


The Sustainable Development Goals (SDGs) applied to Mechanical Engineering

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Received: 13 February 2022; Accepted: 29 March 2022; Published: April 2022

Abstract

In 2015, the United Nations approved the 2030 Agenda on Sustainable Development, an opportunity for countries and their societies to face the challenge of successfully addressing the transition to a more sustainable future for people and the planet, leaving no one behind. The agenda defines a total of 17 Sustainable Development Goals (SDGs) of universal application to promote economic growth, a commitment to social needs and the protection of the environment. For the successful achievement the ambitious and demanding SDGs, individuals, businesses, governments, and higher education institutions should work collaboratively.

This paper aims to contribute to the implementation of the SDGs in the mechanical engineering subjects, and to define appropriate indicators and validation processes to assess their level of fulfillment as established in the 2030 Agenda. As a result, better decisions can be made regarding the efforts that universities - including students, academics and researchers and professional services staff - must invest to incorporate the SDGs into their initiatives, structures, and policies.

Keywords: Sustainable Development Goals; Mechanical Engineering; Indicators

To cite this article: Llopis-Albert, C., Rubio, F., Zeng, S., Grima-Olmedo, J., Grima-Olmedo, C. (2022). The Sustainable Development Goals (SDGs) applied to Mechanical Engineering. *Multidisciplinary Journal for Education, Social and Technological Sciences*, 9(1), 59-70. <https://doi.org/10.4995/muse.2022.17269>

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Mult. J. Edu. Soc & Tec. Sci. (2022), 9(1), 59-70. <https://doi.org/10.4995/muse.2022.17269>

1. Introduction

The 2030 Agenda for Sustainable Development, approved in 2015 by the United Nations, represents the international benchmark for excellence in this matter and is being adopted by governments, organizations, and companies in many countries. The commitments that all these agents put in place will determine the success of this strategy, as well as their collaboration to achieve sustainable development that leaves no one behind.

The agenda comprise an extensive action plan based on three axes: people, the planet and prosperity, which should guide development strategies worldwide for the next few years. The 2030 Agenda proposes 17 Sustainable Development Goals (SDGs) with 169 targets that cover the economic, social, and environmental spheres. The SDGs are interconnected and interdependent, referring to the great challenges facing the world today. It establishes a roadmap towards social, economic, and environmental sustainability, and underlines the need to carry out a significant effort of alignment and coordination on the part of all the agents involved. The agents include governments, civil society, private sector, universities, labor unions, Non-Governmental Organizations (NGOs), etc.

The 17 Sustainable Development Goals (SDGs) are subsequently presented (United Nations, 2015):

- **SDG 1: No poverty.**
End poverty in all its forms everywhere.
- **SDG 2: Zero hunger (No hunger).**
End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.
- **SDG 3: Good health and well-being.**
Ensure healthy lives and promote well-being for all at all ages.
- **SDG 4: Quality education.**
Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
- **SDG 5: Gender equality.**
Achieve gender equality and empower all women and girls.

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- **SDG 6: Clean water and sanitation.**
Ensure availability and sustainable management of water and sanitation for all.
- **SDG 7: Affordable and clean energy.**
Ensure access to affordable, reliable, sustainable, and modern energy for all.
- **SDG 8: Decent work and economic growth.**
Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.
- **SDG 9: Industry, Innovation, and Infrastructure.**
Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.
- **SDG 10: Reduced inequality.**
Reduce income inequality within and among countries.
- **SDG 11: Sustainable cities and communities.**
Make cities and human settlements inclusive, safe, resilient, and sustainable.
- **SDG 12: Responsible consumption and production.**
Ensure sustainable consumption and production patterns.
- **SDG 13: Climate action.**
Take urgent action to combat climate change and its impacts by regulating emissions and promoting developments in renewable energy.
- **SDG 14: Life below water.**
Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.
- **SDG 15: Life on land.**
Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
- **SDG 16: Peace, justice, and strong institutions.**
Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable, and inclusive institutions at all levels.
- **SDG 17: Partnership for the goals.**

Strengthen the means of implementation and revitalize the global partnership for sustainable development.



Figure 1. SDGs proposed by United Nations (2015).

