



A Conceptual Curriculum Design Approach for Educating Engineers of and for the Future

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ABSTRACT

The 4th Industrial Revolution (I4) highlights the demand for engineers equipped with technical expertise, emotional intelligence, communication, leadership, and critical thinking skills to navigate the complexities of modern engineering. This conceptual paper presents a future-oriented approach to engineering curriculum development, emphasizing the adoption of Outcome-Based Education (OBE) and project-based learning. The integration of key frameworks, such as the Conceive Design Implement Operate (CDIO) model and blended learning techniques, enhance the learning experience. The curriculum aims to align with global goals, including the UN Sustainable Development Goals and the 14 Grand Challenges for Engineering. An innovative curriculum is designed to inspire students' passion for engineering and engage them with emerging technologies, such as additive manufacturing and artificial intelligence. By equipping graduates with the necessary skills and knowledge, this curriculum strives to make a significant impact on society, fostering sustainability and addressing complex engineering challenges. This paper contributes to the field of engineering education by providing a comprehensive and forward-thinking approach to curriculum development.

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1. INTRODUCTION

Over the recent decades, engineering faculties experience a continuous necessity to alter and upgrade the existing curricula to meet the ever-changing and more complex societal and industry requirements to produce engineers who can deal effectively with present and future global challenges (Al-Obaidi, 2021; Rosina et al., 2021; Al-Atabi et al., 2013).

These challenges include issues arising from the advent of the 4th Industrial Revolution, the United Nation (UN) for Sustainable Development Goals (SDGs), and the 14 Grand Challenges for Engineering as identified by the National Academy of Engineering, USA. SDGs become main issues for solving current problems (Maryanti et al., 2022; Nandiyanto et al., 2023; Nandiyanto et al., 2023; Rosliana et al., 2023). Such global challenges necessitate faculties to review and rethink their engineering curricula, ensuring relevance, currency, and applicability for the future. Generally speaking, change in terms of the curriculum is driven by (1) accreditation and engineering education standards as well as global goals and challenges, (2) industry challenges, and (3) the current and future generation of learners. The upcoming subsections will dive deeper into how these three areas of influence drive the development of the curriculum.

Engineering accreditation bodies such as the Engineering Council of the United Kingdom, UK, European Accredited Engineering (EUR-ACE) of Europe, EU, Accreditation Board for Engineering and Technology of America, and the Board of Engineers Malaysia, BEM define sets of learning or program outcomes which are used to evaluate the curriculum quality. These are also termed graduate attributes. Some outcome structures are very broadly defined, leaving the details of curriculum design and the justification to the university and the accreditation evaluators. Other accreditation bodies define outcomes more thoroughly in topic and depth, with accreditation hinging on

the general fit of the curricula to these specifications. Accreditation bodies in general guide what is expected of engineering curriculum, ensuring that the minimum standards are met in enabling the university to produce engineers that meet relevant graduate attributes. This allows engineering faculties to maneuver and innovate in terms of their curriculum, in particular, developing platforms and opportunities for its students to address global challenges. Such global challenges are demonstrated by the Grand Challenges for Engineering. The National Academy for Engineering announced 14 Grand Challenges for the 21st Century engineers to address to ensure a sustainable future for the generations to come. These Grand Challenges are in four broad areas, namely, energy and environment, health, security, and learning and computation.

Another feature of the recent curricula design may also address the UN SDGs. On September 25th, 2015, countries adopted 17 goals to end poverty, protect the planet and ensure prosperity for all as part of a new sustainable development agenda. Each goal has specific targets to be achieved over the next 15 years.

In the 1990s a group of professional leaders from the Massachusetts Institute of Technology (MIT) and three pioneer Swedish universities; Chalmers University of Technology, the Royal Institute of Technology, and Linköping University met to work on a project whose goal was to develop graduates who were “ready to engineer”, possessing both technical fundamentals and pre-professional engineering skills. This project produced a new system which is called the CDIO™ approach – focused on teaching students to, “Conceive-Design-Implement-Operate complex value-added engineering products, processes, and systems in a modern, team-based environment.” Currently over 100 universities are using the CDIO™ approach. The main feature of the CDIO™ initiative is teaching engineering technical fundamentals while simultaneously teaching

professional practice. CDIO™ uses active learning and project-based learning techniques, using Conceive-Design-Implement-Operate as the contextual backbone for all of the classes. This system requires a commitment of faculty and administration to completely revamp the curriculum to improve student educational outcomes (Moore and Frazier., 2017).

