International Journal on Interactive Design and Manufacturing (IJIDeM) (2020) 14:739–745
https://doi.org/10.1007/s12008-020-00661-0

ORIGINAL PAPER

Incorporating the sustainable development goals in engineering education

Ricardo A. Ramirez-Mendoza[1] · Ruben Morales-Menendez[1] · Elda M. Melchor-Martinez[1] · Hafiz M. N. Iqbal[1] · Lizeth Parra-Arroyo[1] · Adriana Vargas-Martínez[1] · Roberto Parra-Saldivar[1]

Received: 31 January 2020 / Accepted: 27 March 2020 / Published online: 6 April 2020

Abstract
This paper aims to open the discussion on the incorporation of sustainable development goals (SDG) in the curricular plans of engineering programs. The United Nation has recognized the development SDG by 2030 as a priority. It should be evident that universities embrace these objectives to align with the great challenges facing education today. This is an initial discussion where it is intended to offer some research and challenge ideas to the administrators and policymakers of the universities regarding the incorporation of these objectives. As an example, some academic and research activities that are carried out in our institution to overcome these challenges are described. A logic framework to incorporate SDG in engineering education is presented and some examples of academic projects that somehow touch the SDG are mentioned and finally some recommendations of how these SDG can be explicitly incorporated into the engineering education programs and in general in the high-education institutes.

Keywords Sustainable development goals · Engineering education · Disruptive learning-teaching models · T21 model

1 Introduction

What are the objectives of SDG [1]? Why are they important? How can universities align SDG with incorporating these objectives explicitly into engineering education programs? A schematic diagram is shown in Fig. 1. These are some of the debates that this work tries to inspire, all in the context of incorporating these SDG explicitly in the engineering education plans in the universities. Universities must align their educational strategies to SDG objectives that turn themselves into challenges for the entire planet and the subsistence of the human being on earth. The 2030 Agenda for Sustainable Development of the United Nations (UN) establishes goals and targets in areas of critical importance for humanity [1–3]. This topic has attracted the attention of scientists, academics, industrialists, politicians and society in general. Just review the literature on academic, scientific, political and social manuscripts that translate into debate and discussion events about the importance of these SDG [4–12].

✉ Ricardo A. Ramirez-Mendoza
ricardo.ramirez@tec.mx

[1] School of Engineering and Science, Tecnologico de Monterrey, Campus Monterrey, Monterrey, Mexico

Considering the technological change that the world is going through, our current social environments and generational differences in society focus on the extraneous and declares itself as the savior of the world. The university rises as a relevant and essential agent to ensure knowledge and development of competencies in this fourth industrial revolution, which has been called Industry 4.0 (I4.0) [13–17].

A series of digital technologies converge in applications that transform the industrial processes so, they become more connected, reliable, predictable, resilient, and a high degree of certainty. All of this is due to the articulation of several capabilities of information technologies. Several efforts have been detonated in the world trying to better understand this evolution of industry towards the I4.0 [18].

The industrial world is currently changing due to increasing digitization and computerization in companies. The need for more collaboration between personnel with different fields of expertise arises. This means that members of a multitude of professions need to work and communicate with each other. These developments in the industry also have an influence on current education curricula at schools and universities. Interdisciplinary knowledge across different curricula is required to work in a new environment of teaching–learning.

