Recycling and Sustainable Development

Social challenges in education for sustainable engineering future - transformative guideline

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A R T I C L E   I N F O

A B S T R A C T

Engineers are educated and trained to take the lead in sustainable development, tackling worldwide difficulties like depletion of natural resources, contamination, fast-growing populations, and ecological degradation. The relevance of government entities dealing with sustainable development is linked to the societal problem of future education. While all social-economical and/or technical variables play a role in determining the outlook in which each competence originates, novel-adaptive thinking, social intelligence, design mentality, and sense-making, social imagination (cross-sectoral fertilization), cognitive load management, virtual collaboration and networking, and novel media literacy suggest representing crucial drivers for the development of each ability. An extensive selection of continuing education programs enables graduates to improve subject-specific skills and extend their professional networks, with the objective of preparing motivated and highly-trained professionals for the job market. It is feasible to achieve the aim of a sustainable engineering future by recognizing the relevance of these criteria, comprehending, and adequately fulfilling them.

1. Introduction

Nowadays, there are numerous challenges that people face when it comes to the environment, and currently some of them are global warming, loss of biodiversity, food security, sustainable energy supplies, and overuse of resources. There is an urgent need to engage the entire society in order to tackle with the global challenge of climate change. To overcome this existential goal, the advances in environmental, so called - green, technologies, have to be enclosed with the economic value and social attitudes. The distinction of knowledge production and specific-sectoral training system presents important drivers to achieve sustainable development. Environmental education still remains highly specialized and predominantly focused on natural sciences, with socio-political and empowerment aspects only marginally included if at all (Pineda-Martos et al., 2022). Moreover, environmental education in different disciplines focuses on acquiring specialized knowledge and, while this remains essential, fostering knowledge alone, without links to real life, personal experiences, competencies, and values, is insufficient (Hadjichambis et al., 2020).

Institutional and non-institutional education represents a crucial element in creating a positive impact on environmental behavior. The successful implementation of the European Green Deal must also be carried out through educational system reforms to ensure that all are equipped to meet the challenges of the future, including those related to the labor market (Pineda-Martos et al., 2022). Therefore, 'tailored educational curricula' (Weissbrodt et al., 2020) must contain key competencies and skills needed to support a green economy. Socially and environmentally responsible behaviors may be further reinforced by impermanent education (such as through workplace retraining). Education for the future is a social challenge attached to the importance of public organizations dealing with the environment and climate change.

2. Sustainable engineering practice

2.1. Sustainability - the common denominator

The latest 'State of the environment' report from the European Environmental Agency (EEA) warns that Europe will not meet its 2030 targets unless immediate action is taken in the next ten years to address the 'alarming rate of biodiversity loss'. (European Environment Agency, 2020) Increasing impacts of climate change and the over-consumption of natural resources are present. European countries, leaders, and policymakers are urged to seize the opportunity and use the next decade to radically scale.

The common denominator of society, the environment, and technology - the three fundamental pillars of the circular economy - is presented via multidisciplinary and application-oriented research in conjunction with partners from industry, science, and administrative agencies. (Velenturf and Purnell, 2021)

2.2. Circular economy

Circular economy in Europe: insights on progress and potential, a recent European Environment Agency research, showed that investment in upscaling innovative technologies and tracking progress toward circularity will aid circular economy projects in Europe. According to the survey, European businesses are constantly embracing circular business models, with an emphasis on operational efficiency and waste reduction. Moving away from product-based business models and toward provider, company models are also considered a promising trend. According to the survey, 21 of the 32 EEA member countries that responded supported corporate sustainability proposals, which included the use of regulation and market-based instruments for recycling, energy recovery, and waste management, as well as softer policy instruments like labeling requirements and awareness-raising for green building,

utilization, and reusability. (Ozturk, 2019) Many crucial data, such as manufacturing and supply stages of the production process life cycles, are not obtainable in existing systems engineering, particularly government data, according to the research. It also emphasizes the importance of integrating corporate sustainability policies and efforts with bioeconomy and climate policies. The textile industry is mentioned as a large water user, while the surface and groundwater sector is emphasized as a substantial source of waste flows. Small to medium-sized businesses throughout the European continent were seen to be lowering material and water use, mostly to save inner manufacturing costs. (European Environment Agency, 2016)

2.3. Internationalization

These socio-economical and environmental challenges require a global approach involving cooperation between countries and researchers around the world. Exchange programs for students and staff are an important way of establishing and strengthening collaboration. The experience from different countries provided by these programs leads to a broader general understanding of society and the environment. The professional and methodological skills are expanded, and their social and personal competencies are developed, making it easier for students to start on their career paths. Students can be helped to better integrate their concepts into the work by incorporating fundamental skills and understanding through educational internship opportunities. (Tynjälä, 2008) A further bonus is an improvement in foreign language skills.

