IDEAS

for better education & training for engineers

Engineering Education for Better Engineering Solutions towards a Sustainable World

Committee on Education In Engineering
World Federation of Engineering Organisations
October 2024

WORLD FEDERATION OF ENGINEERING ORGANIZATIONS

FÉDÉRATION MONDIALE DES ORGANISATIONS D'INGÉNIEURS

COMMITTEE ON EDUCATION IN ENGINEERING

Journal IDEAS No. 22 October, 2024

IDEAS is a publication of the WFEO Committee on Education in Engineering, addressed to engineering educators, educational officers at Universities and leaders responsible for establishing educational policies for engineering in each country. The articles it contains reflect the concern of people and institutions linked to WFEO, to provide ideas and proposals with the object of improving formation of engineers. All the issues of IDEAS were and will be partially financed by World Federation of Engineering Organizations. This issue of IDEAS was financed by the Myanmar Engineering Council.

WFEO-CEIE & Myanmar Engineering Council held an International Conference on Engineering Education Accreditation (ICEEA 2024). The Conferences deliberation was on the theme "Engineering Education for Better Engineering Solutions towards a Sustainable World". The conferences were intended to provide a scenario for the interactions among the professionals and experts from world reputed organizations to achieve the quality engineering education and accreditation. It had been launched and designated also for the purpose of deliberating on quality assurance systems, accreditation system, and the best practice in international and local engineering education.

Distinguished speakers of ICEEA 2024 contributed to the IDEAS Journal (issue number 22) that ***WFEO-CEIE & Myanmar Engineering Council*** publishing in October 2024. There are around 6 international papers on Engineering Education from honorable international experts in this issue.

This issue of IDEAS is financed by the Myanmar Engineering Council.

Editors:
1. Mr. Mustafa B. Shehu, President of World Federation of Engineering Organizations (WFEO)
2. Dr. Marlene Kanga, President of World Federation of Engineering Organizations (WFEO) (2017-2019)
3. Engr. U Aye Myint, Patron of Myanmar Engineering Council
4. Prof. Dr. Aung Kyaw Myat, President of Myanmar Engineering Council, Vice President of ASEAN Academy of Engineering and Technology
5. Prof. Dr. Zaw Min Aung, Chair of Committee on Education in Engineering (CEIE) of World Federation of Engineering Organizations (WFEO) and Engineering Education Accreditation Committee (EEAC) of Myanmar Engineering Council

ISBN – 978-99986-0-252-6

Prepared for printing by:

Committee on Education in Engineering Office (CEIE)-Myanmar

Myanmar Engineering Council

No (5A), Khay Yay Pin Street, Lamadaw Township, Yangon, Myanmar

Table of Contents

Message from President of Myanmar Engineering Council, President of Federation of Engineering Organizations of Asia and the Pacific (FEIAP), Vice President of ASEAN Academy of Engineering and Technology (AAET)

Prof. Dr. Aung Kyaw Myat

"I extend my warm greetings to all research scientists, authors, engineers and colleagues. This journal is one of the successive activities of the Committee on Education in Engineering (CEIE) of WFEO. The IDEAS journal issue No.20 & No.21 were already published in mid-October 2022 & 2023 which reflected the excellent ideas of experts from WFEO.

We encourage the Committee for Education in Engineering to continue its efforts in promoting the integration of the United Nations 2023 Agenda of Sustainable Development Goals (SDGs) into engineering education, educational excellence and innovation and also commend the Committee for its unwavering commitment to advancing engineering education in Myanmar.

This IDEAS journal publication stands as a testament to our shared commitment to improving the quality and relevance of engineering education in our country.

Additionally, the journal offers an excellent platform to emphasize the importance of collaboration and knowledge sharing among educational institutions, industry partners, and other stakeholders. By fostering these partnerships, we can bridge the gap between academia and industry, allowing for a seamless integration of theoretical knowledge and practical application. This collaboration will not only enhance the employability of our graduates but also drive innovation and support economic growth.

MEngC is dedicated to maintaining engineering professional registration and licensing, as well as ensuring the accreditation of engineering education in accordance with the Myanmar Engineering Council Law and the Washington Accord guidelines endorsed by the IEA. We also work with international organizations to facilitate the mobility of Myanmar's professional practitioners in line with global standards.

I would like to extend my sincere gratitude to the Committee and all contributors for their invaluable contributions to this journal. Thank you for your steadfast dedication to engineering education. I am eagerly looking forward to the publication of this esteemed journal and the positive impact it will have on our engineering community."

Prof. Dr. Aung Kyaw Myat
President, Myanmar Engineering Council (MEngC)
President, Federation of Engineering Institutions of Asia and the Pacific (FEIAP)
Vice President, ASEAN Academy of Engineering and Technology (AAET)

Message from Chair of Committee on Education in Engineering (CEIE) of World Federation of Engineering Organizations (WFEO)

Prof. Dr. Zaw Min Aung

"It is my great pleasure to convey my words of thanks to you all concerning publishing the IDEAS 22 by our World Federation of Engineering Organizations - Committee on Education in Engineering (WFEO-CEIE) of Myanmar Engineering Council (MEngC). With papers of speakers presented at ICEEA2024, we have published the issues of IDEAS journal annually with the intention to bring the ideas of Better Engineering Solutions to wider audiences globally. We would do the same for this year's IDEAS journal as well.

May I extend our sincere gratitude for your incredible contribution as the distinguished contributors of IDEAS 22. Your expertise and insights added immense value to the journal and we received numerous positive responses from the editors, highlighting the impact of the papers.

We truly appreciate the time and effort you dedicated to making our journal successful. It is really an enlightening and insightful publication also for both MEngC and WFEO-CEIE. I hope that you all feel the same as I am to be part of this great series of publications. I'd like to draw your attention to share with you how important this publication series is for all of us.

Looking at the IDEAS journals published annually every year, they are very significant because there are articles from both academic and industrial backgrounds. For this year IDEAS 22, there are six international experts sharing the innovative ideas regarding the future engineering goals for the sustainable development around the world.

IDEAS journals devoted to current research and theory as well as future perspectives on better engineering solutions related to learning environments in engineering education. It will give contributors and readers a platform to exchange ideas and broaden their knowledge.

In addition to expressing our thanks, we would love to gather your feedback. We always look for ways to improve our publications. Your suggestions are helpful. Kindly provide any thoughts or recommendations you may have. All these arrangements have been great opportunities to work closely together with many international experts leading new achievements in the engineering education field.

Our distinguished contributors' expertise aligns perfectly with our organization goals and we are keen on exploring potential future. Once again, thank you for your exceptional contributions to IDEAS Journals and we really hope to do this terrific job together for many years to come. We do look forward to working together again and again wish you continued success in your endeavors also."