Universities as agent of change have an important role in the fulfillment of this agenda given their responsibility in the field of education, research, development, innovation, and transfer of knowledge to society (Pérez-Sánchez et al., 2020). This is because higher education broadens people's options to develop valuable lives. It constitutes a powerful tool for the achievement of sustainable human development. A good part of the existing inequalities in terms of income or ability to influence relevant political processes is directly related to the possibility of accessing advanced educational levels. Likewise, countries with a higher quality of life have invested considerable resources and efforts in promoting higher education. That is why the objective of development policies and strategies must be to make effective the human right for all people to access higher education.

Therefore, the contribution to the United Nations mandate is still a challenge and requires universities to rethink their activity in a pro-active and operational way towards their specific goals.

This raises a wide range of monitoring indicators for the achievement assessment of the different goals.

This paper is intended to contribute to the theoretical reflection, which must be accompanied by practical proposals that propose concrete and pertinent measurement instruments on the degree of achievement of the SDGs in universities, so that, in the light of the data, decisions can be made regarding the efforts that universities must invest to incorporate the 2030 Agenda into their initiatives, structures and policies. It is necessary to be aware what is being done within the universities, assessing its degree of relevance and effectiveness in order to be able to consider what remains to be done and what are the most appropriate instruments to carry it out.

2. Indicators to measure the degree of compliance of the SDGs at UPV.

The UPV is intended to analyze the role that higher education should play in the new paradigm of sustainable human development and in its contribution to the 2030 Agenda.

The UPV has defined a set of indicators that measures how universities are addressing the 2030 Agenda and their degree of compliance. The indicators are based on relevant, transparent, accessible, and understandable data, not only for experts but for the entire university community, with the goal of normalizing the 2030 Agenda (UPV, 2019; 2020). The set of indicators are flexible, adaptable, and with different levels of depth with the aim of measuring the university commitment to achieve the SDGs. This operational deployment from the most general to the most concrete, also forces universities reconsider the scope and contents of the SDGs, the goals, and the indicators in their context. As a result, a methodological process was carried out for the construction and measurement of an extensive battery of specific and differentiated indicators for each of the 17 SDGs and structured into different degrees of measurement. They range from the most general and fundamental aspects (degree 1), to the most concrete and specific (degree 4).

- Degree 1: it covers the most general aspects of the corresponding SDG. These are quick response indicators (Yes / No / In process) and the result of the measurements is presented in percentage terms, with only three possibilities: 0% / 50% / 100%. This level assesses the existence of minimum compliance by the university institution in

relation to a series of variables referred to 8 categories: organizational structure, preparation / publication of reports, academic / training offer, R+D + i projects, normative framework, relations with the local environment, participation in public policies and existence of alliances. In short, it is a very broad level, covering multiple categories, but with little depth or not very sensitive to intensity.

- Degree 2: it provides specific information through numerical indicators. It is also a general level but one that provides a greater degree of specificity. It should be noted that levels 1 and 2 have been conceived to be able to be compared between the different universities, so the results are always reflected in comparable measurement units, such as percentages, indices, etc., never in absolute terms.
- Degree 3: it is specific for each university and unlike the previous ones, it does not revolve around comparability, but rather its usefulness lies in the internal use of the information by each entity. For this, specific compliance goals are set for each indicator, which will be defined by each university individually, taking into account their priorities, needs and capacities. This level recovers most of the indicators proposed in level 2, which, along with others considered relevant, will appear associated with specific quantified goals, established by each university.
- Degree 4: it is a specific and concerning each area, unit, service, or department, establishing indicators adapted to the functions and responsibilities of the organizational structure considered. The objective is to obtain useful tools for control and decision-making by university authorities, placing emphasis on the SDGs that have a higher level of connection with their specific objectives and purposes.

3. SDGs implementation in Mechanical Engineering subjects

Universities as a socially committed institutions, must contribute to the achievement of the SGGs from their different facets, academic, research, transfer, and innovation, involving the entire university community. All subjects taught in the university should carry out a reflection exercise on how they can contribute to the improvement of society within the framework of the SDGs.

