Project Report 1

The Global View on Skills Needed for Sustainability

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Project title note:

PROFESS 12 is the acronym for “PROFessional skills for Engineering students - Summer School to achieve SDG 12”. The project aims to develop Professional Skills in Engineering Students through an innovative and inclusive Summer School designed to equip students with the intercultural skills necessary to meet the SDGs.

Contents

Executive Summary

Engineers of the future must be technical experts, able to solve problems in an integrated way, a systems thinker, a holistic thinker, a critical thinker, someone who can work with diverse people in multidisciplinary teams. Excellent communication skills and being able to work across cultural boundaries are key components of the engineers toolbox. They must also have a good ethical conscience, grit, adaptability and the ability to challenge the status quo. Finally, the engineer of the future must have sustainability-friendly attitudes and values and a focus on social responsibility so that they can do their part to achieve the SDGs. They will need to understand the impacts of their innovations not only on the environment or the economic bottom line, but upon society in general.

This report outlines the seminal literature on the global view of skills needed for sustainability. It describes key findings from research undertaken to determine what skills engineering graduates will need to help achieve sustainable development in the form of key sustainability competences. It also describes some of the European and National policies which inform education for sustainable development.

Accrediting body requirements are highlighted to show the focus on sustainability competences for engineering education. The final study presented looked at engineers specifically, from the viewpoints of academics, students and employers and lists a nuanced view of competences for engineers in order to solve the SDGs in particular.

Summary of Overall Research Project

The main purpose of the PROFESS 12 (PROFessional skills for Engineering students - Summer School to achieve SDG 12) project is to build on the global research on skills requirements, to translate them to an Ireland-specific framework and to then design, trial and evaluate an innovative and inclusive Summer School to provide students with opportunities to develop these skills. The UNESCO (2017) framework, the Guidelines for the Design of Inclusive Engineering Programmes (Mills, Ayre and Gill, 2010) and the use of the "The Intercultural learning for Pupils and Teachers Toolbox" (http://intercultural-learning.eu/) will inspire the design of the School, which will be co-created with students from North and South with a focus on solutions for SDG 12 (Responsible Consumption and Production).

The project has ***four objectives***:

- To identify and rank in order of importance, the professional skills that engineers will need to meet the SDG goals and Government commitments to 2030.
- To compare and contrast stakeholder views on the importance of specific professional skills so that we may learn from each other through our diverse experiences and gender differences.
- To co-create and test an innovative and inclusive Summer School to help students develop the skills necessary to meet SDG 12.
- To better understand each other's cultural backgrounds and to build mutually beneficial sustainable relationships that capitalise on the intercultural synergies between researchers, academics and students, North and South.

The project consortium has two academic partners (TU Dublin and Ulster University) and the objectives will be achieved through several work packages which are summarised in Figure 1 along with the Project Outputs.

Work Package 1: Literature Review and Professional Skills Survey

First, the research will identify engineering students, academics and employer's perceptions of the professional skills that engineers North and South need to meet the SDGs (WP1). Focusing on the seminal work of Wiek et al., (2011) and UNESCO (2017) coupled with the previous work completed by the project partners in the A-STEP 2030 project, we will review the relevant literature and distil the findings to compile a list of professional skills requirements. We will be mindful of selecting literature from both genders to ensure an unbiased view. We will use this list to create a survey to gather the views of the key stakeholders (employers, academics and students) in engineering education (North and South) to help us to identify and rank the key skills required.

Work Package 2: Key stakeholder perceptions on priority skills

WP 1 sets the scene for skills requirements on a global scale: WP2 turns our focus to the Island of Ireland. Using the results of the survey, we will compare and contrast stakeholder views based on the local context North and South, the discipline and stakeholder view and also the gender specific perception (WP2). The ***key aim of this Work Package*** is to learn from each other, hence a detailed analysis of the survey differentiated by key perspectives will help us better understand the perceptions of each group.