2.4. Research-relevant specialization

The primary focus is on sustainable research, development, and services. They are able to answer complicated challenges due to the wide range of themes and tight collaboration between research units and other universities. Collaboration with the federal government, municipalities, private enterprises, and commercial partners is critical to ensuring the social relevance of their programs and promoting their practical execution. Furthermore, Engineers Without Borders has launched Community Engineering Corps to handle environmental, power, structural, and civil engineer concerns for areas that cannot afford professional technical and engineering advice. (CEC, 2022)

2.5. Individual professional specialization

Nowadays, living in harmony with nature is of utmost importance, which at the same time requires responsible action – not only to satisfy our own demands but also in the interest of future generations. The goal is to prepare motivated and highly-trained specialists for the labor

market, where the wide range of continuing education programs enable graduates to develop their subject-specific skills and expand their professional networks.

2.6. Interdisciplinarity

Unfortunately, one of the current deficiencies related to interdisciplinary is that formal education systems limit communication between different experts. In order to compensate for this deficiency, it is necessary to educate a new generation of professionals and improve the ability of professionals to communicate with different experts and lay communities. One of the conditions for the emergence of modern types of interdisciplinary pedagogies is the formation of educational groups that combine different types of knowledge or sciences (for example, social, ecological and biological sciences). The development of this approach, which includes experiential learning and the collaboration of pedagogues and students from different fields, enables future experts to respond to the complex challenges posed by climate change and the lack of implementation sustainable development in practice.

2.7. Monitoring the impact

To promote sustainable innovations and entrepreneurship in the fields of society, environment, and technology, the main pillars have to be gathered in the following direction:

- Society as a hub for environmental and sustainable issues. Through its behavior, society not only influences production methods and innovation efforts but also dictates the transformative guidelines and further political agenda;
- The environment as a living space and a uniform reflection of society. People change the environment, resulting in the common changes that affect society both directly and indirectly;
- Technology as a human instrument and an important factor that influences the environment. Societal and political portfolios indicate how technological developments are driven forward (conventional towards green solutions, and vice versa) and used, and thus also have an effect on resultant consequences.

3. Future work skills 2020

While all social-economical and/or technological drivers are important in shaping the landscape of future engineering skills, these skills have particular relevance for education in sustainable engineering future:

1) Novel-adaptive thinking;

2) Social intelligence;
3) Design mindset and Sense-making;
4) Social imagination (cross-sectoral fertilization);
5) Cognitive load management;
6) Virtual cooperation, networking; and
7) Novel media literacy.

3.1. Novel adaptive thinking

Rather than being inert beneficiaries of the unavoidable transformation that is emerging in this ongoing period, it is important for society to be the one that directs this transformation for the sake of societal structure and coming generations. To provide it, it is necessary to be adaptive, i.e. to recognize that what has happened in history may not ensure success in this fast-paced transformation phase that will shape tomorrow. According to Kolb, an individual's ability to adjust and evolve during their lifetime is strongly influenced by their capacity to react proficiently to changes. (Kolb et al., 2001; Kolb and Kolb, 2009) "Adaptive flexibility" is the term for this capability. Individuals with a high degree of adaptive flexibility may quickly alter their learning algorithm to the needs of the scenario. (Duchesne, 1997)

3.2. Social intelligence

According to Al-Janabi, the capacity to comprehend and engage with people, and analyze and adjust their behaviors in order to attain personal and social advantage represents social intelligence. (Al-Janabi, 2019) The engineering faculty's major mission is to educate qualified engineers for the local economy. Academic institutions play an important role in the construction and refining of an engineer's consciousness, in terms of providing academic education. Hanbazazah stated that the three skill categories with the lowest ratings are likely the most significant in the work area: cooperation, conflict resolution, and social adaptability. (Hanbazazah, 2020)

Social skills such as emotional intelligence, creative perspectives, and integration in interdisciplinary backgrounds will facilitate us to maneuver through the pace of the fast global cultural evolution in a fair and green manner as machine learning, robotics, and biotechnology become more prevalent in the job market. Hard skills may be acquired, but it is the approach, perspective, and capacity to work successfully with one another as individuals that distinguish us from computers with formulas and programs.

3.3. Design mindset and Sense-making

It is critical to foster an engineering mentality that emphasizes the necessity of having a sense of creativity, as this is a primary consideration for future engineers.