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In this sense, this paper deepens in the implementation of the SDGs for the mechanical engineering subjects taught at UPV, and in defining appropriate indicators and validation processes to assess their level of fulfillment as established in the 2030 Agenda. A wide range of subjects are taught by the Department of Mechanical and Materials Engineering (DMME) at UPV and many research areas are tackled by the different research institutes dealing with the mechanical engineering field. They cover subjects such as:

- Mechanism and machine design (including kinematics and dynamics).
- Mechanical design: fatigue and fracture.
- Failure Analysis of mechanical components.
- Strength of materials and solid mechanics.
- Materials engineering, composites.
- Manufacturing engineering, technology, and processes.
- Maintenance engineering technology, industrial facilities.
- Mechanical vibrations.
- Structural integrity.
- Mechatronics and robotics.
- Biomechanics.
- Vehicle dynamics.
- Engineering design and product design.
- Engineering, services, and work risk prevention
- Instrumentation and measurement.
- Acoustics, noise, and vibration control technology.
- Computational mechanics.
- Computer-Aided Design (CAD).
- Computer-Aided Manufacturing (CAM).
- Computer-Aided Engineering (CAE).
- Finite Element Method.

Due to the closely relation between the SDGs and the different courses offered by the Department of Mechanical and Materials Engineering (DMME), most of them can be easily implemented in those courses. Moreover, some of the SDGs are already worked in the different courses, although further improvements would be advisable. In fact, this is the main goal of the present paper, i.e., to provide tools, concepts, and ideas to further implement corrective actions to incorporate the SDGs in the mechanical engineering courses. For instance, in the current stage of the study program the following sustainable goals are partially worked: SDG 6 (clean water and sanitation), 7 (affordable and clean energy), 9 (industry, innovation, and infrastructure), SDG 11 (sustainable cities and communities), SDG 12 (responsible consumption and production), and SDG 13 (climate action).

It is worth mentioning the extensive experience of authors of the present paper with many of these subjects. Note that to effectively transmit the SDGs to students, it is important that teachers keep up to date with educational and technological advances in the subjects. In this sense, they have published many articles in recent years closely related with the aforementioned subjects. For instance, Llopis-Albert et al. (2018); Rubio et al., (2021); Valero et al. (2017, 2019); Hu et al. (2021); Valera et al. (2021); Zeng et al. (2022).

As stated in the previous section, general rules and indicators are defined by the UPV to deal with the SDGs. Based on that information, we proposed several measures and indicators that can be applied to the syllabus of the mechanical engineering subjects to further implement the SDGs. This is carried out by defining three levels: a first level (level 1) of immediate application, a second level that would be applied in the short term (level 2) and a third level corresponding to the medium and long term, which would imply proposals that would modify the title verification report as certified by the National Agency for Quality Assessment and Accreditation (ANECA) of Spain. Despite the time needed for its implementation, the third level can lead to more integrated and articulated changes throughout the study plan of the title.

- Level 1: introduce in the mechanical engineering courses content related to the 2030 Agenda in a transversal way, so that all students know its content. It could be implemented by proposing a compulsory training activity for first-year students. The activity would explain the objectives pursued by the 2030 Agenda, the 17 SDGs and the 169 targets.

- Level 1: students must incorporate in all laboratory practices and academic works an explicit reflection that justifies the extent to which their works are related to certain SDGs. This can be extended to the final degree projects and master's degree final projects offered by the Department of Mechanical and Materials Engineering (DMME).
- Level 1: students must take lessons related to SDGs in each subject. It is proposed to hold meetings with the teachers responsible of each subject, together with experts in the 2030 Agenda, and to address changes in the syllabus of the subject so that the SDGs are present in the learning results of the students. This level corresponds to improvement proposals that do not involve a modification of the certificate verification report of the university degree.
- Level 2: Defining new transversal competences (UPV, 2020a; Llopis-Albert and Rubio, 2021) related to the SDGs.
- Level 3: Incorporation of the SDGs in the degrees will be encouraged. Elective and specific training courses on each of the SDGs should be offered, either compulsory or optional courses. This action would modify the title verification report as certified by ANECA.
- Level 3: Promote the mechanical engineering field among high school students to increase the enrollments and bridge the still existing gap between men and women.