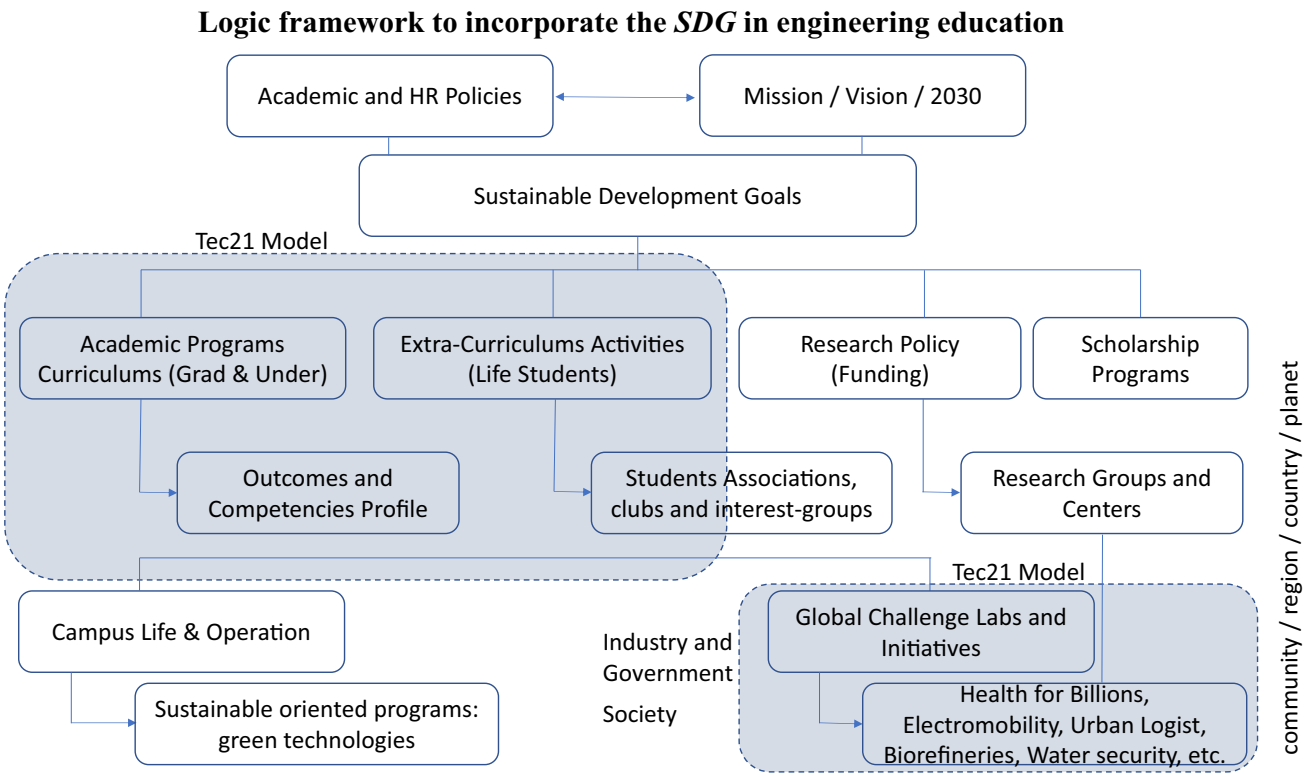

Fig. 1 General strategy to incorporate SDG to engineering education

In effect, technology influences the behavior of a society that has been advancing vertiginously on paradigms and frames of reference for wealth, value, economic development, but often forget the fundamental aspects of sustainable development. The SDG tries to restore awareness to this society to generate public policies, academic and research actions, as well as citizen participation to solve the great challenges of humanity. Hence the importance of taking into account these SDG in our curricular plans in engineering education [19, 20].

A formal framework that has emerged in recent years at the Essex School of Public Policy in the UK is transformative innovation, which rightly recognizes that today's world is ambiguous, uncertain, unpredictable and exponentially changing and that the challenges are evident in this highly industrialized world [21–24]. This framework is a source of inspiration to propose a logic framework to incorporate SDG in Engineering Education.

This paper is organized as follows: Sect. 2 describes the Transformative Innovation as a logic framework to incorporate the SDG in engineering education, Sect. 3 describes some strategies of how to incorporate the SDG in the different dimensions of activity of a university such as the Tecnologico de Monterrey, in particular in the research strategy and graduate studies program. The last Sect. 4 deals with some concluding remarks.