Skill sets that may be learned via interdisciplinary education where human and social sciences comprehend science and technology and vice versa are highly necessary in order to thrive in The Fourth Industrial Revolution. Furthermore, because vision, imagination, and flexibility are not readily computerized qualities, prospective students and engineers need to nurture these characteristics in order to succeed in a progressively mechanical world. Asunda et al. have reported a study related to critical features of engineering design in technology education based on interviews with professors fully engaged in engineering education, but also supporting documentation. Professors should search out efficient strategies to assist their students to focus and engage in the planning phase and the utility of issue answers, according to the findings. These competencies can aid students to develop skills to solve the issues they confront on a constant schedule. (Asunda and Hill, 2007)

3.4. Social Imagination

Mills defined social imagination as a state of mind that allowed one to comprehend history and biography, as well as their interrelationships within society that every human should adopt. (Mills, 2000) While explaining the importance of social intelligence for engineers, it is crucial to note that technical practice does not take place in a bubble. Instead, it takes place in social circumstances that influence engineers' way of thinking and their decisions. In other words, engineering practice is based on creating an easier, better life for humans but also considering sustainability factors. Social factors that impact engineering issue creation and solving problems, on the other hand, are mostly unseen to individual engineering students. (Johnson et al., 2015) Academic education does not provide enough engineering students with the knowledge and skills needed in engineering practice. However, implementing social imagination basics in engineering studies or any other has a role to reveal social factors that shape the behavior of future engineers in practice. This way, future engineers are more likely to be encouraged, self-assured, motivated, and engaged, but also creative when transferring the acquired knowledge into practice. (Leydens et al., 2021)

3.5. Cognitive load management

The origins of cognitive load theory may be traced back to educational studies. It is assumed that learning entails a cognitive load that is restricted by working memory capacity. Dias et al. have explained the word "cognitive load" as a combination of factors such as cognitive stress, mental strain, and mental effort. (Dias et al., 2018) The most straightforward explanation for the significance of these elements stems from the simple truth that greater efficiencies and performance with increasing cognitive load up to a degree. However, overtraining sets in after

this and the result is a reduction in performance quality. Low cognitive load leads to a state of undertraining and, as a result, a drop in performance. (Zimmerer and Matthiesen, 2021)

It is critical to maintain control in this manner by concentrating on the learning phase, the student, and the learning process. Having to learn from disparate pieces of knowledge necessitates more selective attention movement, making the mental consolidation required to comprehend the learning activity more challenging than acquiring from a single source. In addition, inexperienced learners understand more by examining completed cases with solutions than by addressing identical issues. While struggling to understand tasks through critical thinking, on the other hand, students devote the majority of their capacity to implementing the solution approach, resulting in greater unnecessary mental demand and, as a result, almost no educational material. As noted, this theory is related to inexperienced, young students. However, students with more knowledge and experience often do not need already solved repetitive problems, but new unsolved problems to gain more experience. Paas has stated that learners should work together on educational activities to maximize accessible cognitive capabilities, transfer data related to other methodologies, or put more effort into the activity. (Paas and van Merriënboer, 2020)

3.6. Virtual cooperation, networking

According to Shirado and Christakis, the significance of cooperation in human societies is complex, and multiple methods are necessary to maintain it, despite the fact that it frequently regresses over time. (Shirado and Christakis, 2020) Online technology has had little importance in this education until recently, but it can no longer be regulated now without it.

Today, multimedia education is getting a lot of traction as a result of the growing users of digital technology along with the Corona pandemic that drastically altered collaborative practices. The new educational methodology encourages education in a variety of settings, and is, therefore, therefore an important aspect in improving teaching and learning regardless of the learner's circumstances or geographic area. As a result, it offers a genuine learning environment in which students may establish interconnections to the actual world while studying. (Curum and Khedo, 2021) Although the implementation is carried out by participants may be varied, networking shares knowledge, skills, and resources across locations for the mutual benefit of all participants. Networks can bring participants from many sectors or levels of the educational system to each other to pool their combined experience, i.e. all parties must recognize the benefit of becoming a member of the cloud infrastructure for it to work well. All performers profit, but not at the price of anyone else's advantage.

