze a complex decision-making challenge, (ii) develop their own methodology and discuss it with instructor; (iii) implement methodology in code and test it against a set of benchmarks; and (iv) analysis of results and obtain insights on the trade-offs between alternative strategies—in terms of the different sustainability criteria being considered.

	Koeppel et al (2007)s	7	This report aims at assessing and comparing the most important policy instruments for achieving energy efficiency improvements and GHG emission reductions in buildings according to their emission reduction effectiveness, cost-effectiveness and lessons learned. The following questions are answered: 1. Which instruments can achieve high energy savings and GHG emission reductions? 2. Which are especially cost-effective? 3. Which factors enable or enhance the effectiveness of these policies?	book, education material		lecture

	Hutton et al (2004)	6	water sanitation, health	The aim of this study was to estimate the economic costs and benefits of a range of selected interventions to improve water and sanitation services, with results presented for 17 WHO sub-regions and at the global level. Interventions evaluated include (1) improvements required to meet the millennium development goals (MDG) for water supply (by halving by 2015 the proportion of those without access to safe drinking water), (2) meet the water MDG plus halving by 2015 the proportion of those without access to adequate sanitation, (3) increasing access to improved water and sanitation for everyone, (4) providing disinfection at point-of-use over and above increasing access to improved water supply and sanitation (5) providing regulated piped water supply in house and sewage connection with partial sewerage for everyone	book, research study	report, you can yous as professional material, and as case studies	The study covered primer resource and provided arrangement, territorial focus on 17 region of WHO. The entire analysis presented in this paper is based on changes in water and sanitation service levels. Second, there are further improvements that make the water or sanitation services safer, or more convenient. Finally, there are high technology improvements such as • Regulated water supply through a household connection, providing water that is safe for drinking. • Household connection to the sewerage system, and at least partial treatment of the sewage. Based on these different improvements, five different interventions are modelled in this study, by assuming a shift between exposure scenarios shown.

	Khalili et al (2015).	4 , 11	sustainable development, CLEANER PRODUCTION , academia	to understand how academic programs including sust development and cleaner production concepts and theories can be advanced	provides theoretical information based on the results of a questionnaire		journal paper	Five options to include academic programs are listed in the questionnaire for the 25 participants to score, as follows: Type I: Provide Exposure to the Basic Knowledge of CP and SD Type II: Include Fundamental of CP and SD Concepts in All Courses Type III: Design of Cleaner Production and Sustainability Graduate Programs Type IV: Develop Concentration/Minor in CP–SD Type V: Promote Research In the Areas of CP and SD
	Education for Sustainable Development. United Nations (2005–2014)	4, 11	education, sustainability, education for sustainable development	policy document, general guidelines. It explains the evolution of ESD over time.	History of ESD: policy documents, asseblies, reports....inclusion of ESD in different countries.	a theoretical document based on the input of policy makers, scholars and practitioners (?)	report available online UNESCO	Very wide and general document. theoretical information, sometimes very general e.g. types of learning. Mentions ESD certifications. Analyses the estate of ESD in different countries. Includes primary, University, vocational. In University education it mentions the increase in research and university networks with sustainable initiatives at management level.

	Thomas,and Hegart (2012)	4, 11	education, sustainability, university	explore education for sustainability in academia	general	none	none		Very general discusses the nature of Universities and curricula, argues the need to adopt practical actions related to sustainability.
	Thomas, (2009)	4, 11	education for sustainability, universities	explore education for sustainability in academia	general	none	none		Concludes that sustainability teaching needs critical thinking, and hence pedagogy needs to transform to make students think critically.
	Ferrer-Balas, et al (2010).	4, 11		It promotes a certain sustainability conference that was held in the past.	general	none	none		sustainability management issues within universities.
	Nowotny, et al (2018).	4, 11	Education. Energy-related textbook and course. Sustainable Energy.	to consider the structure of an education program and the related textbook where the energy-related fundamental and applied subjects are presented in a concentrated and uniform manner.	proposed areas to include in book/course	none	none	It proposes a general curriculum for an education program on sustainable energy systems.	general content: E.g. the so-called proposed curriculum are just headings. E.g. conclusions are general as follows: 'the energy education program involves a range of disciplines, which are remote in concepts and theoretical background. Therefore, the main challenge in the development of energy programs is the need to overcome the traditional conceptual boundaries in order to form a homogeneous education platform'.

	Kirchherr, & Piscicelli (2019)	4, 11	education circular economy,	describes and discusses a course designed to introduce undergraduates to the CE concept.		course content	Seven exercises were developed for the course: a drill game, buzzword bingo, a teardown lab, an eco-industrial park simulation, policy instruments, a circular party and circular futures.	The course was taught over eight modules (90 min each). The first module was intended to ensure that students would understand the guiding principles and aims of the CE concept. The focus of this second module was on eco-design. The third module introduced students to the idea of eco-industrial parks = as a set of businesses that share resources in order to increase profitability and reduce environmental impacts. The fourth module introduced students to the likely macroeconomic impacts of the CE. The fifth module and the sixth module consisted of excursions (e.g. to a global carpet company that produces new carpets by recycling old ones and runs only on renewable energy) For the seventh module, a CE party was organized with different student groups asked to bring circular foods or drinks to this party and to describe and quantify the economic, social, and environmental impact of the circular business model behind these foods or drinks.

	SDG Academy Library (n.d.). [3] /	All SDGs	All SDGs	climate change, SDGs, sustainability, systems thinking	A massive catalogue of online resources dealing with all SDGs.	Information		Catalogue of online videos and MOOCs	Collection of online courses catalogued according to SDG. All material available for educational purposes.
Earth System	SDGAcademy. [4]	13	Relates to other SDGs	Climate change, SDGs, systems thinking, online course	Giving information on: Reducing global greenhouse gas emissions Decarbonizing the economy Emissions reduction in Russia and Australia Actions for communities and individuals	Information		Full course	Links to EdX Mooc which provides a full (10 week) course of 7 modules.

[3] . Https://Sdgacademylibrary.Mediaspace.Kaltura.Com/. Retrieved February 23, 2022, from https://sdgacademylibrary.mediaspace.kaltura.com

[4] (2019, August 19). Climate Action: Solutions for a Changing Planet [Course]. Available from: https://sdgacademylibrary.mediaspace.kaltura.com/category/By+Series%3EC%3EClimate+Action%3A+Solutions+for+a+Changing+Planet/123652111

	Student & Educator Teaching Material EUSTEPs I.[5]	All SDGs	Relates to all SDGs		EUSTEPs takes a 360-degree approach to sustainability, allowing the diverse academic community to understand, realize, and learn the full complexity of the economy-society-environment relationships. It does so by presenting sustainability within the context of everyday life rather than through a mere abstract teaching of intangible theories and concepts.	Information, content	teaching materials, case studies, examples, conference posters, ecological footprint calculators	Requires registration but open content	Tools, course	Full	Modules on SDGs, ecological footprint, sustainability. 12 hour course
	Pires, S et al (2020).	All SDGs	Relates to all SDGs	SDGs, higher education, teaching, ecological footprint	Gives reasons for implementing sustainability training into HEI and an overview of teaching and curricula literature.	Information, literature review				
	Thew, et al (2021)	13		SDG 13, Climate Change, Climate Change Education, COP26, HEI	Mainstreaming climate change education in higher education institutes. Sets out the challenges and solutions to get students to engage in climate change education and transitioning to net-zero.	Information	Working paper	Sets guidelines		