Work Package 3: The PROFESS Summer School

WP3 will run in parallel with WP2 to meet the key milestones of the project and involves the design and trial of the PROFESS 12 Summer School. Based on the skills identified in WP1 and WP2, we will initially create a Briefing Document for the Summer School (R3 in M11).

The design of the PROFESS 12 Summer School will ***be co-created with engineering students*** from both Universities in two separate Multiplier Events (ME1 and ME2) in M13. We foresee these as a think tank where students will be encouraged to be creative and outrageous in their ideas surrounding the design of the Summer School.

The Summer School will take place ***physically over five days*** with a kick off session (in the border region, meeting half way) on 4th March 2023, to coincide with the World Engineering Day for Sustainable Development (Milestone). Students will undertake icebreaker activities, be introduced to the concepts of gender inclusivity, the SDGs, UDL, unconscious bias and the value in developing intercultural skills. We will then spend two days in the North and two days in the South and in addition to student centred classroom activities, we will include cultural trips and activities to help the students integrate.

Work Package 4: Evaluation of the PROFESS Summer School

Finally, the impact of engaging students, researchers and academics in this Summer School will be evaluated in WP4. The evaluation has three aims. Firstly, through both qualitative (discussions) and quantitative measurements the effectiveness of the Summer School from the students' perspective can be assessed. Secondly, students will be asked to reflect on their experiences and to provide feed forward advice for the next iteration of the project on a European scale.

Thirdly, we also wish to acknowledge and reflect on the importance of an all-Ireland project such as this, as a way to help collaboration between researchers, academics and HEIs, North and South. Hence we will also investigate how effective the project was in enhancing relationships between researchers and academics and the HEIs involved through the use of a focus group between the researchers involved.

