2023

Engineering Curriculum Redesign: Is My School Ready For This?

Aikaterini BAGIATI
Massachusetts Institute of Technology, United States of America, abagiati@mit.edu

Julia REYNOLDS-CUÉLLAR
Massachusetts Institute of Technology, United States of America, jreyn@mit.edu

ENGINEERING CURRICULUM REDESIGN: IS MY SCHOOL READY FOR THIS?

Aikaterini Bagiati [1]
Massachusetts Institute of Technology
Cambridge, MA, USA
ORCID 0000-0003-4238-2185

Julia Reynolds-Cuellar
Massachusetts Institute of Technology
Cambridge, MA, USA
ORCID 0009-0003-0953-3137

Conference Key Areas*: Curriculum Development, Innovative Teaching and Learning Methods*
Keywords*: Curriculum change, curriculum redesign, organizational readiness, institutional readiness, self-assessment tool*

ABSTRACT

As humanity keeps facing grand challenges engineers are expected to be at the forefront and keep providing sustainable solutions to extremely complex problems. In the meantime, we have reached an era where technological advancement moves at a very rapid speed. That poses a big question to academia. “How should we educate engineers to ensure that they are best prepared for a complex world?”

For an engineering curriculum to remain effective and relevant frequent redesign is critical. Despite this generally agreed upon understanding, universities sometimes operate under great pressure and move into initiating curricular change without having considered how multifactorial this process can be. At the same time there are

[1] *Corresponding Author*

A. Bagiati

abagiati@mit.edu

little to no tools to help them determine institutional readiness for engineering curriculum redesign.

The Massachusetts Institute of Technology (MIT) has placed quality engineering education at the core of its mission since its founding in 1861. Since then, MIT has not only founded a great number of very advanced forward-thinking engineering programs, but has also collaborated with a big number of international governments and schools in order to guide and support their engineering curriculum change. The Abdul Latif Jameel World Education Lab (J-WEL) is a global consortium within MIT working on this exact topic. J-WEL staff are currently working with experts on said matter to develop a tool that universities could use in order to self-assess their initial readiness as well as their progress as they move on with their curriculum redesign process. This practice paper presents the first iteration of said tool.

1 INTRODUCTION

“Climate changes, water and food scarcities, a rapidly expanding population with longer life expectancies, increasing migration and displacement, looming threats of terrorism and nuclear deployment; are all posing mounting challenges for contemporary and future engineers” [1] Within this context, as humanity keeps facing grand challenges, engineers are expected to be at the forefront and keep providing sustainable solutions to extremely complex problems.
Although we live in a world of rapid technological development that often provides great solutions, this may come with a cost. Development in the field of Artificial Intelligence (AI) for example is expected to provide multiple solutions to these challenges and affect an increasing range of professional sectors, however “potential impacts of AI indicate both positive and negative impacts on sustainable development” [2]. In 2020 Vinuesa et. al. performed a first systematic analysis on “how AI can either enable or inhibit the delivery of all 17 goals and 169 targets recognized in the 2030 Agenda for Sustainable Development", and concluded that “AI may act as an enabler on 134 targets (79%) across all SDGs, generally through a technological improvement … However, 59 targets (35%, also across all SDGs) may experience a negative impact from the development of AI” [2]. Truby also points out how big tech's unregulated roll-out of experimental AI poses risks to the achievement of the UN SDGs, “with particular vulnerability for developing countries.” [3]. Furthermore, when examining the future of work, “nearly all experts agree that machine learning, AI, and workplace automation following developments in these fields will replace many jobs worldwide” [4], while the COVID-19 crisis has only accelerated this transition.

1.1 Skills for the future

There is no doubt that today’s workforce will need to learn new skills and to learn how to continually adapt as new challenges emerge and new occupations become critical. Defining the most desirable skill set while also designing educational reform and supporting sustainability is a hot topic of discussion among many academic and professional communities. According to Sarma and Bagiati while “fundamental scientific and technical knowledge is always vital, the development of such competencies as leadership, technical communication, cross-cultural

communication, project management, leadership, team work, and problem solving are becoming more sought-after skills in the job market [5].” In the meantime, “as the world moves toward a digital economy, work is becoming more digital, remote, collaborative, and international” [5] while international virtual teams form and disband faster than ever. Examining the same topic, research by the McKinsey Global Institute [6] has looked at the kind of jobs that will be lost, as well as those that will be created, and it has inferred the type of high-level skills that will become increasingly important. According to their analysis the need for manual and physical skills, as well as basic cognitive ones, will decline, but demand for technological, social and emotional, and higher cognitive skills will grow. One more analysis was conducted by J-WEL. Over a period of two years, researchers analyzed 41 skill-related published frameworks and interacted with over 40 faculty, staff, and thought leaders [7]. From their research derives the J-WEL Matrix below (Figure 1).