3.7. Novel media literacy

The advancement of technology and its incorporation into all aspects of people's lives has made it possible for the first time to have instant and unrestricted access to massive amounts of information that is continually enriched, altered, and updated. Including its participatory and more personalized online content, the Digital revolution media communication technologies modified people's routines and behavior, creating a new method for attaining key cues. They are quickly becoming a popular indispensable provider of instruction and a vital instrument for the establishment of innovative reading skills. No other education tool has been embraced by so many people, in so many diverse areas, in such a short amount of time, and with such far-reaching repercussions. (Kumar, 2020) However, new media literacy, as defined by Koc and Barut, is a notion that encompasses a set of critical abilities such as critiquing, generating, and engaging in 'technology-based socio-cultural platforms', as well as aspects of the ubiquitous computer environment. (Koc and Barut, 2016)

Today, young engineers and scientists use social media sites like LinkedIn, Research Gate, and Google Scholar to share their knowledge with the scientific community and possible employers. Certainly, there are many more people who are governed by the old way of thinking and have not yet encountered the social networks that the new century has delivered. This is especially true of elder generations, while younger generations are progressively becoming involved and building their own base, allowing them to obtain new experiences while also sharing old ones with colleagues all over the world. As indicated by the growing interest in social networking in the digital realm, new media literacy is evolving. However, more work is required in the near future to accurately estimate current recent advancements in social media in relation to engineering students.

4. Conclusions

Sustainable development guarantees that socio-economical, and ecological structures are not jeopardized, preserving both the micro-and macro quality of life as well as the viability and range of environmental surroundings. In terms of sustainable development, education, both formal and informal, is a critical component in influencing environmental behavior in a good way. Today, in order to stay up with the fourth Industrial Revolution, the right circumstances must be in place to assure long-term development. Future engineers must have particular attributes and talents in order to usher in a new age of technological advancements. These elements are related to novel adaptive thinking, which is defined as the introduction of new techniques for solving issues based on faculty knowledge, as well as thinking outside the box.

Other factors include finding deeper meaning in negative issues, connecting with other experts from related and unrelated fields who can help solve puzzles in person, developing social intelligence, not retreating to their own hidden world, and utilizing new platforms on social networks that will enable the exchange of information among engineers around the world. In this approach, a more comprehensive view of global sustainability, engineering practice, and the application of innovative ideas to tackle current and future challenges may be obtained. Certainly, achieving the required sustainability will take a lot of effort and labor, but the reason for doing so should be a brighter tomorrow for us and future generations.

References

Al-Janabi S. A., Cognitive Psychology, Amman, Al-Yazuri House for Publishing and Distribution, 2019,

Asunda P. A., Hill R. B., Critical features of engineering designin technology education, Journal of Industrial Teacher Education, 44 (1), 2007, 25-48,

Community Engineering Corps, CEC, https://www.communityengineeringcorps.org/about-us/ (last access, 18.04.2022).

Curum B., Khedo K. K., Cognitive Load Management in Mobile Learning Systems: Principles and Theories, Journal of Computers in Education, 8, 2021, 109-136,

Dias R. D., Ngo-Howard M. C., Boskovski M. T., Zenati M. A., Yule S. J., Systematic Review of Measurement Tools to Assess Surgeons' Intraoperative Cognitive Workload, British Journal of Surgery 105 (5), 2018, 491–501,

Duchesne R., Critical thinking, developmental learning and adaptive flexibility in organizational leaders, Adult Education Research Conference, Stillwater, OK, 1997,

European Environment Agency, Circular economy in Europe (Developing the knowledge base), EEA Report No 2/2016, Publications Office of the European Union, Luxembourg, 2016, 37, ISBN 978-92-9213-719-9,

European Environment Agency, The European Environment - State and Outlook 2020 (Knowledge for Transition to a Sustainable Europe), Publications Office of the European Union, Luxembourg, 2020, 496, ISBN 978-92-9480-090-9,

Hadjichambis A. Ch., Reis P., Paraskeva-Hadjichambi D., Činčera J., Boeve-de Pauw J., Gericke N., Knippels M.-Ch., Conceptualizing Environmental Citizenship for 21st Century Education, Volume 4, Springer International Publishing, Cham, Switzerland, 2020, 261,

Hanbazazah A. S., The Need for Social Intelligence Training for Industrial Engineers, Industrial and Systems Engineering Conference (ISEC), IEEE, July 11 2020, Makkah, Saudi Arabia, 2020, 1-5,

Johnson K., Leydens J. A., Moskal B. M., Silva D., Fantasky J. S., Social Justice in Control Systems Engineering, 122nd 2015 ASEE Annual Conference & Exposition, 14 - 17 June 2015, Seattle, Washington, 2015, 26.1378.1-26.1378.20,

Koc M., Barut E., Development and validation of New Media Literacy Scale (NMLS) for university students, Computers in Human Behavior, 63, 2016, 834-843,