2 Transformative innovation as a logic framework to incorporate SDG in engineering education

A formal frame of reference that has emerged in recent years at the Essex School of Public Policy in the UK is transformative innovation [24]. The rigor of this theoretical framework talks about the transformation process of public policy into innovation, in which, at first stance, countries make great investments in infrastructure, such as the development of human resources, development of physical infrastructure, equipment, laboratories, centers, universities, etc. Then, in the following framework, the emphasis falls on generating a science and technology system, where all the actors developed in the first framework are recognized, with the intent of linking them to strengthen the created capacities.

A transformative approach seeks to contribute to the solution of the great social, environmental, and economic challenges expressed in the SDG:

The SDG establishes five principles: directionality, participation, learning and experimentation, interdisciplinarity, and anticipation of results and effects, as channelers of change and social and technological transformation.

- They must respond to the needs of society, based on the joint design and co-development of solutions, between the

national government, the private sector, the academic community, and civil society.
- Especially the latter is needed to have a more relevant role in the National System of Science, Technology, Innovation and Education, which will undoubtedly help to strengthen and consolidate it.
- The science, innovation and education policy needs to be renewed to face the great challenges facing the countries, regions and the planet so that it can contribute effectively to the transformation demanded by the challenge of SDG by 2030.

Then comes the third theoretical framework [21], which is related to transformative innovation: "How can we evolve towards a type of design in which all this has already been developed and linked, it's really oriented towards solving global problems and generating dramatic changes?" This is the starting point (at the moment), understanding what exactly are the details of framework three.

Recently, the Commission on Science, Technology and Development of UN discussing the fact that innovation, science and technology must also address the SDG. It was a plenary session on this topic, with new approaches to support SDG. It was clear that it is not the same approach to SDG for developing countries or for underdeveloped countries: How can we address these goals? Transformative Technology Consortium [24] is to start thinking about transformation: what does transformation mean? The goal is to ask different questions in the consortium, to see the future of science policies, technologies, education, their design, their bases, and to give an answer to the transition; and the reason for doing this is not because they want to introduce another round of innovation policies, but because the world is changing, there are problems of great pressure in the world that have to be addressed. The Transformative Innovation is another way of thinking, and that is the notion of deep transition. And this has to do with sustainability, much of the innovation is focused on products, processes, technology, and education.

Which is the role of the university and the engineering education to address those SDG intentionally learning-teaching models?. Universities must align the educational strategies and models to SDG objectives that turn themselves into challenges for the entire planet and the subsistence of the human being on earth. The 2030 Agenda for Sustainable Development of UN establishes goals and targets in areas of critical importance for humanity and the Transformative Innovation framework enables academia to incorporate the SDG in a logically and naturally.

In the particular case of Tecnologico de Monterrey, it addresses this seriously and in a disruptive manner through the new educational models. Tecnologico de Monterrey from its beginning, has evolved and has adapted to global changes. In 2013, the institution launched a new educational model named, "Modelo Educativo Tec21" (Tec21 model), the main goal of which is to develop internationally competitive, integral individuals. Its development was based on extensive research that included the participation of its institutional community and a review of the benchmarks of the educational practices in leading worldwide universities and organizations.

The new educational model, exclusive worldwide, activates and boosts the innovation capacity and allows not only to stay current but also to promote agents of change in unprecedented times in which education is experimenting a complete transformation. The Model Tec 21 has a learning process based on the challenge and has its foundations in four main components: challenge-based learning, customization, and flexibility, inspiring professor and memorable experience [23, 24].

In particular, throughout the learning process throughout the bachelor´s degree is centered in the involvement of students along with their professor and classroom environment. So, they develop transversals and disciplinary competences, through real problematic bonded challenge resolution and by proving their knowledge and dominance through learning evidence.

3 Some strategies to incorporate the SDG

The interest in incorporating the SDG into the activity of a university is motivated not only by the positioning in the World Rankings but also because they represent in some way the global challenges that will be faced by future professionals who graduated from our universities [24].