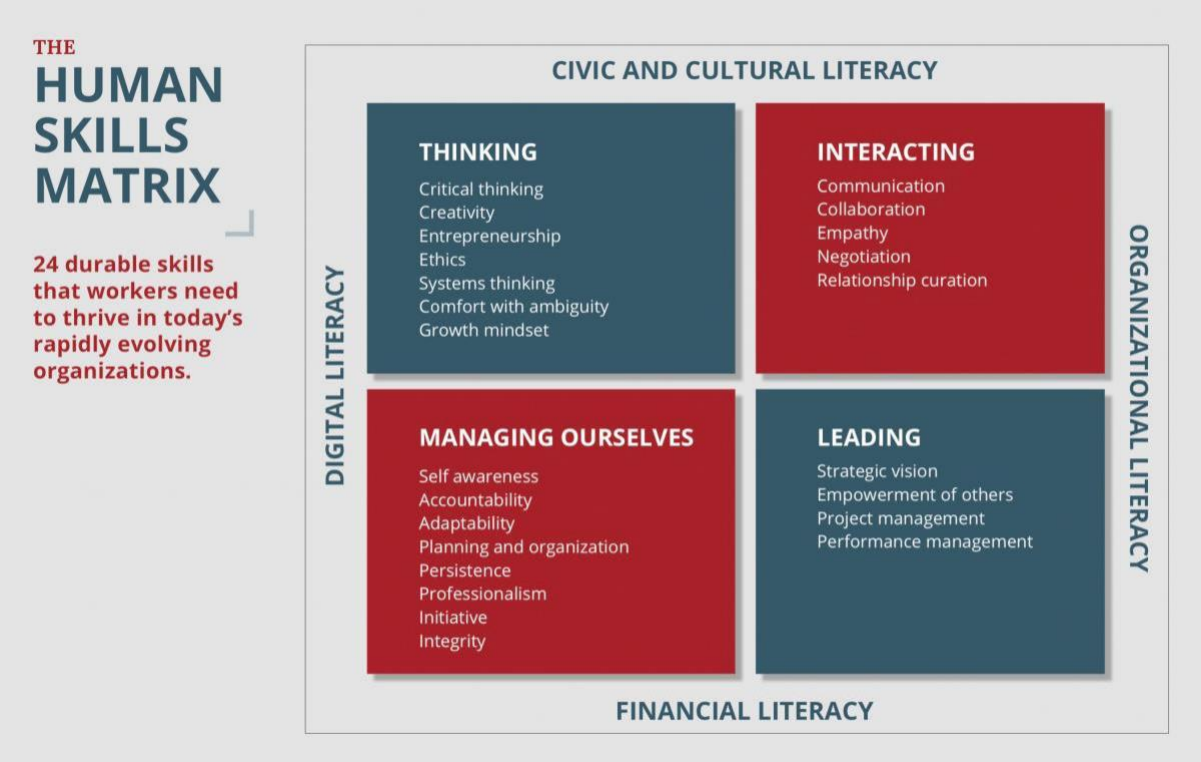

Fig. 1. The MIT J-WEL Human Skills Matrix (https://jwel.mit.edu/human-skills-matrix)

Within this context it is now critical for academic institutions to graduate students who can address the grand challenges of today and tomorrow with sustainability being at the epicenter of their academic philosophy. That will require updated curricula and employment of new pedagogical methods to best support this

goal, and also the involvement of multiple stakeholders that will need to support this mission.

2 SUSTAINABILITY AND EDUCATIONAL TRANSFORMATION AT MIT AND BEYOND

MIT addresses issues and topics of sustainability and grand challenges through a variety of different platforms and approaches. One such approach is the MIT Office of Sustainability. By utilizing the campus as a testbed and incubator, this office aims "to transform MIT into a powerful model that generates new and proven ways of responding to the challenges of our changing planet." [8] Relevant to engineering curriculum, the Office of Sustainability supports multiple sustainability minors (defined in the US as a secondary area of specialization beyond a college major degree program) that are multi-disciplinary and works to ensure that sustainability is fully integrated into teaching. Another initiative towards the same direction is the establishment of the New Engineering Education Transformation program, where students from various majors collaborate in highly multidisciplinary teams to work on authentic problems. The ideas of sustainable development are clearly rooted within the Climate and Sustainability program thread.
Educational innovation has always being at the heart of MIT, in order to promote excellence and transformation in education at MIT and worldwide. In 2017 the Abdul Latif Jameel World Education Lab (J-WEL) was launched as a joint initiative between MIT and Community Jameel. This consortium engages with global partners through a membership program. The majority of members are universities from across the globe that are addressing a specific challenge or goal they have within their own campus. In specific cases, the work of members may warrant a larger custom project that will engage J-WEL staff, MIT faculty and the members. Goal of the members is very often course and curriculum design as well as change of management and systems thinking within their higher education institutions.