Kolb D. A., Boyatzis R. E., Mainemelis C., Experiential learning theory: Previous research and new directions, In Perspectives on thinking, learning, and cognitive styles, (Eds.) Sternberg R. J., Zhang L.-f., Lawrence Erlbaum Associates Publishers, 2001, 227-247,

Kolb A. Y., Kolb D. A., Experiential Learning Theory: A Dynamic, Holistic Approach to Management Learning, Education and Development, In The SAGE Handbook of Management Learning, Education and Development; SAGE Publications Inc., 2009, 42-68,

Kumar R., Digital Information Literacy among the Engineering Students: A Survey, Library Philosophy and Practice, 4326, 2020,

Leydens J. A., Johnson K. E., Moskal B. M., Engineering Student Perceptions of Social Justice in a Feedback Control Systems Course, Journal of Engineering Education, 110, 2021, 718-749,

Mills C. W., The Sociological Imagination, Oxford University Press, New York, 2000, 256,

Ozturk, E. D., Europe's urban air qualityre-assessing implementation challenges for cities, Task Force on Integrated Assessment Modelling (48th meeting), April 23-24, 2019, Berlin, Germany,

Paas F., van Merriënboer J. J. G., Cognitive-Load Theory: Methods to Manage Working Memory Load in the Learning of Complex Tasks, Current Directions in Psychological Science, 29 (4), 2020, 394-398,

Pineda-Martos R., Andreucci M. B., Atanasova N., Baganz G. F. M., Calheiros C. S. C., Castellar J. A. C., Đolić M. B., Istenić D., López A. M. L., Ribeiro A. R. L., Langergraber G., How Nature-Based Solutions Can Contribute to Enhance Circularity in Cities, In: Vasconcelos C., Calheiros C. S. C. (eds), Enhancing Environmental Education Through Nature-Based Solutions, Integrated Science, 4, Springer, Cham., 313-343, https://doi.org/10.1007/978-3-030-91843-9_19,

Reichel, Almut.; de Schoenmakere, Mieke.; Gillabel, Jeroen.; European Environment Agency. Circular Economy in Europe: Developing the Knowledge Base.; Publications Office, 2016; ISBN 9789292137199,

Shirado H., Christakis N.A., Network Engineering Using Autonomous Agents Increases Cooperation in Human Groups, iScience, 23 (9), 2020, 101438,

Tynjälä P., Perspectives into learning at the workplace, Educational Research Review, 3 (2), 2008, 130-154,

Velenturf A. P. M., Purnell P., Principles for a Sustainable Circular Economy, Sustainable Production and Consumption, 27, 2021, 1437–1457,

Weissbrodt D. G., Winkler M. K. H., Wells G. F., Responsible science, engineering and education for water resource recovery and circularity, Environmental Science: Water Research & Technology, 6 (8), 2020, 1952-1966,

Zimmerer C., Matthiesen S., Study on the impact of cognitive load on performance in engineering design, DS 109: Proceedings of the Design Society: 23rd International Conference on Engineering Design (ICED21), 16-20 August 2021, Gothenburg, Sweden, 2021, 2761-2770.

Društveni izazovi u obrazovanju za budućnost održivog inženjerstva – transformativne smernice

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INFORMACIJE O RADU

I Z V O D

Inženjeri se obrazuju i obučavaju da preuzmu vođstvo u održivom razvoju i da se bore sa problemima širom sveta, kao što su iscrpljivanje prirodnih resursa, kontaminacija, porast populacije i ekološka degradacija. Relevantnost državnih organa koji se bave održivim razvojem povezana je sa društvenim problemom budućeg obrazovanja. Dok sve društveno-ekonomske i/ili tehničke varijable igraju ulogu u određivanju perspektive iz koje svaka kompetencija potiče, prilagodljivo razmišljanje, socijalna inteligencija, kreativno razmišljanje, davanje smisla, društvena imaginacija (međusektorska fertilizacija), upravljanje kognitivnim opterećenjem, virtuelna saradnja i umrežavanje, kao i nova medijska pismenost predstavljaju ključne pokretače za razvoj svake sposobnosti. Veliki izbor programa kontinuiranog obrazovanja pruža mogućnost onima koji su diplomirali da unaprede veštine specifične za njihovu oblast i prošire svoje profesionalne mreže, a sa ciljem da se motivisani i obučeni stručnjaci pripreme za tržište rada. Moguće je postići cilj omogućavanja održive inženjerske budućnosti tako što će se prepoznati važnost ovih kriterijuma, omogućiti njihovo razumevanje i ostvarivanje.