Prof. Dr. Zaw Min Aung
Chair, Committee on Education in Engineering (CEIE) of World Federation of Engineering Organizations (WFEO)
Chair, Engineering Education Accreditation Committee (EEAC) of Myanmar Engineering Council (MEngC)

Innovative Approaches to Graduate Outcomes through Tertiary Projects: The World Engineering Day Hackathon – Impact on Engineering Students and their Universities

Dr Marlene Kanga AO FTSE FREng Hon.FIEAust, Hon.FIChemE, FISC,
WFEO President 2017-2019

marlene.kanga@wfeo.org

1. Introduction

The World Engineering Day Hackathon provides an opportunity for project based learning through a real world tertiary project that is presented in a challenging environment that simulates the work environment. This global Hackathon is part of the international celebrations of World Engineering Day each year on 4th March and is hosted by the World Federation of Engineering Organisations. The competition has been held since 2021 and attracted more than 2500 registrations from 28 countries in 2024, with a social media reach of nearly 7 million, making it one of the largest engineering competitions in the world. I am proud to have been a member of the working group that has developed the Hackathon and its challenges since its inception.

WFEO is the leading international body for professional engineering institutions, founded in 1968, under the auspices of UNESCO. WFEO members consist of more than 100 national professional engineering institutions and 12 international and continental/regional professional engineering institutions, representing more than 30 million engineers. WFEO is the Co-Chair of the Major Science and Technology Stakeholder Group at the United Nations and represents engineering at major the UN Organisations, including the UNFCCC and the COP meetings, UNEP, UNDP and other UN organisations. The World Federation of Engineering Organizations (WFEO) is committed to advancing the UN Sustainable Development Goals through Engineering.

2. The Importance of Project Based Learning in Engineering Education

Project based-learning is a phrase used to describe a teaching method in which students learn by actively engaging in real-world and personally meaningful projects. This approach is particularly important in Engineering Education where employers are increasingly demanding that graduates have skills that increase their employability. Employers are seeking engineers with critical thinking and problem solving skills, an understanding of complex systems and an awareness of the need for lifelong learning and, importantly good communication skills, the ability to collaborate and work in diverse teams. An example is the characteristics of top employees from Google, shown in Figure 1.

Google

Characteristics of top employees at Google:

1. Being a good coach
2. Communicating and listening well
3. Possessing insights into others
4. Having empathy, supporting ones colleagues
5. Being a good critical thinker and problem solver
6. Connecting across complex idea
7. Great skills in science, technology, engineering or mathematics

See: The surprising thing Google learned about its employees — and what it means for today's students - The Washington Post

Figure 1: Google: Characteristics of top employees.

The process of Project Based-Learning encourages students to develop strategies for project cooperation, organisation, and management and to take responsibility for developing and implementing their solution. They learn to manage project timelines and outcomes, collaborate effectively and engage in a diverse learning environment, support their peers and develop empathy, connect complex ideas and develop systems thinking approaches, develop as creative and divergent thinkers and consider multiple perspectives and review and critically analyse their solution. As a result, students are empowered, become confident learners and in their capabilities and develop conversational and listening skills, all highly valued by employers.

3. The World Engineering Day Hackathon: Judging Criteria aligned to the International Engineering Alliance Graduate Attributes and Professional Competencies

As President of the World Federation of Engineering Organisations, I initiated a bold and ambitious plan to review the engineering education benchmark. The key goal was to ensure that engineering graduates have the attributes and skills to meet current and future needs by employers, industry and the community.

This project was progressed in partnership with UNESCO and peer international organisations in engineering including: the International Engineering Alliance (IEA) a mutual recognition alliance for engineering education, the International Federation of Engineering Education Societies (IFEES) representing educators, the Federation of International Consulting Engineers (FIDIC), representing the consulting industry, the International Network for Women Engineers and Scientists (INWES), representing women engineers, the International Centre for Engineering Education (ICEE, and the UNESCO Category II Centre) at Tsinghua University, China representing engineering education researchers.

The key areas for change included the ability to accommodate future needs of engineering professionals and the profession – strengthen the required attributes on team work, communication, ethics, sustainability, to be able to learn and keep up with emerging technologies and incorporate digital learning, active work experience, lifelong learning. The revised benchmark addressed emerging and future engineering disciplines and practice areas – while retaining discipline independent approach, recognised the need to enhance skills on data sciences, other sciences and for life-long learning. The benchmark also included the need to incorporate UN Sustainable Goals - in the development of solutions that consider diverse impacts – technical, environment, social, cultural, economic, financial and global responsibility, in recognition of the key role of engineers in advancing the UN Sustainable Development Goals (SDGs). The benchmark also recognised the importance of intellectual agility, creativity and innovation – emphasize critical thinking and innovative processes in design and development of solutions. Finally, it also addressed the need for Diversity and Inclusion and to include these considerations within ways of working in engineering teams, communication, compliance, environment, legal etc. systems.

2024 World Engineering Day hackathon Judging Criteria

	Graduate Attributes that are addressed in the solution, referencing the International Engineering Alliance Graduate Attribute and Professional Competency (GAPC) Framework	Not addressed	Limited attempt to address the element	Some success in addressing the element	Good attempt to address the element	Element addressed very effectively
	Maximum Score per Category Score: 0 Score: 1 Score: 2 Score: 3 Score 4	Score 0	Score 1	Score 2	Score 3	Score 4
1	**1 Application of Engineering Knowledge for problem analysis and development of a solution:** The extent to which the team has used its engineering knowledge and skill in developing a solution and the thoroughness with which the problem has been researched and analysed.					
2	**2 Investigation, research, Design/ development and testing of solutions:** The extent of experimentation applied in developing a unique and innovative solution, which also uses new and emerging technologies and ideas.					
3	**3 Extent of use of digital tools and new technologies:** The extent to which digital tools such as computer modelling, Computer Aided Design and Drawing, 3D printing etc. have been used to design, develop and demonstrate the solution					
4	**4 Contribution to UN SDGs and Consideration of broad ethical issues:** The extent to which the solution advances one or more of the UN SDGs and addresses broad ethical issues in terms of impact on the environment, different sections of society and the economy and how these have been addressed, by mitigating adverse impacts and enhancing positive impacts.					
5	**5 Successful Collaborative, Team work project management and Communication of the final solution** The extent to which the team has collaborated successfully and the success of communication of the challenge and the solution developed, successful project management, financial analysis of the feasibility of implementing the solution and plans for its further development.					