2. METHODS

The following describes the research design and framework of the current work. In particular, the research objective, research question, as well as research hypothesis, will be shared, and these will narrate the purpose and scope of the current work.

The research question driving this investigation is: What are the key components within an engineering curriculum that would adequately aid in educating engineers for the future.

The research objective would then be to identify the key components and propose a curriculum structure that educates engineers for the future.

Finally, it is hypothesized that there exists a curriculum structure, which simulates industry in terms of its projects as well as technology, which may prove useful in educating engineers for the future..

3. RESULTS AND DISCUSSION

3.1. Current Studies Relating to Industry

As for the industry, the challenge faced by curriculum designers is how to meet employers' perceptions and expectations. Although the accreditation bodies define a set of skills that graduates should possess upon graduation, industry expectation is beyond these skills. Based on a report issued by the Department of Institutions of Higher Education Management, Ministry of Higher and Education, Malaysia, and based on criteria emphasized for professional skills from the Accreditation of Engineering Programs (EAC) Manual, listed thirteen (13) most important generic skills acquired by the

engineering graduates. Among these skills are: Understanding professional, social, and ethical responsibilities, Competency in theoretical and research, Knowledge of contemporary issues, Lifelong learning, Design and conducting experiments, Entrepreneurial skills, etc. While there have been numerous changes to the EAC Manual over the years, generally speaking, the skills and broad remain the same.

According to a survey conducted in 2015 by the Institution of Engineering and Technology (IET) UK, more than half of employers say that a typical recruit does not meet their 'reasonable expectations' – with two-thirds of companies concerned that the education system will struggle to keep up with the skills required for technological change. Common expectations primarily focused on the prevalence of 'soft' and 'work ready' skills, as opposed to technical requirements. Many feel there is a disconnection between university courses and industry demands, leaving significant gaps in graduate capability. Government, professional bodies, and education institutions should collectively forge stronger links with industry to ensure curriculum and policy align with skills needs.

The fourth industrial revolution is the current and developing environment in which disruptive technologies and trends. The current development is known as

- (i) The Internet of Things (IoT) (Luckyardi *et al.*, 2022; Anh, 2022; Thapwiroch *et al.*, 2021; Jebur, 2023; Pantjawati *et al.*, 2020),
- (ii) Robotics (Castiblanco *et al.*, 2021; Babalola & Omolafe, 2022a; Babalola & Omolafe, 2022b; Kamarudin *et al.*, 2022; Zengin, 2022),
- (iii) Augmented reality (AR) (Ruhimat *et al.*, 2023; Maulana & Kanai, 2022; Widiaty *et al.*, 2021; Bangkerd & Sangsawang; 2021; Albar *et al.*, 2021),
- (iv) Virtual reality (VR) (Ekunola *et al.*, 2022; Bugarso *et al.*, 2021; Azizah *et al.*, 2022; Ekunola *et al.*, 2022; Firdiarahma, 2021;

- Sison et al., 2024; Rivky et al., 2022; Jumansyah & Luckyardi, 2023), and
(v) Artificial intelligence (AI) (Al-Khassawneh, 2023; Alimi et al., 2021; Agarry et al., 2022).

They change the way we live and work [8]. That is why many reports on these matters were conducted. The advent of the 4th Industrial Revolution (I4) leads to the need for emotionally intelligent engineers, thus empathizing with the needs of society, leading to an enhanced ability to develop sustainable engineering solutions for society's grand challenges.

3.2. Current and Future Learners

The recent generation of students, widely known as Gen Y and Gen Z students, is another challenge that the universities should consider when designing their curricula and finding out what are the most suitable and flexible learning and teaching styles to meet the interest of such students. Based on Seemiller and Grace, these students are accustomed to learning to the test and being provided with regular assessment and feedback. They may also have less experience with creative-based learning and may need help developing their creativity.