Figure 1 shows that the SDG should be very visible and be in the priorities of the top management of the university, the mission and vision of the universities should contemplate the SDG as well as the academic and human resources policies should be aligned and in congruence with these goals. Particularly in Tecnologico de Monterrey, in the design of the new Tec 21 educational model, a competency-based model has been considered in each training unit, a fundamental component of the model, where in particular the so-called transversal skills are based on SDG, but not only in the academic training units of the new programs but also in the extra-curricular activities of student life, as well as in student associations and interest groups, SDG objectives are present. In addition, scholarship policies and research programs take into account the SDG to determine support and management programs and research axes. At the level of the operation of the campus itself, the issues of sustainable development such as energy-saving programs, water sanitation, circular economy, recycling, etc. They are operational activities where the Campus becomes a living laboratory for the implementation and deployment of SDG. The scheme also shows some of our

Table 1 Supporting implementation

Understand	It is necessary to understand the causes of SDG to design policies and solutions at the needed level
Assessment	Assess the SDG at the appropriate level (local, national) based on priorities and strategic indicators to measure the progress of the solutions
Develop	Promote social and technological development through the systematic creation of innovations and solutions of the SDG, valuing its limitations
Strategy	It must be investigated the best way to resolve the SDG according to the community, city or country; as well as interactions or synergies among them. The research will support a more efficient policy and strategy formulation to achieve the SDG
Support	It is very important to investigate the best way to implement and evaluate a global plan to get the SDG identifying the interrelationships between objectives and policies. In addition, it will allow the synthesis, monitoring and evaluation of global progress

Table 2 Main SDG research areas at the School of Engineering and Sciences, Tecnologico de Monterrey

Graduate program	SDG
Engineering Sciences	No poverty, Clean water and sanitation, Affordable and clean energy
Nanotechnology	No poverty, Clean water and sanitation, Affordable and clean energy
Biotechnology	No poverty, Zero Hunger, Good health and well-being, Responsible consumption and production, Life on land, Industry innovation and infrastructure, Sustainable cities and communities, Climate action
Computer Science	No poverty, Quality education, Sustainable cities and communities

strategic projects in particular for the School of Engineering such as Health for Billions, Electromobility, Water Safety, etc. Some of these projects are explained later.

3.1 Incorporating SGD on graduate studies programs

Research to generate and/or transfer knowledge, as well as innovation in science, engineering, and humanities, are essential for the development and implementation of the various goals [25]. Research helps and supports the implementation of all SDG in different ways, as shown in Table 1.

The School of Engineering and Sciences at Tecnologico de Monterrey has four graduate (MSc, PhD) programs. Table 2 shows the research areas of each graduate program according to the SDG.

Table 3 PI facilitates some SDG

SDG	PI contributions
4	Acquire the knowledge to develop a more efficient and sustainable technologies
7	Save energy in large-scale processes and develop compact and cost-competitive processes
8	Generate opportunities for economic growth, because of the higher levels of productivity and resource efficiencies
9	Enable upgrading of industrial infrastructure and retrofit industries to make them sustainable and clean. +
12	Support the development of environmental management and all waste management by improving process safety and reducing waste generation
13	Incorporate renewable energies leading to reductions of greenhouse gas emissions

There are other schools (Business Administration, Education and Humanities, Political Sciences, Medicine, Architecture) at Tecnologico de Monterrey that research on the missing SDG in Table 2.

Example. Chemical engineering research resulting in a smaller, cleaner, and more energy-efficient technology has been named: Process Intensification (PI), and it is achieving a very much change in the chemical industry and supporting many SDG. PI is an approach by function, a break-away from the conventional process design by unit operations; it focuses not only on the process itself, but also on what happens outside or as a consequence of the process. PI contributions are shown in Table 3 [26].

The main industrial motivators start from the SDG and they are related to the increase in environmental constraints that demand more sustainable processes, the need to do more with less, and with more efficient operations. All based on SDG but without neglecting the profitability of the business.

Typically, the most sustainable processes currently incorporate alternating energy sources, such as solar heating, which replaces steam (which exploits fossil fuels). It is innovated with hybrid processes resulting from the combination of two operations (e.g., reactive distillation). Based on the PI principles.