[5] .. https://www.eusteps.eu/resources/student-educator-teaching-material/

	Leal et al (2019)	All SDGs		Sustainability, Higher education, Sustainable development goals, Teaching, Engagement	Presents the current state of sustainability development teaching in higher education institutes and why some institutes are not engaging. Also provides recommendations for incorporating SDGs into teaching programmes.	Gives research about the state of SDG education in HEI			
	Biomimicry toolkit. [6]	15, 14	6, 9, 11, 12, 13, 14, 15	engineering, biomimicry, biodiversity	Provides a toolkit to introduce students to the concepts of biomimicry - to find solutions to technical problems through studying solutions found in nature.	Information	Examples	Guidelines, information and project based learning	Toolkit	Online toolbox can be used in combination with the asknature.com website and further teaching resources from the biomimicry institute
	WBG Academy | World Bank Group.	All SDGs		MOOC, Self paced eLearning, sustainability, climate change	The Open Learning Campus is a collection of MOOCs, webinars and online courses dealing with different aspects of development provided by the World Bank Group.	Content			Courses - self guided learning and MOOCs	Large collection of MOOCs and online courses

[6] https://toolbox.biomimicry.org/

	European Commission, Directorate-General for Environment, (2021)	15	6, 7, 8, 10, 11, 13, 14, 16, 17	European Union, biodiversity, EU Green Deal, EU Recovery Plan	Sets out a strategy of programmes to stop and reduce biodiversity loss in the EU and globally.	Provides information	Strategy, examples and case studies.			
	Oceanwise Innovator Lab.[7]. /	14	2, 12, 13	project-based learning, online task, competition, life below water,	A global project-based competition hosted by Ocean Wise for youth aged 13-30, including university students, student clubs, high school students, youth-led organizations and start-ups. Students are given the task of coming up with innovative material (tiktok video, app, technology to capture ocean plastics) to raise awareness of ocean issues and pollution.	Announces a competition and additional material on the website provides further information on SDG 14		Guidelines, information and project based learning	Competition	Project-based learning to design innovative material

7 Https://Ocean.Org/. https://ocean.org/learn-explore/education/ocean-wise-innovator-lab

Annex II. Courses related to SDGs in place in Trinity College Dublin

Department /School	Module title	Module Code	ECTS	Contents
Engineering	2E7: Engineering and Environment	CEU22E07	5	Environmental measurements and analysis. Environmental chemistry: • Chemistry in the natural environment: • Chemical equilibria: Examples of equilibrium processes: volatilisation, air/water equilibrium, dissolution/precipitation, sorption • Chemical kinetics: rate laws. Biological Processes: • Clean water, Sanitation and Diseases • Carrying capacity: Monod kinetics; Modelling microbial growth • Energy flow in ecosystems: Sources of energy; photosynthesis and primary production. Food chains, food webs, and the energy pyramid • Nutrients and eutrophication in natural waters: trophic state and water quality. Energy demand & Supply: • Energy and environmental impact: greenhouse gases, carbon cycle, climate change • Energy demand – how much do we use? Sectoral usage, electricity, heating • Energy supply - low-carbon generation: wind, wave, tidal, photovoltaic, biofuels, nuclear, solar, geothermal, storage • How much energy use is sustainable? Engineers without Borders (EWB): • Focus on UNSDG of Water and Energy in international development. • Appraising sustainable energy and water technologies for international development projects. • Groupwork to focus on Energy & Water solutions for EWB National competition.

Civil Engineering	3A12: Design Group Project	CE 3A12	10	Sustainable construction, carbon negative materials, LCA, conservation of building energy, calculation of the embodied carbon of structures, EPDs, greenhouse gases in construction.
	C4: Facade Engineering	CE7C04	5	Thermal performance of buildings; occupancy design; facades systems and design; retrofitting; Simplified Building Energy Model system (SBEM).
	C5: Advanced Spatial Analysis Using GIS	CE7C07	5	Spatial analysis; appropriate mathematical methods, numerical techniques and GIS tools for application to new and ill-defined problems.
	E3: Air Pollution	CE7E03	5	Air pollution science - assessment, approaches to AP control (technology and passive), measurement and modelling, EAIR
	E4: Waste Management & Energy Recovery	CEJE04	5	Solid waste and management; energy recovery; processes - solid waste, landfill, thermal treatment, energy recovery
	E6: Water Resource Planning & Climate Change	CE7E06	5	Planning and use of water resources, groundwater protection, Climate dynamics and model projections of future climate scenarios
	E7: Sustainable Water Supply & Sanitation	CE7E07	5	Develop conceptual models to solve water supply and sanitation challenges, infection disease pathways, assessing existing and planning new water scheme infrastructure, compare water supply sources, sustainable resource management throughout water cycle
	J1: Wind Energy	CE7J01	5	Design considerations and economic analysis for wind energy technology; Grid integration and transmission

	J2: Solar Energy Conversion & Applications	CE&J02	5	Variations in diurnal and annual performance of solar energy systems (location, sky conditions, device and application type and load/user behaviour)
	J4: Energy Policy and Building Energy Demand	CE7J04	5	Energy policy; Evaluate of energy projects using economic analysis tools; Building physics and occupancy comfort; LEED / NZEB
	J6: Wave and Hydro Energy	CE&J06	5	Calculate resource and potential output of hydro and wave energy, social and environmental aspect, legislative and economic drivers
	T2: Transport Modelling & Planning	CE7T02	5	Discrete choice models; activity based models; land use planning, public transport planning; transport:emissions interactions
	Civil Engineering & Sustainable Development	DP8018	5	How Civil Engineering contributes to towards the achievement of the Sustainable Development Goals; water supply and sanitation, sustainable transport, health impacts, resilience of structures in response to climate change, policy and technologies relating to renewable energy.
Eng with Mgmt	Supply Chain Management	ME5MM3	5	Supply chain - component, technical and functional aspects of information flow, issues and impacts, tools to quantify, performance analysis (consolidation => best practice), international - sourcing and purchasing
Elec Eng	Deep Learning & its Applications	EE5C16	10	aka AI or Machine Learning, least squares and logistic regression, neural nets
Comp Sci & Stat	Strategic Information Systems	STU45006	10	How existing Strategic Information Systems as well as emerging, disruptive Information Systems can support improved organisational and societal

				performance, design of these systems in order to understand the potential for change
Comp Sci & Stat	Decision Analysis	STU44005	5	Model problems and extract decisions in operations research, optimal route and load, equipment replacement, resource allocation
Comp Sci & Stat	Forecasting	STU33010	5	Define and describe the different time series patterns, propose algorithms and statistical models for analysis, select best forecasting method, interpret output and compute predictions with confidence intervals (ARIMA models, data transformations, seasonality, smothing and performance)
Chemistry	Master in Energy Science		90	Conventional Energy Sources & Technologies Sustainable Energy Sources &Technologies Electric Power Generation & Distribution Managing the Impact of Energy Utilisation Full time over 12 months. Part time over 24 months
Chemistry	Postgraduate Diploma course in Circular Economy and Recycling Technologies	DIP	60	Circular Economy areas including waste management, water and sludge treatment. The course will examine the recycling, reprocessing and remanufacturing processes as well as designs to recover and reuse materials. Waste management, scarcity of resources, minimizing emissions and energy use, while maximizing selective reuse and recycling processes are extremely important for further economic growth, reduction of environmental impacts and to tackle climate disruption.
School Natural Sciences - SNS	Global Environmental Change	BO4105	5	Various elements of current global environmental change, mechanisms and ultimate causes of global environmental change and the extent to which processes operate at different temporal and spatial scales
SNS	Environmental Impact Assessment	ZO4092	5	Initial project screening to the final review, with the emphasis throughout on the role of the natural scientist. Strategic Environmental Assessment