Generation Z is unique. Generation Z students are less concerned about working for a traditional company with an eight-to-five schedule and 63% of Generation Z students believe that college should teach students about starting a business. Generation Z students have access to more resources than ever before, but they need assistance in learning how to deal with and process information (Billano et al., 2021).

The widespread adoption of wireless and smartphone technology has certainly changed the way that we access information and communicate with one another, but Prensky and Berry (Prensky & Berry, 2001) argued that immersion in video games and other technology changes the structure of the brain and how younger people think and learn, and

that video games should be integrated into learning activities.

The unique experiences, skills, and expectations of Generation Z students should be considered, as educators develop new and innovative ways to instruct future engineers. Understanding the historical context and current best practices of engineering education will help to inform decisions on working with Generation Z students most effectively.

Having all these challenges in mind, and with the opportunities of flexibility in designing the engineering curricula given by the accreditation bodies, the objectives of this conceptual paper is to review and discuss the best-known methods for designing engineering curriculum for the future, with particular interest on how such curriculum prepare the engineers of the future for addressing global issues. Another objective is to propose a conceptual curriculum approach, which aims to educate and prepare engineers for the future.

This section aims to explore the initiatives and efforts adopted by some universities across the world. At the end of this section, a summary is delivered with some recommendations to address the above-mentioned challenges.

Five major shifts in engineering education. During the engineering science revolution, curricula moved from hands-on practice to mathematical modeling and scientific analyses. The first shift was initiated by engineering faculty members from Europe, but the questions were; did accreditation hinder curricular innovations? Were engineering graduates ready for practice? To address this concern, ABET required engineering programs to formulate outcomes, systematically assess achievement, and continuously improve student learning.

The last three shifts are in progress. Since the engineering science revolution may have marginalized design, a distinctive feature of engineering, faculty members refocused attention on capstone and first-year

engineering design courses. However, this third shift has not affected the two years in between. Fourth, research on learning and education continues to influence engineering education. Examples include learning outcomes and teaching approaches, such as cooperative learning and inquiry that increase student engagement. In shift five, technologies (e.g., the Internet, intelligent tutors, personal computers, and simulations) have been predicted to transform education for over 50 years.

Moore and Frazier (2017) explored how universities and colleges should prepare to meet the challenges of instructing Generation Z students, as they are unique students. They discussed what are the changing needs and expectations of Generation Z students. Based on the development and major reforms of engineering education in the USA, they concluded and discussed the potential changes in the classroom and curriculum to address some of the characteristics of Generation Z students. They concluded five areas in particular that deserve attention and can be integrated into the classroom without a complete revamp of the curriculum; 1) Integrate active and problem-based learning, 2) Help students extract answers from an ocean of information, 3) Assess often and provide feedback, 4) Engage creativity, and 5) Help students make connections.

Crawley *et al.* (2005) detailed approaches and experiences from curriculum design efforts based on the CDIO™ model at three universities; Massachusetts Institute of Technology (MIT), Royal Institute of Technology (KTH), and Chalmers University of Technology (Chalmers). Curriculum design involves the development of program learning objectives and the realization of these in the curriculum. The key activity in CDIO adoption and implementation is designing the engineering curriculum to integrate personal, interpersonal, and system-building learning outcomes into the curriculum. At MIT, KTH, and Chalmers, it is found that there are three basic mechanisms for achieving this goal; 1)

First-year introductory courses, which let students engage in the practice of engineering and get a first broad outline of the tasks of an engineer, 2) Design-build-test experiences serve as vehicles for learning modern team-based engineering and provide the context in which to develop many CDIO™ Syllabus skills, and 3) 'ordinary' disciplinary courses can be given an explicit task to contribute to the learning of personal, interpersonal and system-building skills.

Al-Atabi and Tien (2013) reported on a Grand Challenges Scholars Program that is developed to prepare engineering students to be able to address the grand challenges using the CDIO™ framework and focusing on five components: research experience, interdisciplinary curriculum, entrepreneurship, global dimension, and service learning. The program was launched at Taylor's University School of Engineering with 16 participants who are expected to graduate in 2016. A preliminary assessment of the programs shows that the participants found the program useful in developing an array of CDIO™ skills. The school intends to continue offering this program to integrate it with a holistic education approach.