It is innovating with new technologies, such as 3D printing, manufacture catalysts, advanced reactor designs, rapid prototypes and upgrade parts of old equipment, renewing the ways to see chemical engineering design. Efficiency is seen as an opportunity for PI to address current challenges based on SDG. Two other major challenges for the chemical industry, namely sustainability, and profitability.

To contribute the SDG in the chemical engineering industry, which are related to efficiency, sustainability and profitability (PI researching), teaching should focus on the following areas: (1) Improve basics skills, (2) Training stu-

dents in creativity, (3) Training students in innovation and (4) Inspire students [27, 28].

In PI research, the scientific community, the industrial sector, and the government are working hard to disseminate the results, especially the progress that is being made in the transformation of industrial and supporting SDG. Also, PI can contribute to a safe and healthy living environment around industrial facilities.

3.2 Research strategy on SDG

After years of significant investment and global participation at independent and rigorous sustainability research, Tecnologico de Monterrey is aligned with SDG to strengthen its research efforts in developing and promoting a long-lasting change. Research is an integral component of the learning process, for a student, across the engineering and related education. Figure 2 shows properly designed modules and investigation processes linked with an appropriate SDG can significantly improve the educational and research criterion with greater and sustainable impact. For instance, referring to the coated goal 6 on clean water and sanitation in Fig. 1 and in accordance with a recent report released by the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), (2017) on the progress on drinking water, sanitation and hygiene: 2017 update and sustainable development goal (SDG) baselines [29], several countries have designed and implemented water collection and treatment strategies under sustainability concept. This enables them to cover almost over 91% of their populations and governmental infrastructure that generates wastewater. This follows the pattern of the 2030 agenda for Sustainable Development [30], that recognizes the need for safe drinking water, effective and efficient sanitation (wastewater treatment), and excellent hygienic environment [31]. Likewise, referring to goals 8 and 11, useful research strategies devoted their courtesy to serious matters that may hamper economic growth. Therefore, the EU 2020 targets and sustainable development of smart cities and societies [32].

Referring back to the given units in Fig. 2, the first step toward the implementation of effective curricula integrating SDG is to identify the research activities and actions that could impact one or several of these goals and its potential linkages across the units. In order to ensure the greatest progress towards each SDG possible while being clear to teachers as well as students, the goals met by a course or project are usually mapped on an online platform that combines machine learning as well as data mining [33]. The platform recommends interdisciplinary teams based on the SDG of interest of each member. This additionally boosts inter- and intradisciplinary research by ensuring the implementation of more effective actions to the unify curriculums interconnected by SDG. Under each unit, each student has

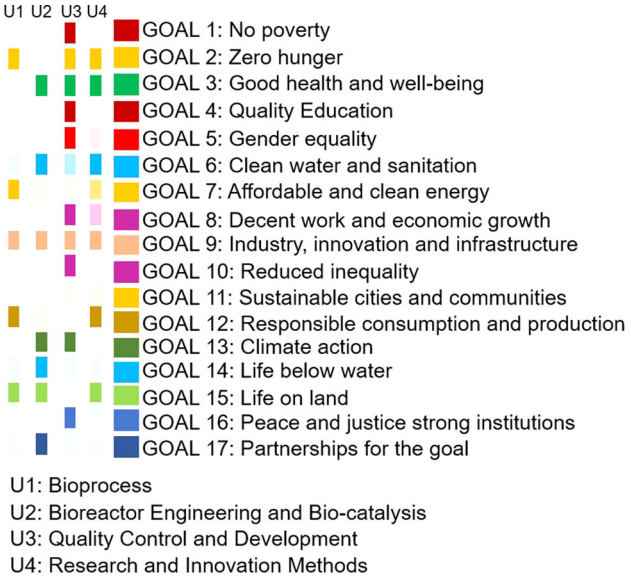

Fig. 2 A roadmap to the SDG developed for four different research-based training units. Each assigned unit critically covered one or more of the SDG under the research-based learning model

the liberty to choose from the given modules, according to the SDG detailed in the lecture's description. Effective research mapping also aids the development of research curricula as the maps work to highlight areas to include more Sustainable Development Goals. The mapping of the curricula and SDG being developed in a collaborative process encourages researchers at a different level to engage with the SDG in a meaningful way and promote an accurate understanding of strengths and priorities the needful actions to maintain the long-term sustainability.