SNS	Plant Conservation and Biodiversity	BO4103	5	Principles of conservation, biodiversity
SNS	Vegetation Description and analysis	BO4109	5	Multivariate analyses to help define vegetation communities, descriptions / measurement / developing hypotheses / remote sensing
SNS	Evolution of plants & plant-atmosphere interaction	BO4110	5	Long-term carbon cycle, changes in climate and atmospheric composition
SNS	Water Technology	ES4020	5	managing the human water cycle from water treatment and supply through wastewater characteristics, treatment and disposal - suitability of the design of treatment plants and unit processes, evaluate process operations and performance
SNS	Environmental Monitoring	ES3040	5	collection and analysis of chemical and biological samples and their application to environmental quality indices, traditional and novel methods being applied in environmental monitoring programs
SNS	Environmental policies		5	critical analysis of environmental policy tools, techniques and outcomes
SNS	Climate Change: Science, Development and Justice		5	Implications on sustainable development of various aspects of climate change, including social, economic, environmental, and moral dimensions... examine the strengths and weaknesses of approaches used to anticipate future climate change and its impacts on society, development, health... adaptation and mitigation

SNS	Master in Smart and Sustainable Cities		70-90	The course comprises 8 compulsory modules, carrying 5 ECTS credits each Dissertation module carrying 30 ECTS credits. 20 ECTS of optional credits Core (compulsory modules) • Urban Governance • Smart Eco-Cities of the Future • Geographical Information Systems (GIS) • Urban Sustainability • Introduction to Machine Learning • Research Method • Fieldtrip • Placement • Dissertation Options (choose 4) • Transportation Policy • Transportation Modelling & Planning • Energy Policy & Building Energy Demand • Urban Computing • Artificial Intelligence • Machine Learning • Environmental Policies • Human Interaction with Biodiversity • Climate Justice, Climate Change & Development
SNS	Master in Development Practice MDP			Blends science and social science. Modules: Global Health • Climate Change: Science, Development & Justice • Research Methods: GIS • Qualitative Research Methods • Globalisation & African Development • Sustainable Agriculture & Land Use • Civil Engineering for Sustainable Development • Theories of Development • Gender & Development • Development Economics • Smart Eco-Cities of the Future • Impact Measurement • MDP Dissertation/Fieldwork Preparation • MDP Global

				Classroom: Foundations of Sustainable Development Practice (optional) One-year full-time or two-year, part-time. Offers professional transdisciplinary graduate degree training that addresses the challenges of sustainable development. The goal is to produce practitioners with an understanding of methods to reduce global poverty.

Annex III. Teaching interests and institutional barriers to integrating teaching materials urban resilience in TU Delft

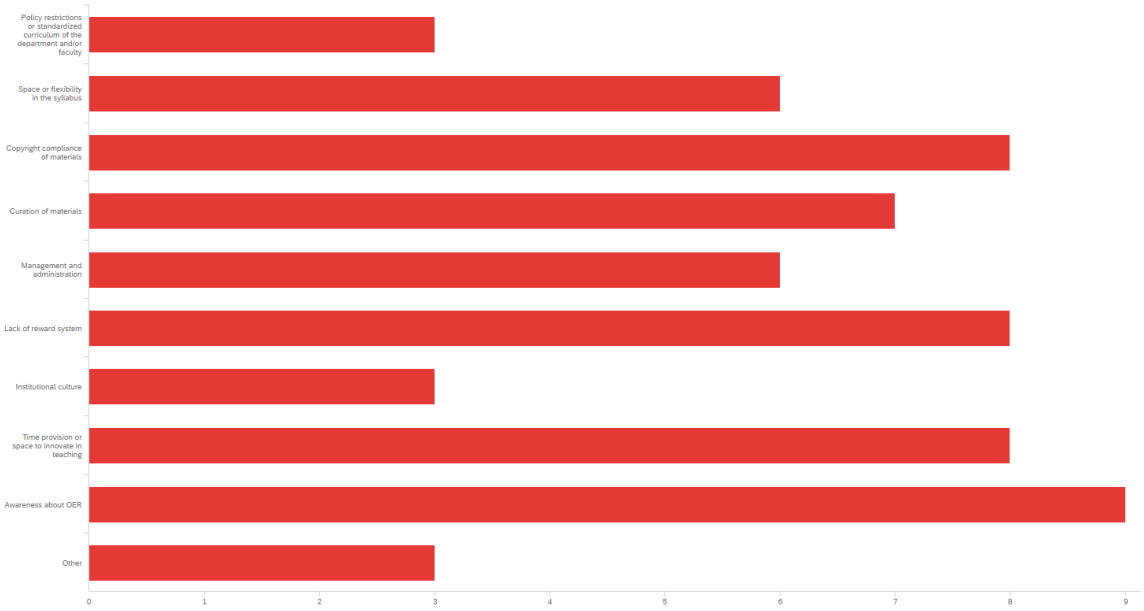

Figure 1 Main institutional barriers preventing the introduction of new materials (OER) in your teaching

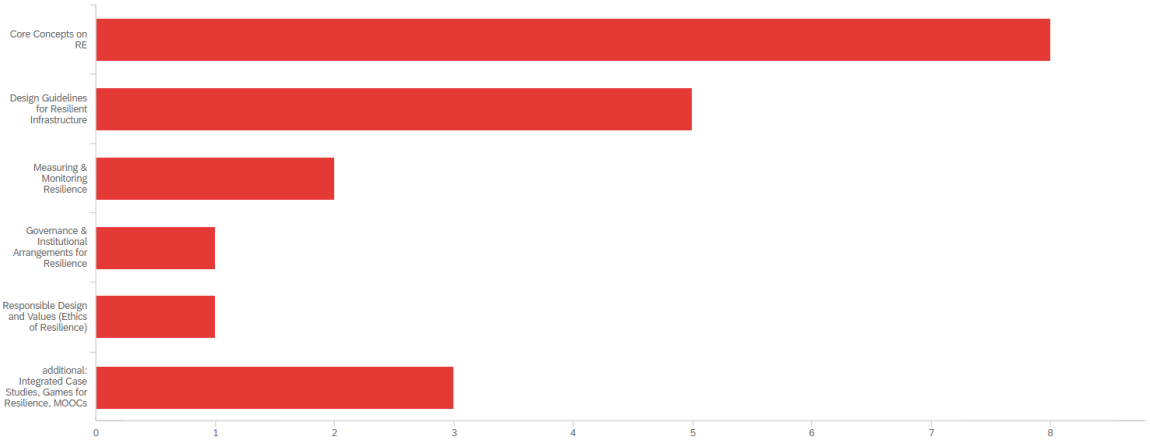

Figure 2 Resilience (societal challenge) domain you would most likely integrate into your teaching