In their research, Namasivayam *et al.* (2017) presented an implementation plan for Taylor's University's School of Engineering's Grand Challenge Scholars Program (TGCSP). The work provided insight into the structure of the TGCSP as well as the details of how the entire program is governed. Also shared are the best practices adopted by the school and the key results obtained by its scholars to date. Lastly, the paper highlighted key areas for improvement, in the spirit of Continual Quality Improvement (CQI) that would lead to the enhancement of the program in the near future.

Yung *et al.* (2016) explored the possibility of delivering holistic education in an engineering curriculum using personalized learning, collaborative learning pedagogy, and appropriate use of technology and space. Surveys were taken and an intervention was

designed to determine the learning styles of engineering students and along with it, a module identifying survey to identify a module to intervene. This was further supported by a survey taken from the industry. The industry survey also supported the importance of affective and psychomotor learning domains. The students were surveyed post-intervention on the effect of collaborative learning, technology, and learning space on their cognitive and affective learning experiences. The statistical analysis showed that there was a significant impact on all areas surveyed except for one. However, the psychomotor domain could not be surveyed since it was not prominent in the identified module. Another survey conducted for learning style indicated that delivery geared to students' preferred learning style was effective.

In their work, Al-Atabi and Al-Obaidi (2011), a unique approach to the use of Project-Based Learning to transform the curriculum into a CDIO™ curriculum is achieved through the use of carefully selected projects for the Engineering Design modules (which are Project Based by nature) and use of the "Engineering Design and Professional Skills" module, offered at the second semester of the second year of a four-year Mechanical Engineering course, in conjunction with a theory based module namely: "Flows with Friction, Drag & Lift" offered at the same semester, to create a CDIO™ environment without introducing any major changes to the syllabus of the theory based modules or their assessment scheme. The students were divided into groups and each group was assigned the task of conceiving, designing, implementing, and operating a fluid-related project. In brief, the "Flows with Friction, Drag & Lift" provided the theoretical backbone for the project, while the "Engineering Design and Professional Skills" module provided the platform through which the project management and teamwork skills are developed, and the progress of the projects is monitored. The

students exhibited a high level of engagement and motivation while gaining a better understanding of the real fluids-related theory.

Bots and Thissen (2000) described a curriculum design in systems engineering, policy analysis, and management (SEPA) at Delft University of Technology (DUT), with a particular emphasis on models, which serve to make knowledge explicit and facilitate communication, and the way they are embedded in a systems approach to curriculum design.

Collins et al. (2019) argued that Challenge-based learning (CBL) can be viewed as an evolution of the Conceive, Design, Implement, and Operate concept, expanding as well as deepening the learning experience. CBL is a multidisciplinary approach that encourages students to work actively with peers, teachers, and stakeholders in society to identify complex challenges, formulate relevant questions, and take action for sustainable development. The study reported investigates the multiple aims of a particular CBL environment (the Challenge Lab at the Chalmers University of Technology), which are to combine significant student learning and societal transformation. The results show that the students perceive that they have developed deep skills in problem formulation and sustainable development, as well as working across disciplines and with different stakeholders. Moreover, the study shows that although few student projects reach the implementation stage, there is a potential for societal impact both during and after the Challenge Lab learning experience.

Everett et al. (2000) The objectives are to define, describe, and discuss integrated programs and their advantages concerning student and faculty outcomes, as well as student retention; and to describe a design process used to successfully develop and deploy an integrated first-year curriculum. The curriculum integrates the first-year components of calculus, chemistry, engineering graphics, English, physics, and

problem-solving. These basic information is important when we do research (Nandiyanto *et al.*, 2018; Maryanti *et al.*, 2020). The results of the design process and the content of the first-year integrated program implemented by the College of Engineering at Texas A&M University are detailed.

Pfotenhauer *et al.* discussed how engineering education in Portugal is being locally transformed with the help of a strong international collaboration. The MIT-Portugal Program (MPP) has gathered the country's leading institutions in an innovative education and research consortium centred on the engineering systems paradigm. The goal is to re-orient engineering education in some key areas more towards innovation, entrepreneurship, and industry cooperation.