In addition to studying how to introduce the SDGs into the mechanical engineering courses, we also must consider how to verify that students have achieved these learning outcomes. As a first step, for a validation of the effectiveness of the actions, all students must pass different activities of evaluation (including exams, laboratory practices, academic works, etc.) to certify that they have acquired the knowledge taught in each subject. This can be extended This can be extended to the final degree projects and master's degree final projects. Therefore, the contents related to the SDGs that are introduced in each subject are relatively easy to assess. However, it will be necessary to correctly design the evaluation acts so that this statement is valid. To implement this action an evaluation rubric should be defined to analyze learner development to incorporate the SDGs in their curriculum. This rubric should be designed defining 4 levels (A: ineffective; B: developing; C: effective; D: highly effective), which will be available to both students and teachers. The adaptation of the rubric to 4 levels has been carried out to maintain the same qualification system that is carried out at the UPV to evaluate the transversal competences present in all its degrees (UPV, 2020a).

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As previously mentioned, a way to assess the level of fulfillment as established in the 2030 Agenda is to use some indicators. Some of the indicators presented for the whole university in UPV (2019, 2020) are easily transferable to the mechanical engineering subjects. It should be noted that mechanical engineering subjects mainly deal with SDGs 6, 7, 9, 11, 12 and 13. Subsequently, for the sake of conciseness only a few examples of indicators at degrees of measurement 1 and 2 are presented in Table 1 for those SDGs.

Table 1. Examples of indicators for assessing the level of fulfillment as established in the 2030 Agenda. The Department of Mechanical and Materials Engineering (DMME) and the different research institutes dealing with the mechanical engineering field at UPV mainly deal with SDGs 6, 7, 9, 11, 12 and 13.

SDG 6	
Degree 1	-Do the DMME or the research institutes participate at the local, national, regional or international level in the debate and / or elaboration of institutional policies on the subject of sustainable water management and the promotion of sufficient and adequate water and sanitation systems?
SDG 7	
Degree 1	-Do the different subjects offered by DMME contemplate academic / training in sustainable energy, efficient energy management and renewable energy? -Are there R+D+i and transfer projects / programs at the research institutes focused on the production of sustainable energy, its sustainable management, and the promotion of renewable energies?
SDG 8	
Degree 2	-Temporality rate for hired personnel. -Employability rate of graduates in the mechanical engineering degrees and masters. -Percentage of graduates who have carried out external internships in companies
SDG 9	
Degree 1	-Do the different subjects offered by DMME contemplate academic / training in the development of sustainable infrastructures, innovation, and promotion of industrial sectors? -Are there R+D+i and transfer projects / programs at the research institutes aimed at promoting sustainable infrastructures and supporting industry and the productive sector?
Degree 2	-Percentage of personnel totally or partially dedicated to Innovation and Technology Transfer -Percentage of revenues from R&D with external funds over the total budget of the department or research institute.
SDG 11	
Degree 1	-Do the DMME or the research institutes include objectives related to the integral sustainability, for example related to mobility, use of ecological transport, management of green areas, promotion of cultural and natural heritage, etc.?
SDG 13	
Degree 1	-Do the DMME or the research institutes promote initiatives, such as actions, campaigns, projects, or programs related to the fight against climate change and its effects (environmental, social, politicians, etc.)?

4. Conclusions

The 2030 Agenda constitutes a roadmap towards sustainable development with the aim to end poverty, protect the planet, and ensure all people enjoy peace and prosperity. This work constitutes a first effort to implement, measure and validate the degree of compliance with the SDGs in the mechanical engineering subjects taught at UPV. Several actions have been defined at three different levels to incorporate the SDGs into the students' curriculum. They differ from the time needed to be implemented, i.e., immediate, short, medium, and long-term. Additionally, a set of indicators have been developed to assess the significance and the degree of fulfillment of the actions undertaken. They cover all the actors involved, students, teachers, and university. Eventually, we propose to define a rubric similar to those existing for the transversal competences to facilitate the evaluation.

Author Contributions: Conceptualization, C.L.A; methodology, C.L.A and F.R.; validation, C.L.A and F.R.; formal analysis, C.L.A and F.R.; investigation, C.L.A and F.R.; resources, C.L.A and F.R.; data curation, C.L.A and F.R.; writing original draft preparation, C.L.A and F.R.; writing review and editing, C.L.A and F.R.; visualization, C.L.A and F.R.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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ISBN: 978-84-09-17979-4, pages 3995-4005. <https://doi.org/10.21125/edulearn.2020>

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