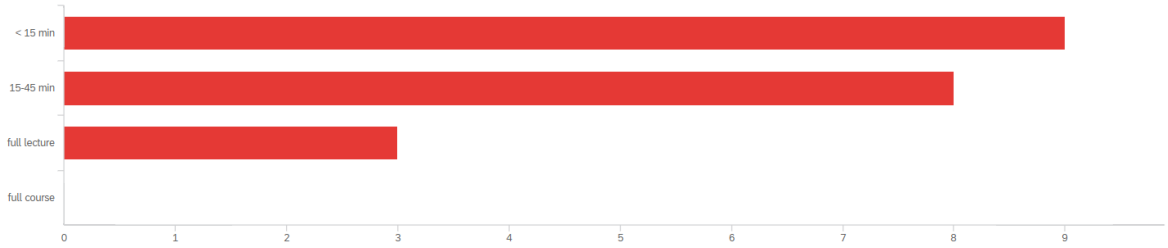

Figure 3 How much time would you typically use a grand challenge topic in your course?

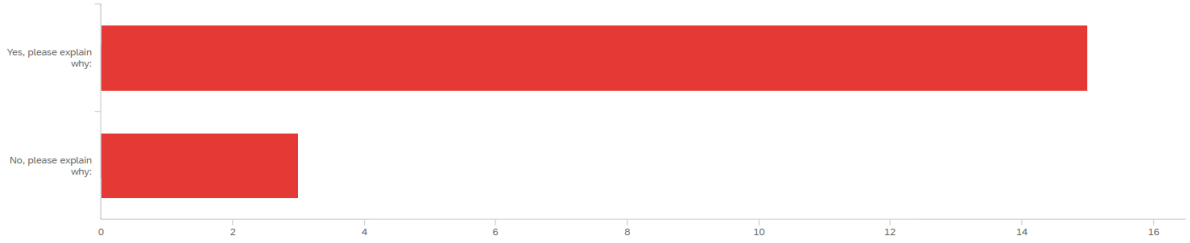

Figure 4 I would recommend using open access materials on grand challenges in education programs to course coordinators in my faculty or department

Annex IV. Survey of the teaching staff at the University of Pécs about introducing SDGs into the teaching curriculum

At present, 145 lecturers are employed at the three institutes of the Faculty of Engineering and Information Technology. These institutes are the Institute of Architecture, Institute of Information and Electrical Technology, and Institute of Smart Technology and Engineering, and in addition, there is the Centre for Foreign Languages for Technical Purposes. The representation of the institutes in the questionnaire is nearly identical. Out of 46 teachers at the Architectural Institute of Architecture, nine individuals (20%) responded, out of 31 teachers at the Institute of Computer Science and Electrical Engineering four individuals (13%) responded, out of 64 teachers at the Institute of Engineering and Smart Technologies 14 individuals (22%) responded, and out of four teachers at the Centre for Foreign Languages three individuals (75%) responded.

In the first question (Figure 1), we asked which field(s) the colleagues teach in, and in the second question, whether they participate in teaching courses in English. A total of 28 instructors responded, and the subjects they teach cover all the 22 education programs (not including postgraduate certificate programs) offered by the faculty, ranging from vocational training to BSc, BA, MSc, MA, and doctoral programs.

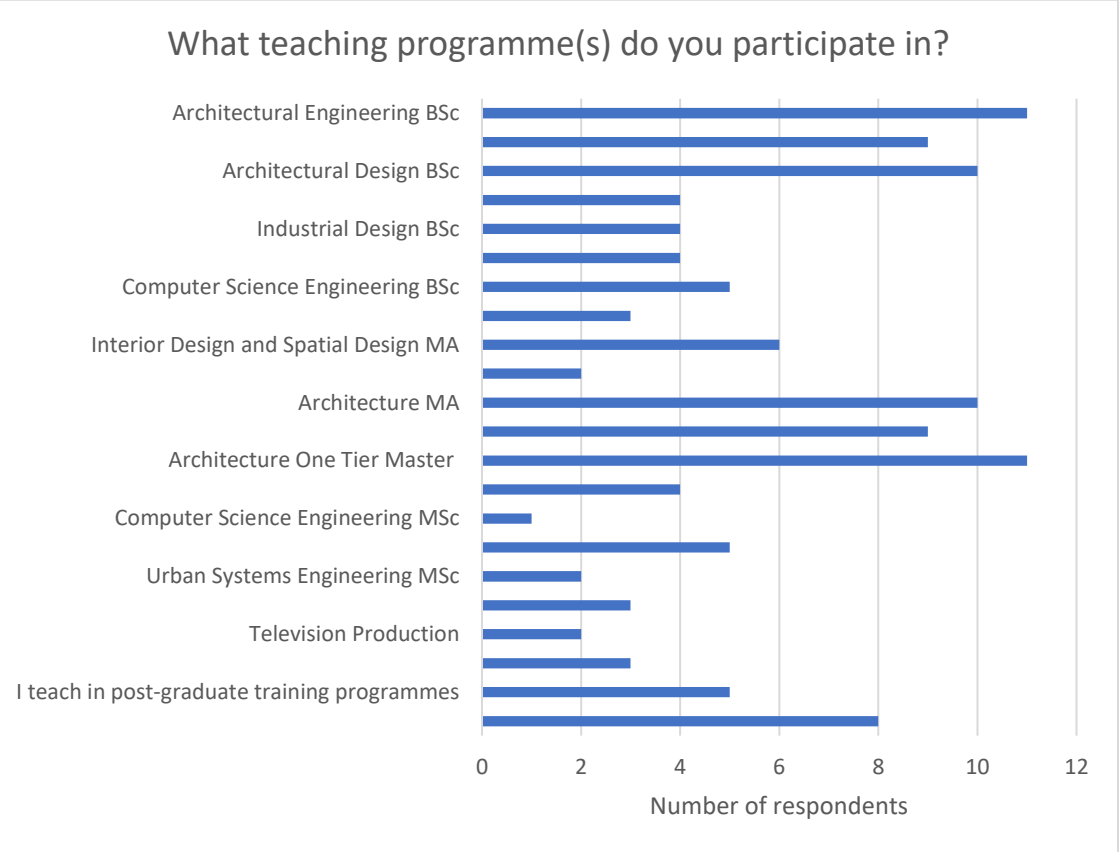

Figure 1 Teaching program participation.

On average, instructors participate in four different programs. There is one instructor who is present in all the programs and also participates in teaching foreign language courses. This instructor is crucial for our topic because of his commitment to sustainable development as an environmental engineer.