One key challenge in addressing the research-based SDG lies in encouraging cross-faculty collaboration. Every year for the past 50 years, Tecnologico de Monterrey has hosted the 'Congreso de Investigación' (Research Congress), a platform to present cutting edge technologies and research development to greening up the twentyfirst century education across the disciplines. It is a fitting platform to converse about how the SDG are being implemented in an open window to students, researchers, and collaborators to produce a dynamic process and progression enhancing the SDG impact in the academic and research-based facilities. This forum provides a helpful framework for researchers from different faculties to draw links between their work based on the SDG framework. Using the SDG framework in this way has allowed the Network to connect areas within Tecnologico de Monterrey, which may otherwise be prone to be siloed. It has also highlighted and promoted a common purpose for researchers at Tecnologico de Monterrey at an international level.

4 Concluding remarks and outlook

The main idea of this study was to understand how universities are having a positive impact incorporating the SGD and therefore and by logic in contributing to building a more sustainable world. The study also shows how specifically higher education is working forward in addressing these SDG with learning activities, academic projects, definition of competencies, courses, extracurricular activities etc. that complement education now integrate very fashionable in the teaching–learning models. Such practices comprehensively conceptualize and stresses to fulfill the requisite nature of education for sustainable development across the disciplines mentioned earlier. Thus, significantly acknowledge the growing need of the entire education system to strengthen the positive and long-lasting contributions of SDGs. Moreover, in each discipline, strategic measures should be taken into account to make it creative, effective, acceptable, and aligned to the requisite level of SDGs.

A general strategy to incorporate SDG to the Engineering Education has been presented in this manuscript. The given strategy is remarked that SDG should be very visible and be in the priorities of the top management of the university, event at the level of the operation of the campus itself, the SDG becomes a living laboratory for the implementation and deployment of SDG. Not less important, the graduate studies programs and research initiatives must be incorporated strategic research projects as Health for Billions, Zero-Emission, Electromobility, Water Safety, etc.

Considering the effective deployment of SDG in engineering education, the following outstanding questions or measures should be taken as supreme interest as an outlook for futuristic vision.

- The academic and research infrastructure should be aligned to strengthen the co-existence of teaching and research, in a meaningful way, at a multi- and transdisciplinary level.
- The related educational units and research-based learning environment should be protected to facilitate their long-lasting impact as per SDG. Otherwise, considering the past examples, many of them will be guzzled up and downgraded throughout the curriculum development.
- The national and international level legislature authorities should play an active role in accelerating the effective establishment of SDG in various sectors of academia and industry alike.