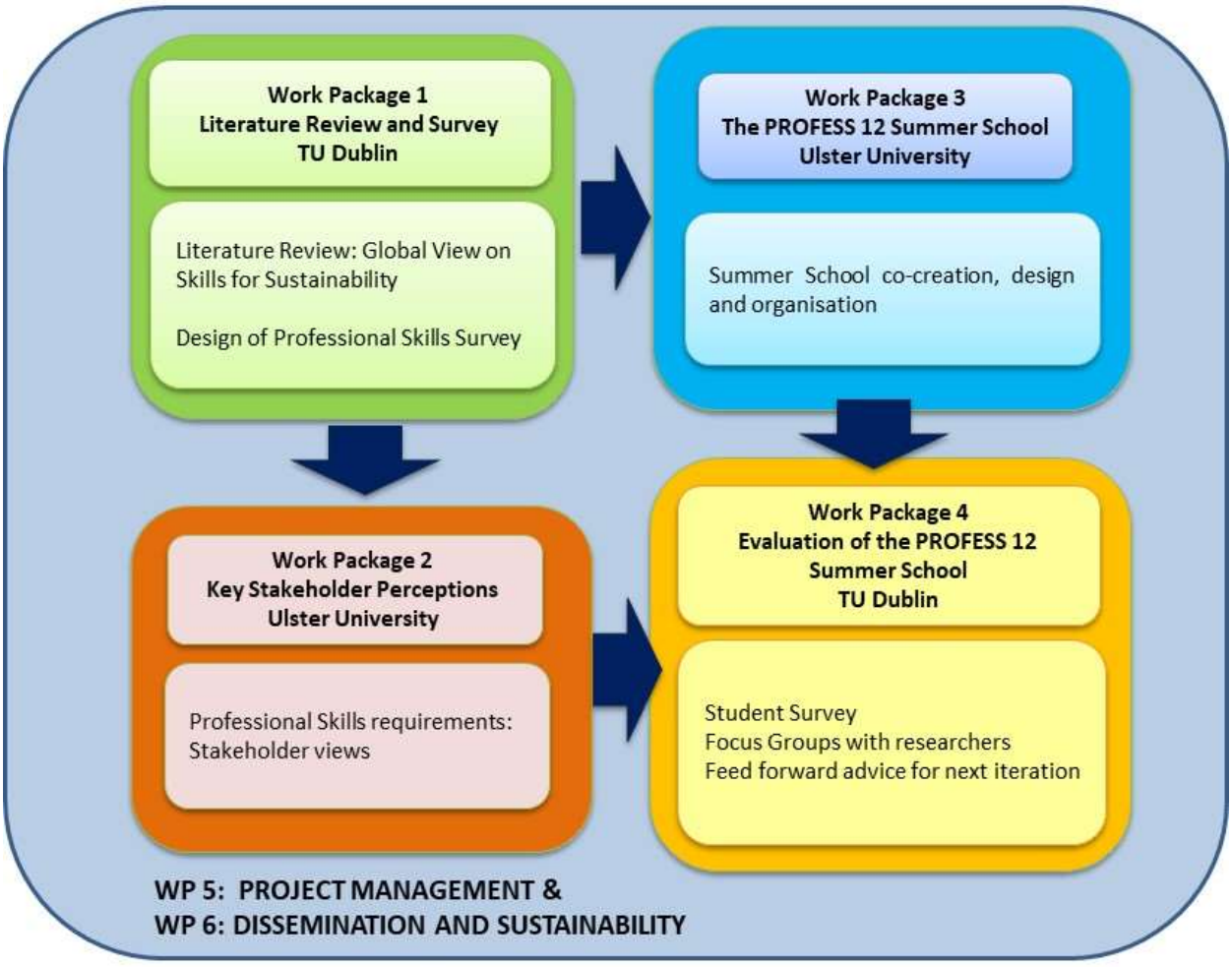

Figure 1: Work packages and Project Outputs in PROFESS 12

In addition to specific outputs from work packages, we also hope to achieve some additional outcomes such as an improved cultural awareness, better understanding of skills requirements in engineering, implementation of innovative teaching practices, promotion of co-creation of curriculum elements and a better appreciation for the role of gender in research planning, data collection, analysis and dissemination.

Research Questions

The purpose of this literature review report is to briefly synthesize the literature in relation to the skills that engineers need in the future. Focusing on the seminal work of Wiek et al., (2011) and UNESCO (2017) which reference skills needed for sustainability generally, coupled with the previous work completed by the project partners in the A-STEP 2030 project, this report synthesizes the professional skills requirements and specifically skills for sustainability to be used in Work Package 2.

The main research question associated with this activity was:

1. What are the key skills identified in the literature that engineers will need to help support a sustainable future?

Literature Review

In recent decades, engineering educators have witnessed an increasing demand to include sustainable development concepts in engineering programmes with a view to improving the skills and competencies of the engineers we educate and train. The complex challenges facing our society as a result of climate change, pollution, loss of biodiversity and increasing population can only be addressed with a diverse team of professionals working together to provide multiple perspectives to solve the most challenging, complex and often termed 'wicked' problems (Lönngren, 2015; Guerra, 2017). Engineers are key drivers of future innovation but have in the past been accused of being technologically focussed without reference to the needs of society: forgetting the human dimension within the problem (Miller, 2015).

Yet the role of the engineer is changing from a focus on fundamental technical skills to more wide ranging tool box of competencies that will be required in order to solve these future challenges (Tabas et al., 2019) and there have been calls for reform of Engineering Education which have aimed at ensuring that current students are equipped with the relevant skills to meet future societal challenges (UNESCO, 2010; ASEE, 2013; Wulf, 2008; Miller, 2015). The framework of the Sustainable Development Goals (SDGs) issued by the United Nations (UN, 2015) allows us to focus our curriculum on the requirements for a sustainable world and this literature review provides a snapshot of key literature in relation to skills requirements for engineers of the future.

The most common definition of sustainable development comes from the 1987 publication of the World Commission on Environment and Development, or more commonly known as the Bruntland Report and is development that: "meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p.39). Sustainable Development was originally considered to have three pillars: environment, economic, social (Lozano, 2008, GoI, 2022) although this has later been supplemented by additional pillars of governance and culture (Cohen, 2017). These pillar models make the point that sustainable development cannot be achieved by considering only one component (such as saving our environment) but that a collaborative model with many people working together considering different perspectives is a requirement.