Figure 2: The Judging Criteria for the World Engineering Day Hackathon

The resulting benchmark, the Graduate Attributes and Professional Competencies framework, forms the basis of the judging criteria for the World Engineering Day Hackathon and provides engineering students with the opportunity to develop innovative solutions that advance the UN SDGs.

4. The World Engineering Day Hackathon for Engineering Students:

4.1 Process and Judging

The eligibility for entry to the World Engineering Day Hackathon is flexible. Any university student attending any university, for the entirety of the year, whether undergraduate or graduate students, may enter, excluding PhD students. Entries must be made by a group of 2 to 5 individuals working as a team and the team must contain at least 50% of students enrolled in an engineering degree. Entrants are required to provide evidence of their eligibility under the rules as a part of their submission. Example of evidence is a university ID card. An individual may only participate in a single team. They cannot work across multiple teams. Participants from each team do not need to be restricted to the same university or country. Submission (video) can be in any language, but must have English subtitles.

A project report is not required. Only the challenge is defined. The process of developing the solutions is developed by the students and is developed continually during the course of the Hackathon. This is a fast-paced global challenge with two weeks to develop a solution and prepare a 5-minute video that presents the solution.

The cash prizes for 2024 were: 1st place - €4,000; 2nd place - €2,000 and 3rd place - €1,000.

4.2 Challenges and Themes

The theme of World Engineering Day 2024 was *Engineering Solutions for a Sustainable World*. In 2024, the focus was on UN SDG 13 – Climate Action with focus also on SDG2 - Zero Hunger, SDG11 – Sustainable Cities and Communities and SDG3 - Good Health and Wellbeing.

The challenges that were developed were:

Challenge 1 – UN SDG 2 No Hunger: feeding 10 billion people in a changing climate, and sustainably provide affordable, accessible nutritious diets for future populations

Challenge 2 – UN SDG 11 Sustainable Cities: Promote climate action through sustainable cities and communities from the buildings we live in, transport and mobility and data and information to make informed decisions.

Challenge 3 – UN SDG 3 Good Health and Wellbeing: Improve city design and infrastructure, by rethinking new technologies and infrastructure and retrofitting existing ones so that our living places are dynamic equitable places for people to enjoy better health and wellbeing

4.3 Registrations and Prizes

The Hackathon received more than 2500 (1000 in 2023) pre-event registrations, 200+ (112 in 2023) submissions. The competition had 39 judges (27 in 2023) for Preliminary Round and 5 judges from WFEO partners for the Final Round. An automated Portal was used for the judging process.

4.4 Winners of the Hackathon

The winners were announced live on air, on 4th March, World Engineering Day, during the Global Stream, as has been the case for the past three years.

1st place was won by Team SOMIANT, from Yachay Technical University, Ecuador. The team addressed Challenge 2 - SDG 13 Climate Action and SDG 11 Sustainable Communities.

Figure 3: Winner of the 2024 World Engineering Day Hackathon: SOMIANT

SOMIANT (Satellite-Oriented Monitoring of Integrated Analysis of el Niño Tracking) is a climate intelligence network tool which shows the areas that are most susceptible to damage due to the El Niño phenomenon in the coastal area of Ecuador. The tool uses using data from multiple sources to predict weather and provide warnings to the general population. This is a wonderful example of the creative and innovative solutions that are submitted as solutions to the Hackathon challenges.

Further information on the finalists and winners in 2024 and the history of the hackathon can be found at www.worldengineeringday.net

5. The Hackathon: Outcomes and benefits for engineering education

The participating students were surveys for the first time in 2024 and the results are shown below. The characteristics of registered students were:

1. Broad range of disciplines: 25% electrical engineering, 11% civil, 48% other
2. 35% 4th year, 23% second year
3. Female 31% Males 69%

Figure 4: Approaches to developing a solution

Students indicated that they developed a particular approach through group discussion and developed their approach through several iterations, showing that they needed to collaborate and communicate for an effective solution.

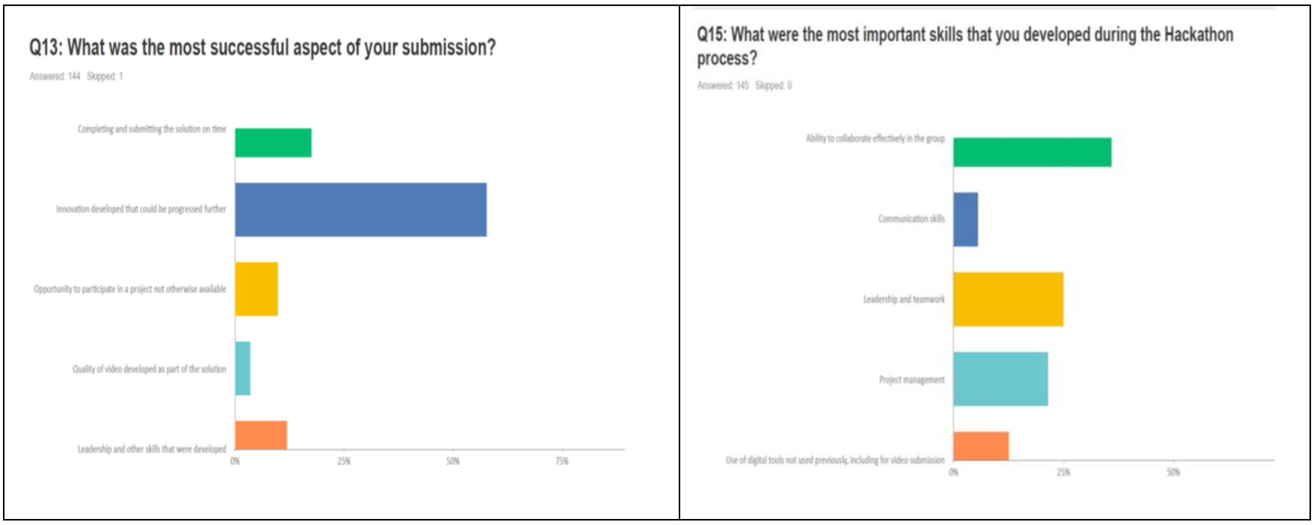
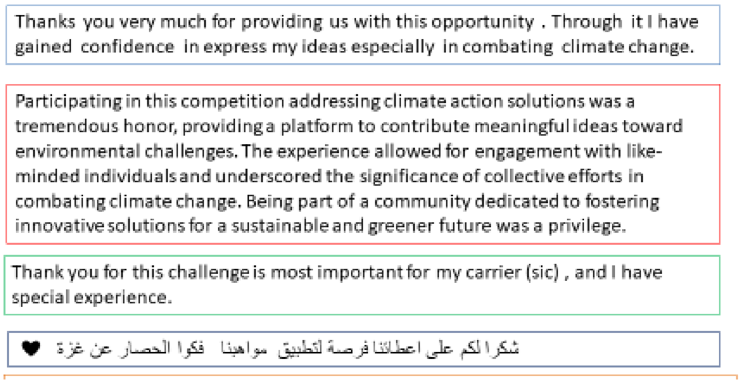


Figure 5: Innovation, Leadership, Collaboration and teamwork were important skills that were developed

Students indicated that innovation was the most enjoyable part of the competition. Leadership, Collaboration and teamwork were important skills that were developed.