References

1. UNDP.: 2030 Agenda for Sustainable Development - Sustainable Development Goals. United Nations. https://www.undp.org/content/dam/undp/library/corporate/brochure/SDGs_Booklet_Web_En.pdf (2015). Accessed 22 Dec 2019
2. Guterres, A.: The Sustainable Development Goals Report 2017. United Nations. https://www.un.org/development/desa/publications/sdg-report-2017.html (2017). Accessed 25 Jan 2020
3. Rieckmann, M.: Education for sustainable development goals: learning objectives. Paris, France (2017)
4. ECLAC.: Regional and global dimensions of the 2030 Agenda for sustentainable development. United Nations. https://www.cepal.org/en/infografias/dimension-regional-global-la-agenda-2030-desarrollo-sostenible (2016). Accessed Dec 2019
5. Congress of Local and Regional Authorities.: SDGs - Agenda 2030. Council of Europe Portal. https://www.coe.int/en/web/congress/sdg (2019). Accessed 20 Jan 2020
6. Congress of local and regional authorities.: Sustainable Development: High level political forum in New-York -. Council of Europe Portal. https://www.coe.int/en/web/congress/high-level-political-forum-on-sustainable-development#%7B%2250459471%22:%5B%5D%7D (2019). Accessed 20 Dec 2019
7. Congress of Local and Regional Authorities.: Implementation of the SDGs: strengthening local and regional democracy, social inclusion and institucional partnerships. Council of Europe Portal. https://www.coe.int/en/web/congress/-/implementation-of-the-sdgs-strengthening-local-and-regional-democracy-social-inclusion-and-institutional-partnerships (2019). Accessed 20 Dec 2019
8. Congress of Local and Regional Authorities.: Congress President meets with UN Secretary General. Council of Europe Portal https://www.coe.int/en/web/congress/presidency/-/asset_publisher/XKZo3826TCuM/content/congress-president-meets-with-un-secretary-general?inheritRedirect=false (2019), Accessed 24 Jan 2020
9. Hirata, S.: Higher education practices accounting for gender differences in technological development as part of SDGs achievement. In: Lee, M.J.W., Nikolic, S., Wong, G. K. W., Shen, J., Ros, M., Lei, L. C. U., Venkatarayalu, N. (eds.) Proceedings of 2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering, TALE 2018 Wollongong, Australia, pp. 207–214 (2018)
10. Tull, R., Jangha, S., Medina, Y., Bell, T., Parker, R.: Sharing peace engineering with US-based minority students, through the UN's sustainable development goals, in Peru. IEEE (2018). https://doi.org/10.1109/weef-gedc.2018.8629764
11. Maclachlan, A., Joye, N.: Project education-based applied technologies for poverty alleviation, ending hunger, achieving food security and promoting sustainable Ag. IEEE Canada International Humanitarian Technology Conference (IHTC). IEEE (2017). https://doi.org/10.1109/IHTC.2017.8058170
12. Ramirez-Mendoza, R.A., Morales-Menendez, R., Iqbal, H., Parra-Saldívar, R.: Engineering education 4.0:—proposal for a new curricula. In: IEEE Global Engineering Education Conference (EDUCON) (2018). https://doi.org/10.1109/EDUCON.2018.8363376
13. Sanchez, D. O. M.: Sustainable development challenges and risks of industry 4.0: a literature review. Global IoT Summit (GIoTS). IEEE (2019). https://doi.org/10.1109/GIOTS.2019.8766414
14. Klaus, S.: The Fourth Industrial Revolution. World Economic Forum. https://www.weforum.org/about/the-fourth-industrial-revolution-by-klaus-schwab (2016). Accessed 20 Dec 2019
15. del Val Román, J. L.: Industria 4.0: la transformación digital de la industria. Revista Deuso Ingeniería. https://revistaingenieria.deusto.es/industria-4-0-la-transformacion-digital-de-la-industria/ (2016). Accessed 22 Dec 2019
16. Ngjeqari, V.: The sustainable vision of industry 4.0. The Role of Information and Communication in achieving Sustainable Development Goals. United Nations Industrial Development