The UN have also taken a lead in orientating educators towards teaching for sustainable development and Education for Sustainable Development (ESD) can be defined as initiatives which encourage "changes in knowledge, skills, values and attitudes to enable a more sustainable and just society for all" (UNESCO 2018, p. 7). The recent publication Education for Sustainable Development Goals: Learning Objectives (UNESCO, 2017) calls for a transformation of the way we think and act and a call for new skills, values and attitudes to lead to more sustainable societies. They attest that education systems must therefore respond by introducing appropriate pedagogies and relevant learning objectives to empower learners to meet these needs. Specific learning objectives, topics to be covered and implementation methods are all proposed and aligned to specific SDGs (UNESCO, 2017). This European directive has also filtered down to a national level with a second edition of the Government of Ireland publication "ESD to 2030: Second National Strategy on Education for Sustainable Development" being published in 2022 (GoI, 2022). This document sets out five priority actions for Ireland including; advancing policy, transforming learning environments, building capacities of educators, empowering and mobilizing young people and accelerating local level actions (GoI, 2022).

ESD can further be refined into Engineering Education for Sustainable Development and the Barcelona Declaration was a call for higher education institutions to review their education system, to create a holistic education experience which would produce a different engineer, one whom can deal with broad and complex issues whilst using systemic thinking and considering ethics in their daily practice (EESD, 2004; Fenner & Morgan, 2021). The Barcelona Declaration specifically calls out the skills needed by engineers: to understand how engineering interacts with society on a local and global stage, to appreciate how their work contributes culturally, socially and politically, to work in multidisciplinary teams, to apply holistic and systemic approaches to problem solving, to listen to the demands of key stakeholders and to participate actively in discussion to help redirect society to more sustainable development and finally to do all of this whilst considering universal values and ethics (EESD, 2004). The declaration was updated by the EESD community in 2021 to include six further themes to be considered including; values (committing to achieve SDGs), context (real world constraints), uncertainty (flexibility and adaptation), change (Challenge orthodoxy and innovate), limits (consider planetary health and societal well being) and vision (anticipatory thinking) (Fenner & Morgan, 2021).

At a national level, many accrediting bodies have included sustainable development competencies within their accreditation criteria. Many countries align with the International Engineering Alliance Graduate Attributes and Professional Competencies agreement which sets out the graduate attributes and professional competency profiles for three professional tracks: engineer, engineering technologist and engineering technician (IEA, 2013). Engineers Ireland is the accrediting body for engineering programmes in Ireland and has recently updated it accreditation criteria for the Bachelor Degree in engineering to reflect best practice in sustainability education. Seven Programme Areas (PA), define what students should learn, understand or appreciate as a result of their studies. The first three PAs could be considered of a technical nature or the core of engineering: knowledge of mathematics and sciences, discipline specific technology, software and information systems. The fourth PA covers creativity and innovation

and the final three PAs acknowledge some of the more non-technical skills required of engineers; engineering practice, societal and business context and finally sustainability (Engineers Ireland, 2021). The focus of one full Programme Area on sustainability highlights the critical nature that engineers play in delivering on sustainable development and the SDGs both nationally and internationally. The criteria highlights five key competences required to achieve this aim; critical thinking and reflection, envisioning, systemic thinking, building partnerships and participation in decision making (Engineers Ireland, 2021).

The Engineering Council in the UK have also recently updated their accreditation criteria (fourth edition) to include more of a focus on inclusive design and innovation, sustainability and ethics and equality, diversity and inclusion (EDI) (AHEP, 2020). They specify six broad areas of learning outcomes for Bachelor of Engineering Programmes; Science and Mathematics, Engineering Analysis, Design and Innovation, The Engineer and Society and Engineering Practice. Under sustainability, engineering students are required to "Evaluate the environmental and societal impact of solutions to complex problems and minimise adverse impacts."(AHEP, 2020, p.35).