The newly created educational programs include mandatory components of innovation, entrepreneurship, management, and leadership skills, to mention a few. A focus on internationalization of education and science, raising the percentage of international students to almost 40% (four times higher than comparable Portuguese graduate programs), and fostering international mobility and outreach. The authors presented the results of multiple surveys to demonstrate how the program, now in its final year of the first 5-year funding phase, has yielded important and visible successes in overhauling engineering education in key areas for Portugal's future. Moreover, the Program trajectory holds important lessons for other countries trying to prepare their traditional engineering education with a greater degree of industry orientation, an innovation-prone ecosystem, and a culture of entrepreneurship.

According to Crawley *et al.* (2008), there are two central questions regarding improving engineering education: 1. What is the full set of knowledge, skills, and attitudes that engineering students should possess as they leave the university, and at what level of proficiency? 2. How can we do better at ensuring that students learn these skills? The

suggested answers lie in an innovative educational framework, called CDIO™ (Conceive-Design- Implement-Operate). The CDIO™ approach is described along with the needs it meets, its goals, context, vision, and pedagogical foundation. The first question is answered by the CDIO™ Syllabus, and the process for reaching stakeholder consensus on the level of proficiency that students should attain in a given program. The second question is addressed through a best practice approach, which discusses curriculum design, design-implement experiences, teaching and learning, student assessment, program evaluation, and faculty competence. Examples are provided of the implementation of best practices within the CDIO™ program in Aeronautics and Astronautics at the Massachusetts Institute of Technology (MIT).

The structure and contents of the outcome of several accreditation bodies, including the Engineering Council of the UK (EC UK), EUR-ACE of the EU, and ABET of the USA. A thorough comparison and analysis of these three systems of outcomes plus the AEPC outcomes indicate that high-quality, internationally recognizable curricula can be developed when using outcomes as the design specifications of the curriculum, courses, and their contents. Similarities and differences between the outcomes of the bodies are highlighted. Based on this comparison, a comprehensive set of learning outcomes has been developed to serve as the basis of the design of engineering curricula for undergraduate and graduate programs for the Alfaisal College of Engineering at Alfaisal University. The designs for integrated BS, MS, and Ph.D. curricula were developed over two years, based on the defined learning outcomes, by a committee comprised of the Founding Dean of Engineering and faculty from the Massachusetts Institute of Technology (MIT), the University of Cambridge, and independent reviewers. Example BS and MS curricula and their fit to the outcome specifications are described. This approach offers several advantages. First, the

technique allows the design team to directly take advantage of work accomplished by the accrediting agencies in defining program quality. Second, employing internationally-proven quality standards in the design process improves the opportunities for future accreditation from these organizations. Finally, the approach will significantly enhance the success of graduates in work environments throughout the Middle East region, as well as in Europe and North America. Critical thinking as an important graduate attribute is investigated by Ahern et al. (2012). The work described a series of in-depth, semi-structured interviews with academics involved in teaching and learning in

many disciplines, including engineering. The objective of these interviews is to look at how different disciplines define critical thinking and how they teach critical thinking in their courses. The paper also describes how an analysis of student work and module descriptors has led to the development of a model of critical thinking that can be used across disciplines.

As a summary and based on the literature reviewed, **Table 1** shows what efforts and initiatives some universities achieved to address the engineering and technology skills and demand in industry required of future engineers.

Table 1. Summary of some changes in curricula adopted by many universities.