Typically, instructors in architecture have more diverse fields, mainly due to the variety of architecture programs. Out of the 22 programs, seven are architecture programs, and this is also the main focus of the doctoral school. However, most respondents are present in only one program, and the same number of instructors teach in less than four programs as in more than four programs. Out of the 28 respondents, 20 instructors participate in teaching foreign language courses compared to eight who do not.

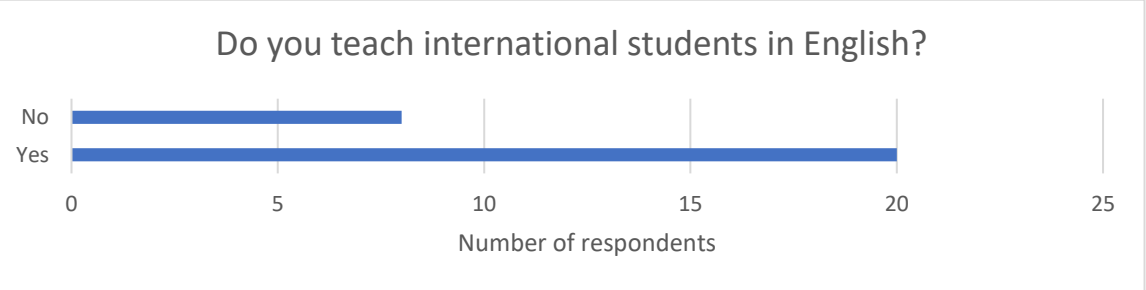

Figure 2 Teachers who teach international students.

In the third question, we asked: "Which of the following SDGs are relevant to your courses? (Multiple answers are possible)" Unfortunately, due to a technical issue, the 2nd SDG (Zero Hunger) did not appear in the options, so the colleagues evaluated 16 SDGs (Figure 3).

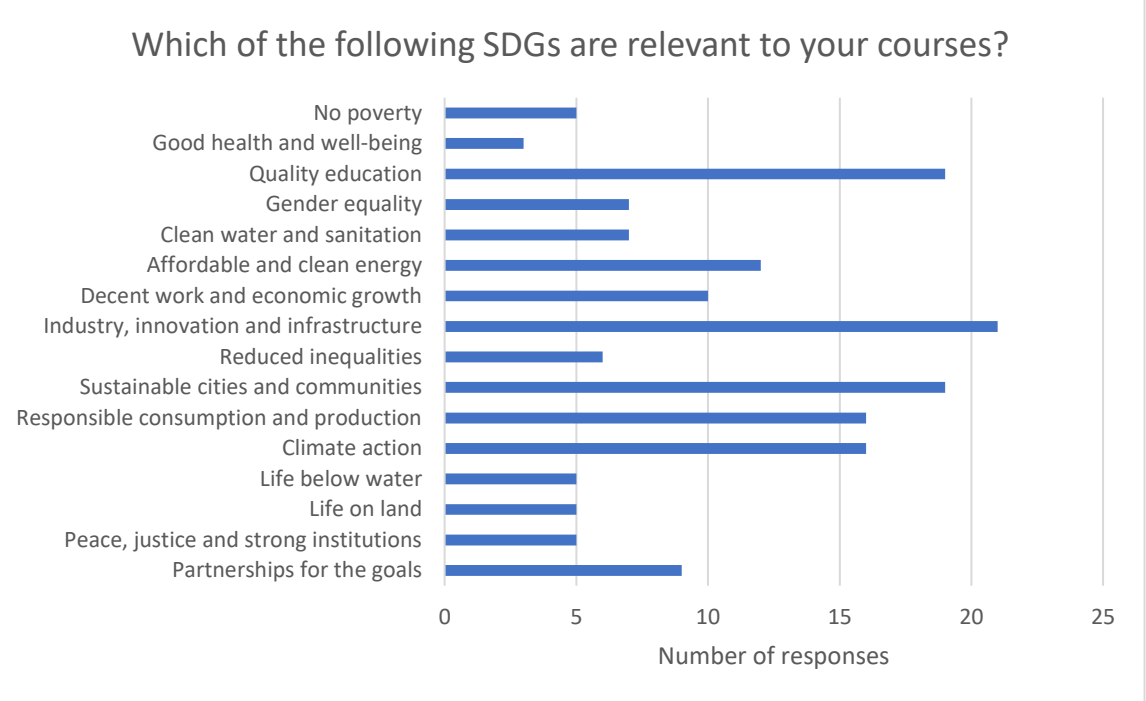

Figure 3 Relevance of SDGs in your courses.

According to the results, the lecturers marked an average of six out of the 16 sustainable development goals (SDGs) that they felt were related to their courses. Two lecturers marked all 16 goals as relevant to their courses. The SDGs that were most frequently mentioned as related to the courses were industry, innovation, and infrastructure

(mentioned 21 times), quality education (mentioned 19 times), and sustainable cities and communities (mentioned 19 times). The goals of decent work and economic growth, as well as responsible consumption and production, were also prominently mentioned, each receiving 16 mentions. The goal of poverty received the fewest mentions, only three. Gender equality was mentioned seven times, and the data shows that it was more frequently mentioned by female lecturers. However, it is concerning that the SDG of partnerships for the goals received very little attention, with only 9 out of 28 lecturers marking it as relevant to their courses in their responses.

The fourth and fifth questions related to the extent that teachers have already introduced SDGs to their teaching. A total of 11 respondents have introduced sustainability into their courses, 12 have just started doing so, and five say they have not started at all yet (Figure 4).

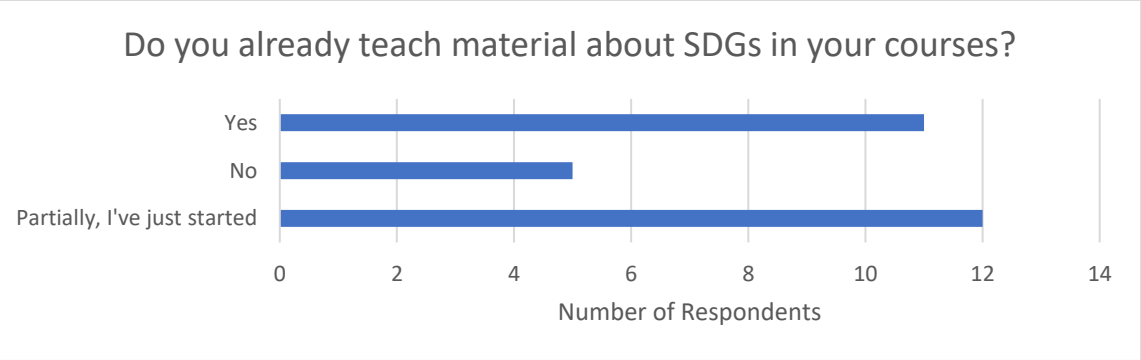

Figure 4 Adoption of teaching SDGs currently.