Verbatim comment from the students are shown in Figure 6. They show the global reach of the competitors and the enjoyment and learning that was achieved.



Thanks you very much for providing us with this opportunity . Through it I have gained confidence in express my ideas especially in combating climate change.

Participating in this competition addressing climate action solutions was a tremendous honor, providing a platform to contribute meaningful ideas toward environmental challenges. The experience allowed for engagement with like-minded individuals and underscored the significance of collective efforts in combating climate change. Being part of a community dedicated to fostering innovative solutions for a sustainable and greener future was a privilege.

Thank you for this challenge is most important for my carrier (sic) , and I have special experience.

شكرا لكم على اعطائنا فرصة لتطبيق مواهبنا فكوا الحصار عن غزة ♥

Figure 6: Verbatim feedback from hackathon participants.

6. Case Study: Batangas State University: Outcomes and benefits for engineering education

Batangas State University is the national engineering university for the Philippines with more than 30,000 undergraduate students and more than 2000 postgraduates. Recognition of the UN Sustainable Development Goals has been a priority and the alignment of the Hackathon with the SDGs is important The University has been encouraging students to participate in the World Engineering Day (WED) Hackathon since 2022. The WED Hackathon is part of the University annual calendar and is promoted through its Centre for Innovation in Engineering Education. World Engineering Day celebrations at the University include a presentation of all the entries in the global competition and a local Hackathon. The University has been very successful in the Hackathon with a team winning the competition in 2022 and winning 3rd place in 2024.

Figure 7: Consultation for the Case Study on the World Engineering Day Hackathon with Batangas State University: Assoc Prof. Divina Gracia D. Ronquillo, Director, Center for Innovation in Engineering Education (CIEE), Prof. Cristina Amor Rosales, Eng. John Kevin De Castro, Eng Edgardo Titus Jr. Kaalim, 17 May 2024.

The University has a systematic program for the World Engineering Day Hackathon, The University identifies programs that fall within the scope of the challenges each year and runs workshops to promote the Hackathon. It has developed its own promotional publications for the Hackathon and runs a similar local Hackathon within the University. It calls for applications from students in the College of Engineering. Workshops are run with teams to flesh out initial ideas for solutions that respond to the challenges. Ideally the solutions align with a particular aspect of the engineering curriculum. Faculty members volunteer as mentors for various teams to encourage more holistic insights and encourage competiveness and those who volunteer their time are recognized during WED celebrations.

The University encourages students to participate in the Hackathon because of the significant positive benefits it observes as a result of this experience of project based learning. The Hackathon is an opportunity for students to learn about global approaches to sustainable development. All challenges, including from previous years are reviewed by final year students when developing their capstone projects – for ideas, because the challenges present new ways of thinking and develop new ideas. The students also enjoy the social media interactions that promote the Hackathon.

Students develop higher levels of engagement and become more active in their studies and develop a greater awareness of world issues through the challenges. The students refer to previous challenges to develop ideas for their Capstone projects, as every Capstone Project targets at least 1 UN SDG.

Significantly, previous winners have developed into leaders and have done very well academically after the Hackathon experience. Overall, winning in the Hackathon is a big positive for the students and the university and creates pride that a developing country can compete on the world stage e.g. the winners Wonderpets (2022) (all female team) were motivated to become outstanding students and go deeper into engineering and one member topped her batch.

The WED Hackathon has raised the profile of the university and attracts more students. The WED Hackathon brings together innovative apaches in engineering education and engages both students and faculty. The University achievements in the WED Hackathon are promoted to the government: Outcomes of the WED Hackathon are reported to the Commission for Higher Education in the Philippines and the University presents the results of the Hackathon as an example of successful Outcomes Based Education (OBE), a key accreditation requirement of the IEA Graduate Attributes and Professional Competencies benchmark, during accreditation visits. It is partnering with Singapore Polytechnic for future innovations in engineering education.

7. Conclusion

The World Engineering Day Student Hackathon is a Project Based-Learning (PBL) opportunity which, based on research on PBL, will result in higher levels of engagement as the relevance of what students are studying is immediately apparent. In addition, it challenges students to direct their own learning because projects are open ended, requiring them to critically evaluate multiple solutions and justify their decisions; requiring a higher degree of thinking. The case study of Batangas State University indicates that these benefits are occurring.

The Hackathon also develops greater employability skills including complex problem solving, critical thinking, creativity and emotional intelligence. The Hackathon is an effective way for students to gain these skills and to demonstrate these skills in practice to a global audience. Participation and winning, results in improved academic performance as the Hackathon promotes self-discovery, develops problem-identifying and problem-solving skills, leading to deeper understanding of students' engineering skills and abilities. Students are able to demonstrate increased creativity through a student-directed project and encourages exploration of a wide range of solutions and methods, not always considered through conventional teaching. The Hackathon experience enables students to be connected and engaged with their studies.

The World Engineering Day Student Hackathon is an opportunity for faculties of engineering education to demonstrate how their students are achieving the IEA Graduate Attributes and the success and impact of their engineering programs.

All engineering faculties are invited to encourage their students, especially final year students, to participate in the World Engineering Day Hackathon. There is no cost and widespread benefits. The Hackathon is announced in early October each year at www.worldengineerignday.net.

Work-Integrated Engineering Education – an Introduction

Prof. Dr. Jürgen Kretschmann,
Hainan Bielefeld University of Applied Sciences, Hainan, China

Abstract

The world is now changing almost continuously and very rapidly. Multifaceted challenges are facing humanity. Great minds have highlighted that you cannot solve problems on the same level of consciousness that created it. Better engineering is a basis to give our planet and our people the best possible perspective. It can ensure a safer, more fair, healthier, more efficient and peaceful future. To improve the world in a sustainable and an ethically responsible manner, future engineers need the best possible education. Students should learn to develop and apply better technologies, and universities have a responsibility to deliver them outstanding knowledge based on best possible methods. In the applied sciences know-how should not only be generated and transferred within academic circles, but should be primarily used in real life. Theory has to be integrated with practice. In the classroom engineering students should be empowered to meet challenges in life, at the working place and beyond.