Institution (University)	Curriculum aspect or feature added or altered	Reference(s)
Massachusetts Institute of Technology (MIT), US	• CDIO initiative	(Crawley et al., 2005; Crawley et al., 2008)
Royal Institute of Technology (KTH), Sweden	• CDIO initiative	(Crawley et al., 2005)
Chalmers University of Technology (Chalmers), Sweden	• CDIO initiative • Challenge-based learning (CBL)	(Crawley et al., 2005; Collins et al., 2019)
Taylor's University, Malaysia	• Grand Challenges Scholars' Program • Grand Challenge Scholars Program (TGCSP) - personalized learning, collaborative learning pedagogy, and appropriate use of technology and space • CDIO and Project-based learning	(Al-Atabi & Tien, 2013; Namasivayam et al., 2017; Yung et al., 2016; Al-Atabi & Al-Obaidi, 2011)
Delft University of Technology (DUT), Netherlands	• Systems engineering, policy analysis, and management (SEPA)	(Bots & Thissen, 2000)
Texas A&M University, US	• Integrated programs	(Everett et al., 2000)
MIT-Portugal academic institutions	• Innovation, entrepreneurship, industry cooperation, management, and leadership skills	(Crawley et al., 2008)
Alfaisal University in Saudi Arabia	• Alfaisal Engineering Program Committee (AEPC) outcomes	

There is no doubt that academic institutions will continue such efforts and initiatives to further enhance and modernize their engineering curricula (Adeoye, 2022). However, there is a need to develop an innovative and unique approach with the notion of ensuring that the approach must be essentially based on a standard educational model to meet the requirements of the accreditation bodies, but at the same time, the approach should be also based on project-based learning utilizing the CDIO framework. Another important feature of such an approach is to be flexible to meet the interest and the style of Gen Z students as well as be futuristic to drive and ignite students' passion by engineering gearing or mapping the projects towards the 14 Grand Challenges for Engineering and/or the UN SDGs

3.3. Discussion

From the best-known methods provided in the preceding section, an attempt would now be made to discuss the proposed curriculum structure. Opportunities for improvement as well as other key areas for discussion will be highlighted to identify a sustainable approach.

3.3.1. Educational Model

As prescribed by the Board of Engineers Malaysia, the educational model to be adopted by all accredited engineering degree programs must be that of Outcome-Based Education (OBE). In summary, the OBE model prescribes the type of graduate the school would like to produce and hence develops a set of Program Educational Objectives (PEOs). These are a set of statements of what the school's graduates should achieve 3-5 years after graduation. Based on the PEOs for the Program Outcomes (POs) are crafted. These are a set of statements that prescribe what a graduate should achieve at the point of graduation.

The curriculum is then developed and hence the relevant module or course learning outcomes of the courses are crafted. Curriculum is important for the education

improvement (Widiaty *et al.*, 2020; Landero *et al.*, 2022; Maryanti *et al.*, 2021; Nursaniah, 2023; Maryanti & Nandiyanto, 2021; Gatta *et al.*, 2023; Jamiu, 2022; Wulandari *et al.*, 2022; Widiaty *et al.*, 2020). Direct and indirect measurements are made at the PEO, PO, and LO levels regularly to decide on how to further improve the program annually in the spirit of continual quality improvement (CQI).

It should be noted that the following proposed curriculum concept would align with the accreditation standards as set by the Washington Accord as such a structure would ultimately be accredited to ensure recognition within the Accord itself. It is also important to note that accredited degrees that are to be recognized by the accord would also need to incorporate sustainability, ethics, and social responsibility throughout the curriculum.

3.3.2. Overarching Pedagogies

As evidenced by various authors and investigations, project-based learning is the most ideal pedagogy for education (Wagiran *et al.*, 2023; Puwianingsih *et al.*, 2023; Putra & Sakti, 2022; Muchlis *et al.*, 2023).

This has been described in detail in the preceding section. This pedagogy could be given further structure and enhancement by applying principles that enable it to grow and flourish. For example, to utilize the CDIO™ framework to provide structure to a project-based course or curriculum. A particularly successful example of a curriculum structure that illustrated the application of OBE and project-based learning is provided in (Yong Ze Siin *et al.*, 2020). The authors utilized the CDIO™ approach to assist in the attainment of learning outcomes for an engineering capstone project course – which is a key outcome of an accredited engineering degree.

The application of blended learning is also a key learning delivery method and has shown promise based on the findings of various investigations (Manghano *et al.*, 2022; Ibrahim, 2023; Jibril *et al.*, 2022).

In particular, the technique of a flipped classroom has been particularly successful at

promoting intentional learning and seems to be an appropriate method for implementation in an engineering degree. Take for example a project-based course, where students would be tasked to work in groups to design and build an engineering system that would address an engineering challenge, there would be no need to impart engineering knowledge and skills within such a course. This is because students would have fulfilled the necessary learning outcomes before joining such a course.