2.1 Readiness Assessment Tool

While working with multiple members for years it has become obvious to the J-WEL team that member institutions often lack the understanding of how complex and multifactorial the process of redesigning an engineering curriculum can be, in order to successfully address all aforementioned needs. At the same time, when conducting a literature review there was little to no information at all regarding preparing and guiding an engineering school through the curriculum redesign process and the necessary organizational change process, especially one that would reflect state of the art educational needs. With this gap in mind authors engaged into the design and testing of a tool that could introduce member universities to all factors deemed essential during their curriculum redesign journey, that could also be used by them as a self-assessment mechanism helping them to track progress.

3 METHODOLOGY

3.1 Designing and Testing the Readiness Assessment Tool

Authors of this paper based the first development on two documents. First is the Sarma and Bagiati paper [5], commissioned by the National Academies of Engineering, discussing equity needs for the future and presenting 10 current pathways to innovation in STEM education (Table 1.) The second paper is a very detailed presentation of the development of a tool measuring organizational readiness for curriculum change in the medical field [9]. Authors adapted the aforementioned tool, specifically in terms of the critical factors, in order to reflect current needs in engineering education, and then asked five experts to go through each item presented in the tool and rate it according to their perception of importance during the process of engineering curriculum redesign (with 1 being the least important factor and five being the most important factor), as well as providing additional recommendations about factors they consider critical. The panel of five experts consisted of two MIT faculty and one program director all with extensive experience in developing engineering schools and programs, and two faculty from institutions that have collaborated with MIT in the past when designing/reviewing their engineering curriculum.

Table 1. Innovations in STEM Education [5]

1. Applying Active Learning Pedagogies	2. Implementing Competency Based education
3. Adopting a Multidisciplinary / Integrative Approach	4. Supporting beyond classroom learning experiences
5. Providing flexible, cost-efficient educational paths to continuous learning	6. Enhancing Inclusive Entrepreneurship and Innovation
7. Providing advanced support mechanisms for educational research and development	8. Developing new credentials.
9. Support connections with K-12 and peer learning/mentoring	10. Enhancing sharing and dissemination of information

4 RESULTS

Table 2 presents the organizational readiness assessment tool as well as the mean score as provided by the five experts for each category of the tool. The first two questions do not have a score, but developers think that these are questions important to clarify and consider at the beginning of the process, as they also guide the curriculum redesign process. It is expected that different countries follow different

top-down or bottom-up approaches when it comes to topics such as introduction of educational innovation. Furthermore, depending on the country, there may be different governmental influences in academia.

The scale used was 1-5, with one being the least important factor and five being the most important factor (factors scored below were considered more important the closer they are to 5). Those ranked as being the most important factors by our expert respondents include ‘Focus on training students on professional/soft skills’; ‘University leadership is supportive of the curricular change’; and ‘Faculty and teaching personnel duties are clearly aligned to the goals of this change’.

Table 2. Organizational Readiness Assessment Tool for Engineering Curriculum Redesign.

Theme	Factors		Expert Score
Pressure to Change initiated from the	1. University Leadership 2. Faculty 3. Government 4. Students	5. Industry 6. Community 7. Alumni	
Necessity to Change	1. Future of work 2. Grand challenges that need to solved		
Appropriateness	1. The new curriculum will focus on training students on professional/soft skills 2. The new curriculum includes real life problems as identified by the community/industry 3. The new curriculum is guided by the latest findings of the science of learning 4. The new curriculum will focus on training students for state-of-the-art technical skills 5. The new curriculum aligns with requirements as stated by local accreditation mechanisms		4.60 4.40 3.83 3.80 3.75
Management & Leadership support	1. University leadership is supportive of the curricular change 2. University leadership is willing to provide time to staff and faculty involved in the curriculum change process 3. Government is supportive of the curricular change 4. University leadership has effective systems in place to support the change 5. University leadership is willing to provide resources 6. Government has effective systems in place to support the change.		4.80 4.20 4.00 3.80 3.40 3.40
Staff culture: Faculty and teaching personnel …	1. ...are willing to innovate and/or experiment to improve teaching 2. ...cooperate to maintain and improve effectiveness of teaching 3. ...feel a sense of personal responsibility to improve teaching and learning 4. ...are ready for co-teaching a multidisciplinary / cross-disciplinary course		4.40 4.40 4.40 4.25