Regarding whether colleagues in your department incorporate sustainability goals into their teaching, opinions are divided (Figure 5). Three of them believe that this is already a common practice, two of whom are environmental engineers and one is an architect. Fifteen others phrase their response more cautiously, stating that the integration of SDGs into teaching has begun, but it is not yet widespread practice. One computer science teacher, according to the questionnaire, not surprisingly claims that SDG education is not incorporated into the curriculum at all, and nine others responded with "I don't know," essentially abstaining from expressing their opinion.

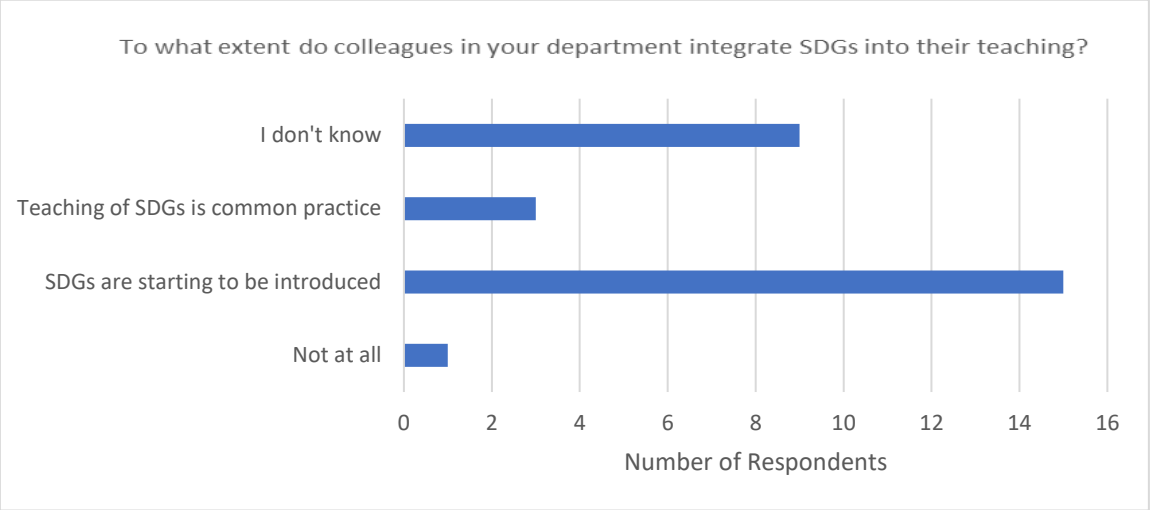

Figure 5 Teaching of SDGs in the department.

Question six looked at the obstacles to incorporating sustainability topics into education (Figure 6). This question needed to be evaluated from several aspects, weighing the possible obstacles. According to the respondents, it is not the strictly regulated compulsory course material or that it might distract from other concepts which is the main obstacle to better integration of SDGs into courses (these received low ratings in average, mode, and median), but rather the lack of financial support or recognition, which is generally considered a significant obstacle (with an average rating of three). All other aspects, including external materials, especially the accessibility and integration of Hungarian-language external materials into their own courses, are generally seen as problems with a rating of three on a scale of 1-5, defined as slightly stronger than average.

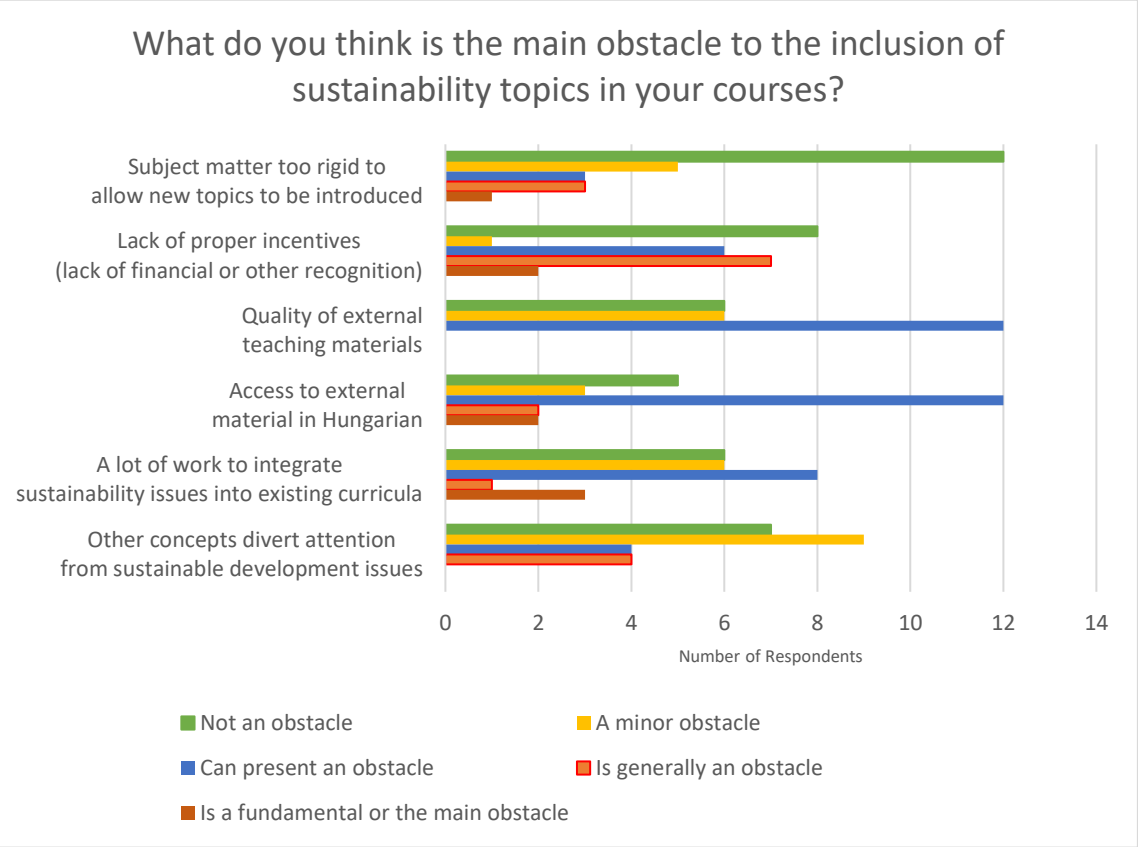

Figure 6 Obstacles to introducing SDGs into teaching.

Question seven asked respondents to note the biggest problem they face when using educational materials, textbooks, or lecture materials developed by others (Figure 7). According to the answers given to this question, it turns out that the biggest obstacle is the alignment with their own curriculum. To a lesser extent, but generally, it is also an obstacle to ensuring the quality of material and finding the most suitable one. Generally, it is considered a very minor obstacle or none at all when it comes to editing and technically adapting other material.