It is clear therefore that at European policy level there is an acknowledgement and a focus on preparing graduates with the skills needed to achieve sustainable development. Furthermore, at a national level there is an emphasis in creating learning environments with sufficient supports to transform our learning environments into places where well trained educators can empower young people to think strategically, ethically and with a global view (GoI, 2022).

Returning to published literature studies, it is important first of all to acknowledge some of the seminal studies which specifically look at sustainability competences in generic fields. Perhaps the most well known study is Wiek et al., (2011) who offers a literature review of selected peer-reviewed publications from which they deduce five key competence domains. These include: systems thinking abilities, anticipatory competence (futures thinking), normative competence (values thinking), strategic competence and interpersonal competence. Rieckmann (2012) built on this work and through a Delphi study determined that two additional competences were needed: critical thinking and integrated problem solving. This was further supported by Wiek et al. (2016) who also added integrated problem solving to the initial list. It is important to recognize however that in the context of sustainability, skills or competences mean little without the proper attitudes and values to support them. Segalas et al., (2009) for example, suggests that skills and abilities need to be coupled with attitudes, knowledge, and understanding, with an attitude being defined as "a complex mental state involving beliefs, feelings, values and dispositions to act in certain ways." (Segalas et al., 2009, p.18).

In a similar project, Brundiers et al., (2010) grouped the key sustainability competences into three clusters. The first is a strategic knowledge cluster which includes anticipatory, normative and action-orientated competencies. The second, a practical knowledge cluster includes skills necessary for linking knowledge and action, while the third, the collaborative cluster, focuses on working with people. Brundiers went on to describe eight key competences for sustainability in a more recent study in 2020; systems thinking, future thinking, values thinking, strategic thinking, interpersonal thinking, integrated problem solving, implementation and intrapersonal or self-awareness (Brundiers et al., 2020)

Bianchi (2020) describes “Key competences“ as groups of competences that are closely related to each other and summarises the key sustainability competences from a wide-ranging literature review from 2010-2020. What emerges is an ongoing growth of the range of competences required to achieve sustainable development, which incorporates ways of thinking, global orientation, collaboration with others, integrated problem solving and personal attributes including ethical orientation.

The seminal papers which discuss competences for sustainability do so without regard to discipline and many of competences are indeed generic to all graduates of current universities. The most recent study which focusses specifically on competences for engineers and specifically in relation to achieving the SDGs (rather than sustainable development more generally) was carried out as part of an Erasmus + project entitled “A-STEP 2030 – Attracting Diverse Talent to the Engineering Professions of 2030” (www.astep20320.eu).

The study included focus groups with engineering academics, engineering students and engineering employers in four countries in Europe (Ireland, Finland, France and Denmark) and sought to answer the question: What do key stakeholders of engineering education perceive are the competences that engineers need to support the SDGs? (Beagon et al., 2022). The focus groups encouraged discussion amongst participants to reveal each stakeholders’ views on the required competences, without reference to any of the seminal literature noted above. All competence suggestions were collected and the data was analysed using an open coding exercise, to determine the desired list of competences that engineers need. This resulted in a typology of competences and identified six categories which were determined to be; (1) Fundamental Technical Skills, (2) Application Skills, (3) Outward Facing - People Orientated Skills, (4) Inward Facing - Ways of Thinking, (5) World View and Character and (6) Ethical Orientation. These were further classified under three main categories of Technical, Non-Technical and Attitudes (Beagon et al., 2022). The full list of 54 skills and their relevant categories is included in Appendix A and to our knowledge this is the only study which specifically looks at competences for engineers in relation to solving the SDGs.

Conclusions

The literature review highlights that almost none of the papers reviewed list the exact same skills. Upon reflection this should be unsurprising: achieving sustainable development will require a highly diverse range of skills as sustainability is a complex, multifaceted and “wicked” problem. Overall, the picture that emerges from the literature suggests that the role of the engineer in the future will be broader than at present with entanglement in social, environmental and global issues.