This paper introduces a innovative approach in engineering education based on the cases of work-integrated study programs at the Hainan Bielefeld University of Applied Sciences in Hainan, China.

Keywords: Engineering education, work-integrated study program, empowerment, university-industry partnership

1. Introduction: Engineering education for a better future

The increasing speed of technological progress especially, is constantly producing new and revolutionary innovations such as Artificial intelligence, robotics, nanotechnologies, 3D-printing, blockchain and smart grids. In addition to technological change, the challenges of climate change, population growth and urbanization require innovative engineering and technology, better solutions and transfer, plus increasing engineering capacity and competence building. Given the speed of these changes, and the challenges faced by humanity, the engineering profession itself, also "needs to undergo transformative development worldwide to address the multifaceted challenges facing humanity" (Gong 2021, p. 12.).

"For millennia, engineers have been recognized as individuals with the ability to find solutions for everyday problems" (Kanga 2021, p. 18.). Today, engineering has a central role in the United Nations 2030 Agenda for Sustainable Development (SD) adopted by the United Nations 2015 (UNESCO 2021.). Better engineering is a basis to give our planet and our people the best possible perspective. It can ensure a safer, more fair, healthier, more efficient and peaceful future.

"Engineering is a problem-solving profession" (Kolmos 2021, p. 122.). Engineers have a creative mindset, are innovative, and seek improvement. Engineers actively contribute to the innovations in their companies and beyond. They influence practically everybody´s daily life, everywhere, today and tomorrow. Engineering can lead to results that can change parts of the world forever. Currently we see this in the development of artificial intelligence (AI).

2. The Two Worlds-Problem

To improve the world in a sustainable and an ethically responsible manner, future engineers need the best possible education. Students should learn to develop and apply better technologies, and universities have a responsibility to deliver them outstanding knowledge based on best possible methods. Regarding the rapid technological evolution the learning outcome in "engineering education should follow suit, which will involve changes to both the content of education and the method of learning" (Kolmos 2021, p. 122.). The aim is clear, but practically there are several challenges to meet. It is a question what the best possible education might be? The main stakeholders in education, the students and their universities, the companies as future employers and the society might have different opinions. If there is a disconnect between students´ study at university and what employers value in practice ("two worlds") it might have the consequence of a high youth unemployment rate. All-time highs in graduates from universities and colleges don´t automatically lead to economic growth rate, if the supply with graduates does not meet the demand, quantity is not quality. The "two worlds" can become even more separated if there is an additional disconnect between the students´ focus on degree studies and their personal career preparation, especially if a prestigious university level brand is more important than good job perspectives of an individual program in a lesser known institution.

Two educational worlds can emerge if the student´s competencies are mostly based on theoretical knowledge (know why) and are focused on a narrow subject–area "inside a box". The students learn what the teachers say. The situation in the classroom is hierarchical and teacher-centered. Students have to give "right" answers. In contrast of this employers value practical learning with impact (know how) based on transversal skills (problem-solving, communication, teamwork, creativity, emotional intelligence…) with a focus on real-world challenges "out of the box". They prefer graduates who have developed self-responsibility and –management and innovative thinking. “Can-doers” with soft qualities like willingness to engage in lifelong learning.

To avoid the “two-worlds-problem” in engineering educational approaches need to move away from the traditional teacher-driven theoretical based system towards a more student-centered and problem-or work-based one, and from the technical knowledge focus to a much broader interdisciplinary approach to learning (Gong 2021, p. 14). This approach should aim to empower the students to meet future real-world challenges pragmatically, efficiently, effectively, and sustainably.

The interests future employers, students and society can be outlined as follows (See figure 1).

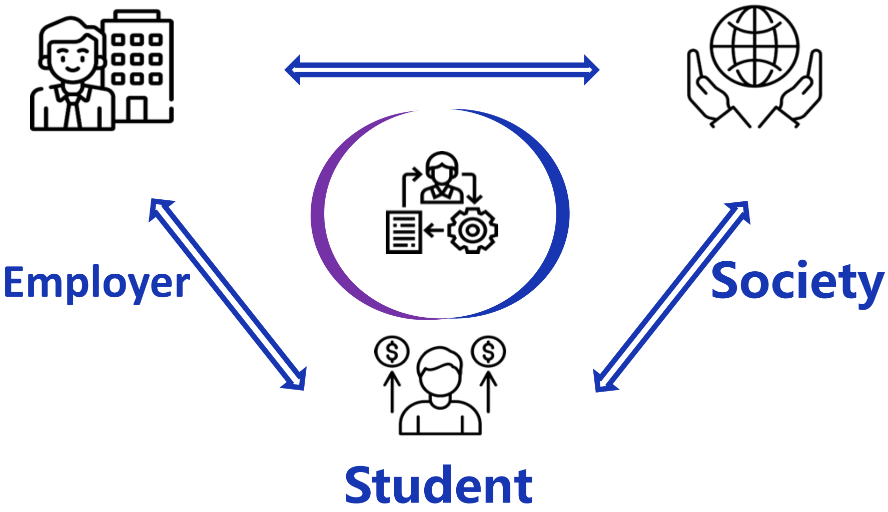


Figure 1: Main Stakeholders of Engineering Education

Future employers prefer to employ excellent educated talents who are highly motivated and loyal to secure their future competitiveness. In the best-case scenario, there is no gap between the required skills and the available talent and all graduates are productive and innovative for the company from Day 1. The students are interested in a future-orientated study program, an ideal preparation for their professional life, job security, career perspectives, and a suitable job environment. The society needs highly qualified experts with the required skills for the job market. It is crucial that graduates can be integrated into the job market as soon as possible so that they can contribute to social stability in their communities (avoidance of emigration). Later, they can help to secure sustainable development in the region if they are able to work in an innovative environment like a high-tech zone, a science park, or a special business incubator.

That´s why the development of engineering education should be the joint effort of many stakeholders like governments, academia, industry, engineering organizations and even civil society. Fostering partnerships between universities, companies, administrations, and governmental institutions are crucial for this. Universities are part of a local, regional and often global network. They are funded with public money, so they have the responsibility to meet big and small challenges of society and its stakeholders with excellent education, research and transfer. Students should be aware of this and be integrated in the societal networks of the universities to be able to contribute positively to them. Sometimes this is called the “third mission” of the university next to education and research.