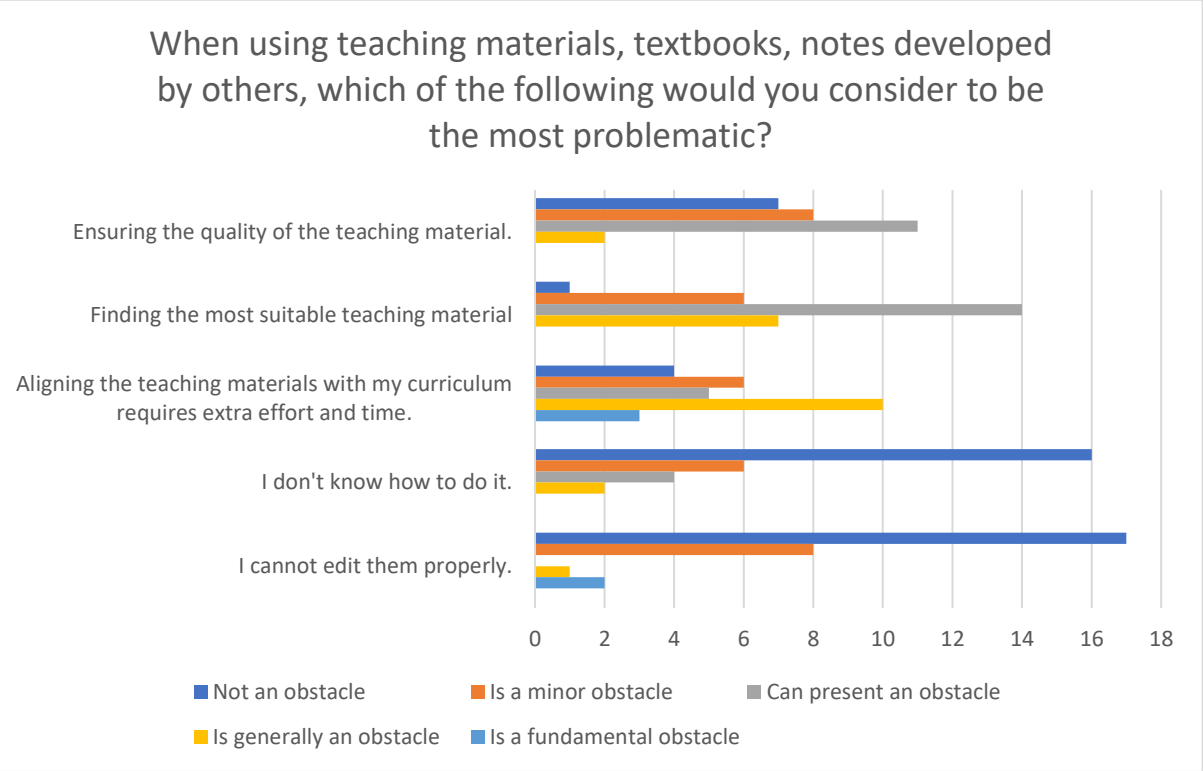

Figure 7 Perceived problems faced when using material developed by others.

If thinking about sustainability is introduced early (in undergraduate studies), it can have a significant impact on engineering sciences – the majority of respondents consider this to be of fundamental importance (this was the most commonly mentioned aspect, but even considering the average of the responses, we must consider it as a significant factor). The unanimous opinion of the teachers is that progression and differentiation are significant factors, and it is also a fact that open-access teaching materials increase the circle of participating teachers.

Question eight dealt with what teachers thought contributed to the inclusion of sustainability topics in the curriculum and educational materials (Figure 8). The unanimous opinion of the teachers is that open access to resources and background materials would fundamentally promote interdisciplinarity, and therefore this is the most essential factor.

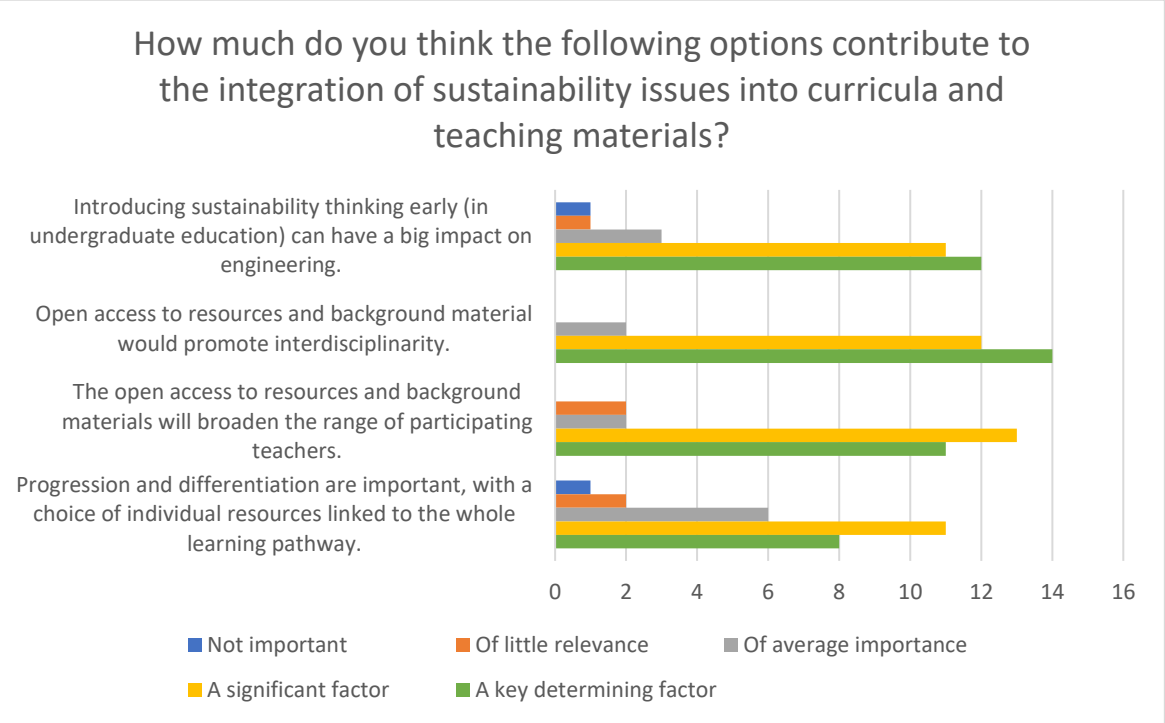

Figure 8 What contributes to the integration of sustainability in curriculum and teaching materials?

Question nine asked whether the institution where they teach recognizes their efforts to improve course materials (Figure 9). Eleven people answered this question with a clear "yes," four with a "no," and 12 consider the recognition of their efforts to improve the curriculum by the institution to be variable, feeling that sometimes it is acknowledged, and sometimes it is not. One person says that they are not affected.