According to the literature, the engineer must be a technical expert able to solve problems in an integrated way, a systems thinker, a holistic thinker, a critical thinker, someone who can work with diverse people in multidisciplinary teams. Working across cultures and excellent communication skills are key components of the engineers toolbox. At the core they must have good ethical conscience, grit, adaptability and the ability to challenge the status quo. Finally, the engineer of the future must not only have technical and non-technical skills such as those described above but have sustainability-friendly attitudes and values and a focus on social responsibility so that they can do their part to achieve the SDGs.

They will need to understand the impacts of their innovations not only on the environment nor the economic bottom line, but upon society in general.

Engineers are key drivers in our move towards a sustainable world. Better understanding what is needed from them can help reform engineering education so that tomorrow's engineer will be better prepared, both in technical and human terms, to make sustainable development a reality.

Appendix A

Table 1: Focus group outcomes of competences needed for engineers to support the SDGs (from Beagon et al., 2022).

Technical		Non-Technical		Attitudes	
Fundamental Technical Skills	Application Skills	Outward Facing - People Orientated Skills	Inward Facing - Ways of Thinking	World view	Character and Ethical Orientation
Mathematics Skills Digital Skills Economic Skills Research Skills Technical Skills	Multidisciplinary Skills Problem Solving Design Skills Interpretation Skills Conceptual understanding Resources optimisation Innovation Entrepreneurship Decision Making Skills Learning to Learn Project Management Organisation Skills Problematisation	Inter Cultural Skills Collaboration Leadership Conflict Management Negotiation Communication* Foreign Languages Listening Respecting Diversity Teamwork	Critical Thinking Life cycle thinking Holistic Thinking Systems thinking Creativity Analytical Thinking Stress Management Time Management Self-Reflection Multi-perspective thinking	Global Awareness Social Responsibility Challenging the status quo Sustainability Awareness Environmental Awareness General Knowledge Lifelong Learning	Respect for others Open mindedness Agility Adaptability Curiosity Empathy Emotional Intelligence Perseverance/Grit Ethical Conscience Personal engagement/agency

* Communication was identified as a competence which included communication, foreign languages and listening skills.

References

Barcelona Declaration (2018). Settled at the 2nd International Conference of Engineering Education for Sustainable Development. Accessed December 28, 2018. https://eesd2018.org/conference/the-barcelona-declaration/.

Bianchi, G., 2020. Sustainability competences – A systematic Literature review, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-28408-6,

Beagon, U., Kövesi, K., Tabas, B., Nørgaard, B., Lehtinen, R., Bowe, B., Gillet, C., & Spliid., C. (2022). Preparing engineering students for the challenges of the SDGs: what competences are required?, European Journal of Engineering Education, DOI: 10.1080/03043797.2022.2033955

Beagon, U., Kövesi, K., Tabas, B., Nørgaard, B., Lehtinen, R., Bowe, B., Gillet, C., & Spliid., C. (2021). Sustainable Development and the SDGs: Revealing Engineering Academics, Students and Employer viewpoints. Presented at SEFI Conference, 2021, Berlin.

Brundiers, Katja, Arnim Wiek, and Charles L. Redman. "Real-world learning opportunities in sustainability: from classroom into the real world." International Journal of Sustainability in Higher Education 11, no. 4 (2010): 308-324.

Brundiers, K., & Wiek, A., 2017. Beyond interpersonal competence: Teaching and learning professional skills in sustainability. *Education Sciences*, *7*(1), 39.

Brundiers, K., Barth, M., Cebrián, G., Cohen, M., Diaz, L., Doucette-Remington, S., Dripps, W., Habron, G., Harré, N., Jarchow, M. and Losch, K., 2021. Key competencies in sustainability in higher education—Toward an agreed-upon reference framework. *Sustainability Science*, *16*(1), pp.13-29.