3. Integrating theory and practice in education

Today academic knowledge is mostly published through the internet and high-ranked journals in a one-way transfer. But one-way communication from academia to the “outside world” is not enough to secure sustainable effects on science, society and politics. Theory has to be applied. This is not a new insight. The famous German scientist Gottfried Wilhelm Leibniz wrote in his dissertation in the year 1666 that academic disciplines should unite “theoriam cum praxi” (theory with practice) (Leibniz 1666).

In the applied sciences know-how should not only be generated and transferred within academic circles, but should be primarily used to improve the outside world. Therefore, the theoretical input has to be transferred into real life. Applied science aims to provide solutions to everyday challenges that everybody has to face, all around the world. Big challenges like climate change, deforestation or conserving the global fresh water supply; as well as specific problems like implementing safe working conditions in factories and offices. This understanding should be transferred to students, that every challenge is important and every question should be addressed. Teaching applied science should encourage and equip all students so they are ready, willing and able to use their knowledge, not only in their working environment, but also in taking political and social responsibility based on knowledge transfer, self-confidence, dialogue and cooperation.

As Anette Kolmos (2021) has described, re-defining and modernizing engineering education needs both a top-down approach and a bottom-up approach. Based on the university´s mission and the development plan, the university board as the “educational leader” has to define the overall strategy for the future engineering education and implement it top-down. By promoting this strategy, the “usual tradition” of teacher-centered education will be changed by the lectures. Kolmos describes three different strategic options a university could follow to foster application knowledge (know-how, know-why) in engineering education:

- The add-on strategy which adds more student-centered and active learning in the single lectures
- The integration strategy that integrates project-based modules and team learning in the lectures (project management, collaboration in labs) and uses real life projects done in so-called learning factories in existing courses
- The re-building strategy that restructures the whole education program by integrating all kinds of active learning, interdisciplinary project work and work-integration (internships) to educate both technical knowledge and competencies, and professional or employability competencies (Kolmos 2021, p. 125.).

4. Empowerment education in the classroom

The bottom-up approach in engineering education should be based on the empowerment of the student in the classroom. In conventional lectures, the teacher defines what is to be taught and the methods to be used. This also corresponds to a strongly deductive teaching style, which Felder and Silvermann (1988) describe as the prevailing method where teaching starts with principles and "fundamentals" (Felder and Silvermann 1988: 677) and only later proceeds to applications. This approach of lectures is traditionally based on the idea that the lecturer knows everything, while the students know nothing (deficit orientation). The lecturer defines the particular set of what students need to learn and how these learning needs can be met. Students do not have any active role during this process. The lecturer becomes the central point, around whom the entire process revolves. In applied sciences, this method cannot be regarded as state-of-the-art. The success of communication (teaching) depends on the listener not on the speaker. Because of this, effective teaching requires a change of the lecturer´s role from being a mere sender of knowledge to a coach, then to a motivator, and finally, to a mentor.

Participatory training methods are based on an empowerment-orientated approach. They promote learner-centered development through training and learning. Participatory training methods help learners by enabling them to develop knowledge, skills and attitudes individually and to share perceptions so that they can actively contribute to renewal and improvement (Nguyen 2011). They aim to increase the potential of the learner (potential orientation). Empowerment teaching thus boosts the confidence of learners which then impacts on the motivation of learners (Graham et al. 2013).

If participatory training methods are applied during the teaching programs the lecturer can motivate and mentor the learners´ initiative and encourage them to contribute more at work, for example, by looking for difficulties and problems and working out how to improve the situation themselves. Participatory teaching methods promote learner-centered development through learning and practicing. Therefore, teaching should be multi-sectoral, interactive and focused on group work. Participatory teaching is learner-centered as it recognizes, evaluates and seeks to build on the existing knowledge of the learners.

In addition, the lecturer should explain the "big picture" of the lecture, the framework and the rules he expects to be followed in the course of the lectures. It must be kept in mind that learning is set within a frame which might incorporate cultural differences (Hofstede 1986) between the teacher and the learner. Culture is changing. The students from today don´t have the same attitudes as students in the "good old days", when the professors did their own studies.

A main goal of the teacher should be that the students are eager to come to class and learn as they have been inspired by the transmitted new ideas and learning processes. Due to the possibility to contribute to class in a two-way-learning-process (which increased their acting competence) a trust and belief in their competencies is enhanced more and more which contributes to an increasing self-efficacy and self-esteem. This can also impact on students‘ self-belief in their own intelligence and abilities – studies have shown that students' fixed growth mindsets (fixed abilities and intelligence) are predictors of their academic performance (Blackwell et al. 2007).

Planned distractions like participating in sports events, field trips or excursions to cultural sites or even touristic places will foster the group cohesion and support the creation of a student network, which is especially important if students in the courses come from different regions or countries. Extracurricular activities help to overcome barriers between the lecturer and the students and among the students themselves. Enjoying free time together brings collective positive experiences into the classroom. The aim is to create "happy moments" (and many photos by the learners) to show the learners that lecturers can be good company. The learners sometimes will remember these happy moments for the rest of their lives.

By creating a positive and challenging atmosphere the lecturers should guide the students through the exams. Lastly, after the exams, all students should be asked to (anonymously) evaluate the course. Student evaluation of teaching (SET) is an acknowledged instrument of evaluating teaching effectiveness in institutions of higher education worldwide (Spooren et al. 2013). It can give valuable insights into students' reception to further refine and develop the lectures (Gezign 2011). Giving meaningful feedback is also a strong motivation for students' participation in teaching evaluations (Chen & Hoshower 2003) thus accepting students' opinions and feedback may also strengthen the relationship between lecturers and students.

Overall, it is the final and most important task for the lecturer to encourage the students to be proud of themselves. In order to strengthen the emotional bond and build a trustful and long-lasting future relationship, the class and staff of the institution which supported the course could jointly celebrate the end of a course or a semester. This will close the whole education process in an appropriate way.

5. Fostering Employability: Work-integrated study programs

Following the theory of Edgar Dale´s "cone of experiences", people remember much more by field trips, demonstrations and own experiences than by verbal or visual symbols (reading or listening) (Dale 1969). So, the aim of work-integrated studying is firstly to learn with all senses, to develop skills and attitudes, and to understand processes and relations. Learning is often not done with the head alone, but with the hands (touching), the heart (emotions), the skin (heat, coldness) and sometimes with the whole body (very strenuous work), and of course mostly in teams. Secondly, the students get to know why their study program is very relevant in practice, why she or he is important for industry and beyond. Practical work can allow future engineers to gain and apply valuable knowledge through structured, supervised, hand-on experiences (Chakrabarti et al. 2021, p. 131.) The students learn what they will be able to do in the future. This can be an immense driver for their motivation to finish their program as successfully as possible.