The important knowledge and skills that would need to be transferred in such a course would be that of team management, and project management as well as aligning engineering knowledge and skill by applying it to the solution that is being proposed to address the challenge. As such, the blended learning approach may be used to record micro-lectures on the areas mentioned above, allowing students to view this content before group discussion classes with their supervisors.

The discussion sessions with the supervisors would then be more meaningful as students will attempt to address any shortcomings within the areas mentioned previously and the supervisor may work and facilitate these gaps to ensure adequate attainment of the relevant learning outcomes. In essence, such an approach also supports the flipped classroom model, which allows for learning to occur before the start of a class.

The new generation of learners prefers flexibility. The preceding section has detailed how future learners would prefer the option to design their curriculum and choose their destiny. As such, it would make sense to allow for some degree of flexibility, allowing students to choose a small number of modules or courses in the form of elective subjects that could complement their major.

To enhance pass and graduation rates, the curriculum should allow student's retake modules they have failed while still within the stipulated timeframe of the degree, in favor of graduating on time. Similarly, to support

student progression every year, the curriculum should be designed in such a way that year 1 introduces the student to the subject matter in the broadest sense, years 2 and 3 focus on the acquisition of specific and key knowledge and skills and finally year 4 focuses on the application of the relevant knowledge and skills.

3.3.3. Futuristic

The curriculum design should also have a drive and focus that will ignite students' passion for engineering. For example, gearing or mapping the projects towards the 14 Grand Challenges for Engineering (as identified by the National Academy of Engineering, NAE) and/or the UN SDGs would create a reason for why students should work on developing a solution for a specific challenge in the form of an engineering project. The curriculum design should embed the exposure and utilization of technologies that would be driving the future needs of society. In particular, the needs of I4.

If such a curriculum structure can produce engineers who attempt to address these grand challenges, and if this approach is adopted by a majority of engineering faculties globally, the impact this would have on humanity would be significant. In particular, such engineering graduates would aim to address any of these challenges providing an avenue in terms of humanity's sustainability into the 22nd century.

Another way such a curriculum may be futuristic would be to embed I4-related technologies. Examples of which may include additive manufacturing as well as robotics and artificial intelligence, which may be general courses for all engineering disciplines, since such knowledge is becoming prevalent within all industries an engineer may work in. Such specific courses and content may also be tagged with a project-based course since the projects that students design and build may utilize 3D printing and artificial intelligence to some extent.

4. CONCLUSION

In conclusion, this paper has presented a future-oriented approach to engineering curriculum development, focusing on the adoption of OBE and project-based learning. The integration of key frameworks, such as the CDIO model and blended learning techniques, enhances the learning experience and prepares engineers to address the challenges of the 4th Industrial Revolution (14).

Below are the key findings and contributions of this research:

- (i) The proposed curriculum emphasizes the development of not only technical expertise but also essential skills such as emotional intelligence, communication, leadership, and critical thinking, enabling engineers to navigate the complex and interdisciplinary nature of modern engineering (Purwianingsih *et al.*, 2023).
- (ii) The curriculum aligns with global goals, including the UN SDGs and the 14 Grand Challenges for Engineering, fostering sustainability and addressing societal needs.
- (iii) By integrating project-based learning and emerging technologies like additive manufacturing and artificial intelligence,

the curriculum ignites students' passion for engineering and promotes their engagement.

- (iv) The paper suggests actionable steps for implementing the curriculum in engineering faculties, enabling institutions to prepare graduates who are well-equipped to tackle global challenges effectively.
- (v) this research contributes to the field of engineering education by providing a comprehensive and forward-thinking approach to curriculum development, preparing engineers to thrive in the 4th Industrial Revolution and make significant contributions to society.

While the proposed curriculum presents promising opportunities, it is essential to consider potential limitations and challenges, such as faculty training and resource allocation, as institutions adopt and implement this future-oriented approach.

5. AUTHORS' NOTE

The author(s) declare(s) that there is no conflict of interest regarding the publication of this article. The authors confirmed that the data and the paper are free of plagiarism.

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