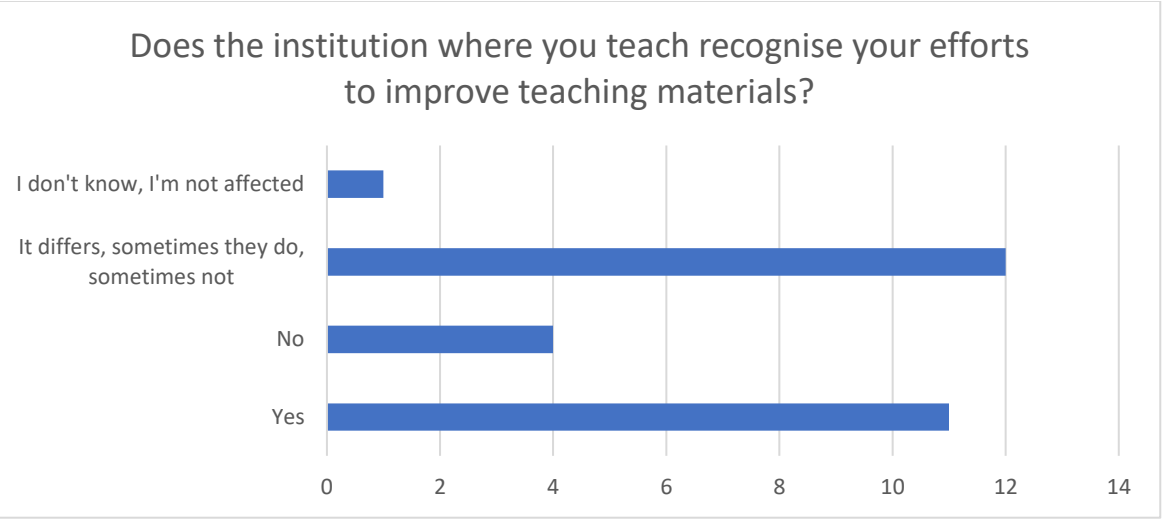

Figure 9 Recognition of developed materials by the institute.

Question ten asked how much time teachers could devote to sustainability issues within a course. Four instructors mentioned that they could only touch on the topic briefly, with 4-5 slides, while 9 instructors said they could dedicate 1-2 hours at most to sustainability within a course (Figure 10). Nine instructors said they could spend several hours on the topic throughout the semester, and it is known that sustainability is strongly related to the courses and programs they teach. Six instructors suggested that a separate sustainability course should be offered, and they come from various fields, so this statement is not specific to any particular discipline.

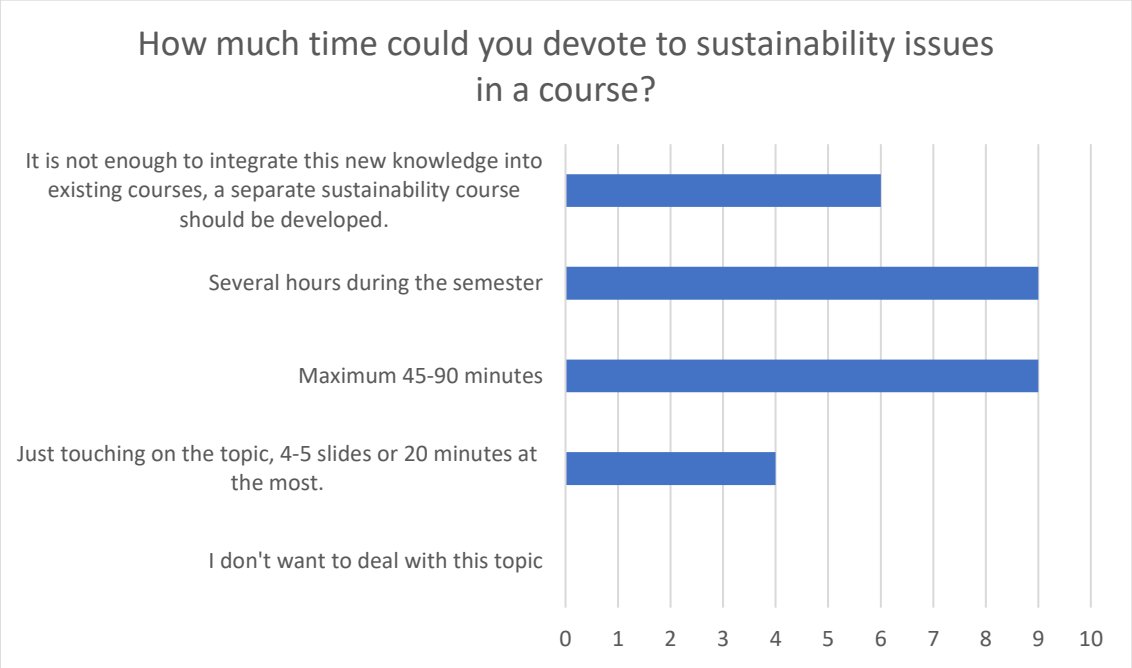

Figure 10 Allowance of time devoted to sustainability in a course.

Question eleven asked who should be most interested in promoting the teaching of sustainability in education (instructors, program coordinators, department heads, etc. (Figure 11). The answer to this question was that everyone, including the faculty leadership, program coordinators, instructors, course directors, and students, should be interested in promoting the teaching of sustainability in education.

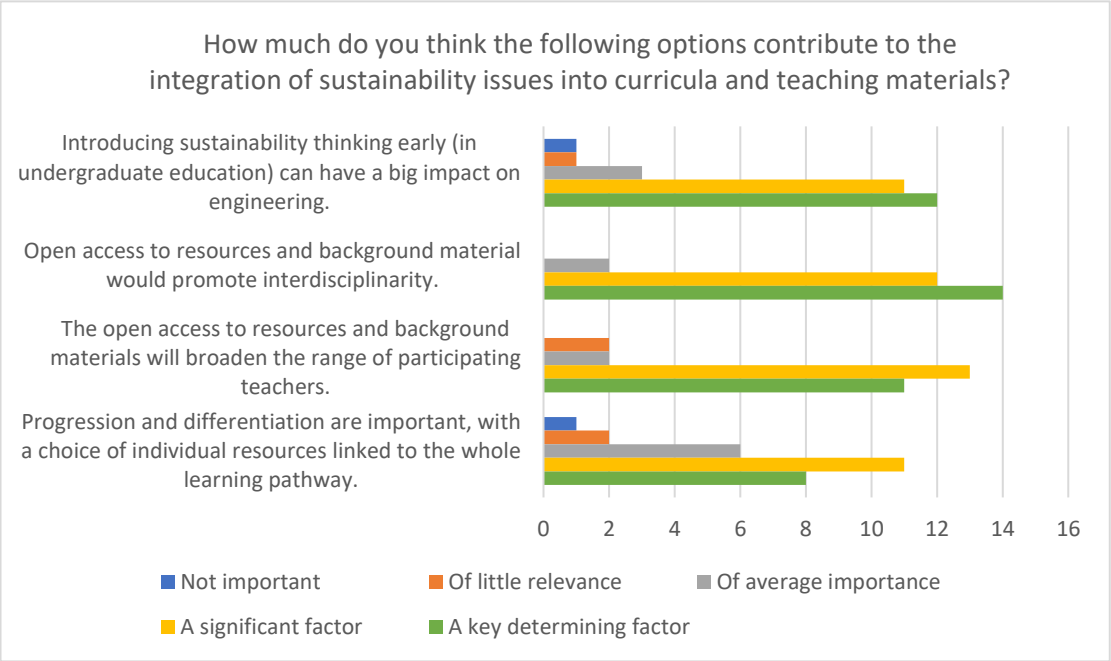

Figure 11

Factors influencing the integration of SDGs into teaching.

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Joint development of **in**novative blended learning in STEM curricula based on SDGs for a resilient, inclusive and sustainable education

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