Universities of applied science in Germany, for example, are responsible for educating around 70% of all engineers. Since their foundation in 1971 they have been working very closely together with companies and other state-owned and private organizations. These collaborations have been very successful. Today there are more than 200 universities of applied sciences in Germany being a strong pillar for the development of the national economy.

One of them, the Bielefeld University of Applied Sciences and Arts has developed a work-integrated study model based on alternating phases of theoretical and practical education. The theoretical parts are taught in lectures, seminars, exercises on campus, while the practical parts are taught in collaborating companies and other institutions. The joint aim is to train innovative, multidisciplinary and practically experienced talents in line with the needs of economic, social and environmental development. Students should gain fundamental and comprehensive expertise in theory and practice and be proficient in essential procedures. Rich work experience should be combined with high academic standards to develop high-quality engineering talents with excellent employment prospects. This practice-integrated model has been adapted by the Hainan Bielefeld University of Applied Sciences on Hainan Island in China.

During their internship phases, students must be given space to realize self-effectiveness and competence and to develop future skills. They should understand that the details can be seen in the workplace by staff involved directly and not by the management board. Their mentors in practice should foster their acting competence. They should encourage teamwork and demand students' contribution by actively asking questions, sharing experiences and observations, reflecting on implications and consequences and leading the discussion with people in industry. To sum this up, students must test themselves in order to become future engineers, decision-makers and team players. The mentor should set the goals and rules, provide orientation and lead the practical learning process! Most importantly they have to create a positive learning atmosphere with the aspiration in mind – yes, we apply! In many cases the companies will employ the students after the exam, because they simply do a "good job" during the internships.

6. Case Study: The work-integrated study program Digital Technology of Hainan Bielefeld University of Applied Sciences

The first semester is an "onboarding" semester. The focus here is to integrate the students who are coming from many different regions in China into the university and its processes. The first steps involve empowering the students to use their knowledge and creativity, the improvement of their self-organization and team-work, plus the improvement of their language skills as the focus of study programs. The students learn what it means to study engineering and are informed about their career perspectives by the professors and guest lecturers from companies. They are introduced into scientific writing and project work. Furthermore, they have to improve their English skills and start to learn German. In the second and third semester the students learn the necessary fundamental knowledge of their study program: mathematics, foundations of computer science, algorithms and data structures, object-oriented programming, data bases, data security, foundation of business administration and other classes. After a three-month long third semester, the students do their first internship for two months in companies and get the opportunity to apply their knowledge. Of course, at the beginning, the employer has to invest time and efforts in the engineering talents. But, the more they learn in practice the better they know how to apply their knowledge to support the company.

During the following semesters, students expand their theoretical knowledge on campus in classrooms, in exercises and in special teaching support facilities like laboratories or (virtual) learning factories. Courses deal with topics like business process modeling and IT systems, data mining, machine learning, AI, speech and image recognition, web technologies etc. Elective modules are change management, diagnosis and predictive maintenance, industrial control technologies, marketing and technical sales, sensors and actuators among others.

To increase the employability of the students based on the demand of industry and administration lecturers with special expertise from practice are employed. They enrich the theoretical knowledge of the students with their applied knowledge, especially in elective modules. This is a win-win situation for both sides: The students learn about the relevance of their knowledge in future jobs, and the lectures from the companies have the opportunity to get to know students who might be future employees.

The more theoretical, but application orientated education alternates with the internships of the students in practice. A work-integrated study program means the academic year is divided into four parts: the education on campus starts middle of August and ends in November, the internship follows from December until the end of January, the students are back on campus from end of February until middle of May, and learn in the companies again until middle of July. Finally, Bachelor theses will be written companies and supervised by both, the university professor and the expert from practice.

7. University – industry partnership: tripartite agreement with the student

To better cultivate talents for enterprises and realize the work-integrated studying model, a tripartite internship agreement between the university, the enterprise and the students should be formulated. The agreement is necessary to define the rights and obligations of each party. It should be signed by legal or authorized representatives of the University and the enterprise and the student. The term of the agreement should be medium or long term to secure a reliable strategic cooperation in the interest of all participants.

The obligation of the university is to organize interviews with students for internships, work out specific internship plans and timetables with the enterprise. During the internship, the university will appoint a person responsible for supervising and supporting the student, give her or him guidance, and inspect the internship situation. Furthermore, the university has to establish management methods and feedback mechanisms for students in enterprises, motivate them and secure the transparency of information.

The enterprise will appoint a professional tutor to guide the practice process. He is responsible for formulating the internship plan and guiding the content of the internship, as well as carrying out an evaluation and assessment of the student´s internship. The tutor must have a bachelor's degree or higher. He has to guarantee that students will be provided with specific hands-on practice related to their study program and may participate in company projects. The enterprise should provide an appropriate subsistence allowance for the student during the internship.

Students are strictly required to follow the rules governing the internship phase and must not violate the Student Code of Conduct or the company's rules. During the internship phase, students might attend classes or have self-study as required by the university. They have to submit a certificate or internship report on their activities. Besides, they have the obligation to keep trade secrets and confidential matters related to intellectual property rights of the enterprise. This kind of agreement can assure the engineering students can be included in the personal development of the companies. When they have graduated the students should be highly employable. They know their employer, they have seen different sections of it and worked in different projects. They have been empowered, theoretically and practically. So from the first day as an employee, they are able to meet the challenges in the work place, be self-responsible and competent as qualified professionals.

8. Conclusion

In applied sciences like engineering, theory and practice should be developed in harmony. This means that education at the universities should be as innovative as the practice in companies and other institutions. As the philosopher Leibniz said it is a necessity to unite “theoriam cum praxi”. Universities should teach the students both with an integrated strategy from the beginning. This is more efficient than a sequential procedure learning theory first, and years later practice and can avoid the “two-worlds-problem”. The empowerment of the “next generation of engineers” should be the paramount aim of engineering education to secure a sustainable development and a better future for everybody. This could motivate young talents to study engineering. They are having an excellent reason to do so.