Organization. https://www.unido.org/news-centre/events/past-events/unidos-50th-anniversary-youth-competitions/unidos-50th-anniversary-research-paper-competition (2016). Accessed 23 Dec 2019
17. Romero, D., Wuest, T., Stahre, J., Gorecky, D.: Social factory architecture: social networking services and production scenarios through the social Internet of Things, services and people for the social operator 4.0. In: Lödding, H., Riedel, R., Thoben, K.D., von Cieminski, G., Kiritsis, D. (eds.) Advances in Production Management Systems, pp. 265–273. Springer, Cham (2017)
18. Romero, D., Stahre, J., Taisch, M.: The operator 4.0: towards socially sustainable factories of the future. Comput. Ind. Eng. (2020). https://doi.org/10.1016/j.cie.2019.106128
19. Romero, D., Stahre, J.: Social sustainability of future manufacturing—challenges & strategies. 2019 World Manufacturing Forum Report—Skills for the Future of Manufacturing. (2019). https://www.researchgate.net/publication/336134963_Social_Sustainability_of_Future_Manufacturing_-_Challenges_Strategies. Accessed 18 Jan 2020
20. Schot, J., Steinmueller, W.E.: Three frames for innovation policy: R&D, systems of innovation and transformative change. Res. Policy **47**, 1554–1567 (2018)
21. Ramirez, M., Romero, O., Schot, J., Arroyave, F.: Mobilizing the Transformative Power of the Research System for Achieving the Sustainable Development Goals. SPRU working paper series (2019). https://doi.org/10.2139/ssrn.3497623
22. Ting, B., Daniels, C.: TIPC policy brief -transforming science, technology and innovation policies in Africa: insights from Ghana, Senegal and South Africa. Transformative Innovation Policy Consortium. https://www.tipconsortium.net/wp-content/uploads/2019/12/4575_TIPC_policy_brief_03_2nd.pdf (2019). Accessed Jan 26 2020
23. Tecnologico de Monterrey.: Learning–teaching model: Tec21. Tecnologico de Monterrey. https://tec.mx/en/model-tec21 (2019). Accessed 25 Jan 2020
24. Casanova, A.M., Caballero, A., Kandri S.E., Kerr, T., Sterlin, E.: Breaking paradigms to develop leaders for the 21st century. Tec de Monterrey: How a Top University in Mexico Radically Overhauled its Educational Model. International Finance Corporation. https://www.ifc.org/wps/wcm/connect/06d96e58-6aa1-4317-8ce3-87fb60b86cd1/IFC-TechMontereyCaseStudy-final-2.pdf?MOD=AJPERES&CVID=mYvGsnF (2019). Accessed Jan 25 2020
25. Science Policy.:United Nations Secretary-General´s Scientific Advisory Board. The world Academy of Science. https://twas.org/united-nations-secretary-generals-scientific-advisory- board (2016). Accessed 20 Oct 2019
26. Rivas, D.F., Castro-Hernández, E., Perales, A.L.V., van der Meer, W.: Evaluation method for process intensification alternatives. Chem. Eng. Process. Process Intensif. **123**, 221–232 (2018)
27. Gudino-Paredes, S., Rivera-Vázquez, N.: My teacher is a hologram: measuring innovative STEM learning experiences. In: IEEE Integrated STEM Education Conference (ISEC) (2019). https://doi.org/10.1109/ISECon.2019.8882042
28. Membrillo-Hernández, J., Muñoz-Soto, R. B., Rodríguez-Sánchez, Á. C., Díaz-Quiñonez, J. A., Vazquez-Villegas, P., Castillo-Reyna, J., Ramírez-Medrano, A.: Student engagement outside the classroom: analysis of a challenge-based learning strategy in biotechnology engineering. In: IEEE Global Engineering Education Conference (EDUCON) (2019). https://doi.org/10.1109/EDUCON.2019.8725246
29. WHO and UNICEF.: Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines. UNICEF. https://apps.who.int/iris/bitstream/handle/10665/258617/9789241512893-eng.pdf (2017). Accessed 22 Jan 2020
30. Sustainable Goals Development.: Transforming our world: the 2030 agenda for sustainable development. Resolution. United Nations https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pdf (2015). Accessed 22 Jan 2020.
31. Parra-Saldivar, R., Bilal, M., Iqbal, H. M.: Life cycle assessment (LCA) in wastewater treatment technology. Current Opinion in Environmental Science & Health (2020). https://doi.org/10.1016/j.coesh.2019.12.003
32. Fleacă, E., Fleacă, B., Maiduc, S.: Aligning strategy with sustainable development goals (SDGs): process scoping diagram for entrepreneurial higher education institutions (HEIs). Sustainability (2018). https://doi.org/10.3390/su10041032
33. Kestin, T., van den Belt, M., Denby, L., Ross, K., Thwaites, J., Hawkes, M.: Getting started with the SDG in universities. Sustainable Development Solutions Network. https://ap-unsdsn.org/regional-initiatives/universities-sdgs/university-sdg-guide/ (2017). Accessed 21 Oct 2019