	5. ...discuss this change with each other in both formal and informal situations	4.20
	6. ...work together as a team	4.20
	7. ...are receptive to changes in the curriculum	4.20
	8. ...share responsibility for the success of the curriculum redesign	3.80
	9. ...university leadership has effective systems in place to support the change	3.80
	10. ..are ready for co-teaching a traditional course	3.50
Formal Leader of this Innovation…	1. ...accepts responsibility for the success of this project	4.40
	2. ...cooperates well with the both university leadership, faculty and teaching personnel	4.20
	3. ...has the authority to carry out the implementation of this change	4.20
	4. ...has been identified	4.20
Key stakeholders involved	1. Have all stakeholders been identified?	4.20
	2. Have all stakeholders been involved?	4.00
Project Resources	1. Faculty and teaching personnel training on new content	4.40
	2. Faculty and teaching personnel awareness of this change	4.40
	3. Evaluation mechanism	4.20
	4. Faculty and teaching personnel training on new pedagogies	4.20
	5. Expert staffing	4.00
	6. Facilities	3.80
	7. Equipment and materials	3.40
	8. Financial resources	3.40
Clarity of Missions and Goals	1. Faculty and teaching personnel duties are clearly aligned to the goals of this change	4.60
	2. Curriculum developers presented clear goals and objectives regarding the new curriculum	4.40
	3. Faculty and teaching personnel understand how the change fits in with the desired competencies of learners	4.20
Implementation Plan	1. ...acknowledges faculty and teaching personnel input and opinions	4.20
	2. ...includes appropriate training	4.20
	3. ...includes a plan for improvement based on recurring evaluations	4.00
	4. ...identifies specific roles and responsibilities	4.00
	5. ...describes tasks and timelines	3.80

FUTURE WORK

Authors are currently incorporating additional expert suggestions, and will first share the tool with J-WEL's university-members who are currently working on curriculum development and reform, receive further feedback from members, and use this opportunity reiterate and improve the tool. Particular attention will be paid in order to identify cases in which what the tool suggests may be counter to local legislations, conditions, academic cultures, and protocols. Members are expected to use this tool

when they will start planning their curriculum design/redesign, but also use it for regular check-ins throughout the process to identify and measure progress.

Following this stage, authors will make the updated version of the tool open and useable for all and share widely via the J-WEL website.

Furthermore, there is opportunity for future work by sharing this tool with policy makers and determining if it may influence the way they design educational policy and how they might support and encourage academia partnerships with local communities and the industry.

REFERENCES

[1] TC. Haldi, A. Bagiati, E. Crawley (2019) "Developing MIT's LASER -- Leadership Academy for Scientists, Engineers, and Researchers -- Program" Proceedings of the 47th SEFI Conference, 15-19 September, Budapest, Hungary

[2] Vinuesa, R., Azizpour, H., Leite, I. et al. (2020) The role of artificial intelligence in achieving the Sustainable Development Goals. Nature Communications, Vol. 11, pp. 233. https://doi.org/10.1038/s41467-019-14108-y.

[3] Truby, J., (2020), Governing Artificial Intelligence to benefit the UN Sustainable Development Goals, Sustainable Development. Vol 28, pp.946–959..

[4] Hobson ,L., Carramolino, B., Bagiati, A., Haldi, TC., Roy, A.(2020) Teaching and Learning Technical and Managerial Leadership Skills Through Scenario-Based Learning. Proceedings of the 48th SEFI Conference, 20-24 September, Enschede, The Netherlands.

[5] Sarma, S., Bagiati, A. (2020) *Current Innovations in STEM Education and Equity Needs for the Future.* Paper commissioned by the National Academies of Science, Engineering, and Medicine. Presented at the *Imagining the Future of Undergraduate STEM Education* Symposium on Nov 13, 2020.

[6] Dondi, M., Klier, J., Panier, F., (2021), Defining the skills citizens will need in the future world of work. McKinsey&Company. Retrieved May 5th 2023 from https://www.mckinsey.com/industries/public-and-social-sector/our-insights/defining-the-skills-citizens-will-need-in-the-future-world-of-work#/

[7] Stump, G., Westerman, G., Hall, K. (2020) Human Skills: Critical Components of Future Work. *The Evolllution*. As retrieved on Oct 6th 2020 from https://evolllution.com/revenue-streams/workforce_development/human-skills-critical-components-of-future-work/

[8] http://sustainability.mit.edu/.

[9] Bank, L., Jippes, M., van Luijk, S. , de Rooyen, C., Scherpbier, A., Scheele, F. (2015) Specialty Training's Organizational Readiness for curriculum Change (STORC): development of a questionnaire in a Delphi study. *BMC Medical Education.* Vol. 15, 127. https://doi.org/10.1186/s12909-015-0408-0.