Cohen, S. *The Sustainable City*. New York: Columbia University Press, 2017.

Engineers Ireland, *Accreditation Criteria: January 2021*, Available from https://www.engineersireland.ie/LinkClick.aspx?fileticket=Mz3SCCk_uRg%3D&portalid=0&resourceView=1. Accessed 7 July 2022.

Fenner, R. A., & Morgan, D. C. (2021, June). The Barcelona Declaration revisited: core themes and new challenges. In *EESD2021: Proceedings of the 10th Engineering Education for Sustainable Development Conference* (pp. 1-12). University College Cork.

Government of Ireland. (2022). 2nd National Strategy on Education for Sustainable Development - ESD to 2030. Available: https://www.gov.ie/en/publication/02952d-national-strategy-on-education-for-sustainable-development-in-irelan/

Guerra, A., 2017. Integration of sustainability in engineering education: Why is PBL an answer?. International Journal of Sustainability in Higher Education. Vol. 18 No. 3, pp. 436-454.

Lönngren, J., & Svanström, M. (2015). Assessing" Wicked Sustainability Problem"-Literacy in Engineering Education. In *122nd ASEE Annual Conference & Exhibition. Seattle, USA, 14-17 June, 2015*. American Society for Engineering Education.

Lozano, R. (2008). Envisioning sustainability three-dimensionally. Journal of Cleaner Production, 16, 1838-1846.

Miller R., 2015. *Why the hard science of engineering is no longer enough to meet the 21st century challenges.* Olin College, May. Retrieved January 2nd, 2016 from www.olin.edu/sites/default/files/rebalancing_engineering_education_may_15.pdf

Rieckmann, M., 2012. Future-oriented higher education: Which key competencies should be fostered through university teaching and learning?, *Futures*, *44*(2): 127-135.

Romero, S., M. Aláez, D. Amo, and D. Fonseca. 2020. "Systematic Review of How Engineering Schools Around the World Are Deploying the 2030 Agenda." Sustainability 12 (12): 5035.

Segalàs, J., Ferrer-Balas, D., Svanström, M., Lundqvist, U., & Mulder, K. F. (2009). What has to be learnt for sustainability? A comparison of bachelor engineering education competences at three European universities. *Sustainability Science*, *4*(1), 17-27.

Segalàs Coral, J., & Sánchez Carracedo, F. (2020). Educating for sustainable development goals in spanish engineering degrees. In SEFI 2020: 48th Annual Conference "Engaging engineering education": Enschede, The Netherlands: September 20-24, 2020: proceedings (pp. 485-497). European Society for Engineering Education (SEFI).

Tabas, B., Beagon, U. and Kövesi, K. (2019). Report on the Future Role of Engineers in the Society and the Skills and competences Required for Engineers, First Project Report, A-STEP 2030 project, pp. 1–40. Accessed 21st November 2021. Available: www.astep2030.eu.

Tejedor, G., Martí R-C., and Segalas, J. (2019). Patterns and trends in engineering education in sustainability: A vision from relevant journals in the field. *International Journal of Sustainability in Higher Education*, 20(2): 360-377.

United Nations. 2015. Transforming our world: the 2030 agenda for sustainable development. Available: https://sdgs.un.org/publications/transforming-our-world-2030-agenda-sustainable-development-17981 Accessed 15th May 2021.

UNESCO. 2017. Division for Inclusion, Peace and Sustainable Development, Education Sector, Education for sustainable development goals: Learning objectives. 1-62.

UNESCO. (2007). Education for Sustainable Development. Education for Sustainable Development Unit

UNESCO (2021). Engineering for Sustainable Development: delivering on the Sustainable Development Goals, 1-183.

WCED, 1987. Our common future. World Commission on Environment and Development, Oxford, England: Oxford University Press.

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

Yearworth, M. (2016). Sustainability as a 'super-wicked'problem; opportunities and limits for engineering methodology. *Intelligent Buildings International*, 8(1): 37-47.

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