9. References

[1] *Blackwell, L. S., Trzesniewski, K. H., and C. S. Dweck (2007): Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. In: Child Development, 78, p. 246–263. http://dx.doi.org/10.1111/j.1467-8624.2007.00995.x, 28 February 2007.*

[2] *Chakrabarti, S., Soeiro A., Baker, N. and J. Kretschmann (2021): Liflong Learning in Engineering: An imperative to achieve the Sustainable Development Goals. In: UNESCO (2021), p. 129-135.*

[3] *Chen, Y. and L. B. Hoshower (2003): Student Evaluation of Teaching Effectiveness: an assessment of student perception and motivation. In: Assessment & Evaluation in Higher Education, 28 (1), p. 71-88.*

[4] *Dale, E. (1969): Audiovisual Methods in Teaching, 3. ed., Dryden Press, University of Michigan.*

[5] *Felder, R. M., and L. K. Silverman (1988): Learning styles and teaching styles in engineering education. In: Engineering Education, 78(7), p. 674–681.*

[6] *Gezgin, Ulas Basar (2011): Potential Problems of Student Evaluation of Teaching (SET) in Off-Shore Campuses in Southeast and East Asia and Suggestions. In: Journal of Higher Education Theory and Practice, 11 (2), p. 90-101.*

[7] *Gong Ke (2021): Introduction. Engineering to accelerate delivery of the Sustainable Development Goals. In: UNESCO (2021), p. 10-15.*

[8] *Graham, Mark J., Jennifer Ferderick, Angela Byars-Winston, Anne-Barrie Hunter, Jo Handelsman (2013): Increasing Persistence of College Students. In: STEM, Science, 341 (6153), p. 1455-1456.*

[9] *Hofstede, G. (1986): Cultural differences in teaching and learning. In: International Journal of Intercultural Relations, 10, p. 301-320.*

[10] *Kanga, M. (2021): Engineering a more sustainable world. In: UNESCO (2021), p. 16-38.*

[11] *Kolmos, A. (2021): Engineering education for the future. In: UNESCO (2021), p.121-128.*

[12] *Leibniz, G. W. (1666): Dissertatio de Arte Combinatoria, in Latin.*

[13] *Nguyen, N. (2011): Participatory training method can be applied in safety training courses in Vietnamese coal mining industry. In: Mining Industry Journal 6, p. 39–40.*

[14] *Spooren, P., Brockx, B. and D. Mortelmans (2013). On the Validity of Student Evaluation of Teaching: The State of the Art. Review of Educational Research, 83 (4), p. 598-642.*

[15] *UNESCO (2021): Engineering for Sustainable Development, published by UNESCO, Paris 2021.*

Engineering Education: Preparing Innovators for a Sustainable Future

Prof Dr Rodrigo Pérez Fernández CEng CMarEng FRINA FSNAME FIMarEST
Universidad Politécnica de Madrid

rodrigo.perez.fernandez@upm.es

1. Introduction

The 21st century has ushered in an era where sustainability is no longer an option but a necessity. Engineers play a pivotal role in designing and implementing solutions that mitigate environmental impact and promote sustainable development. However, traditional engineering education often falls short in preparing graduates to tackle these challenges comprehensively. This paper aims to underscore the importance of reorienting engineering education to better align with the goals of sustainability and to propose strategies for achieving this transformation.

The new century has brought unprecedented environmental and social challenges that threaten the sustainability of our planet. Climate change, resource depletion, pollution, and the loss of biodiversity are just a few of the critical issues that necessitate immediate and effective action. Engineers, as problem solvers and innovators, are uniquely positioned to develop and implement solutions that can mitigate these challenges and promote sustainable development. However, the traditional engineering education model, with its heavy emphasis on technical skills and compartmentalized disciplines, often falls short in preparing graduates to address these complex and interconnected issues comprehensively.

The concept of sustainability involves meeting the needs of the present without compromising the ability of future generations to meet their own needs. It encompasses three key dimensions: environmental, economic, and social. For engineering solutions to be truly sustainable, they must consider all three dimensions, balancing the need for technological advancement with environmental protection and social equity. This holistic approach requires engineers to possess not only technical expertise but also a deep understanding of the broader implications of their work.

Current engineering education, however, often prioritizes technical proficiency over holistic thinking. Traditional curricula are typically structured around distinct engineering disciplines, such as civil, mechanical, electrical, and chemical engineering. While this approach ensures that students gain specialized knowledge in their chosen field, it can inadvertently create silos that hinder interdisciplinary collaboration and integrated problem-solving. Additionally, sustainability topics are frequently relegated to elective courses or specializations, rather than being woven into the core curriculum.

To equip future engineers with the skills and knowledge necessary to develop sustainable solutions, engineering education must undergo a paradigm shift. This shift involves rethinking the curriculum to integrate sustainability principles throughout, fostering interdisciplinary learning, and emphasizing the ethical and social responsibilities of engineers. By doing so, educational institutions can produce graduates who are not only proficient in their technical fields but also capable of addressing the multifaceted challenges of sustainability.

The urgency of this transformation is underscored by the accelerating pace of environmental degradation and the growing recognition of the interconnectedness of global systems. As engineers are called upon to design resilient infrastructure, develop clean energy technologies, and create sustainable urban environments, their education must reflect the complexity and interdependence of these tasks. This paper explores the current state of engineering education, identifies key areas for improvement, and proposes a comprehensive framework for integrating sustainability into engineering curricula. Through case studies and examples of best practices, we demonstrate how a sustainability-focused engineering education can lead to more effective and holistic engineering solutions.

In conclusion, the future of our planet depends on the ability of engineers to lead the way towards a sustainable world. This paper advocates for a transformative approach to engineering education, one that places sustainability at its core and prepares future engineers to build a better, more sustainable future for all.

2. The need for sustainability in engineering education

2.1 Global Challenges and the Engineer´s Role

The world faces numerous environmental challenges, including climate change, loss of biodiversity, pollution, and the unsustainable use of natural resources. Engineers are at the forefront of developing technologies and infrastructures that shape our interaction with the environment. Thus, their role is crucial in advancing *Sustainable Development Goals* (**SDGs**) set by the United Nations.

The contemporary world is confronted with a multitude of environmental, social, and economic challenges that threaten the sustainability of our global systems. Engineers, with their expertise in designing and implementing technological solutions, are at the forefront of addressing these challenges. Understanding the scope and urgency of these issues is essential for comprehending the critical role engineers play in fostering sustainable development.

Climate change represents one of the most pressing challenges of our time. The increasing concentration of greenhouse gases in the atmosphere, primarily due to the burning of fossil fuels and deforestation, is driving global temperature rises, leading to severe weather events, rising sea levels, and disruptions to ecosystems. Engineers are pivotal in developing technologies and systems to mitigate and adapt to climate change. This includes the design of renewable energy systems (such as wind, solar, and hydroelectric power), energy-efficient buildings and transportation systems, and innovative carbon capture and storage technologies.

The Earth´s natural resources are being consumed at an unsustainable rate. Non-renewable resources, such as fossil fuels, minerals, and metals, are being extracted faster than they can be replenished, leading to shortages and increased environmental degradation. Engineers must innovate to create more efficient processes and develop alternatives to scarce resources. This includes advancements in recycling technologies, the development of sustainable materials, and the promotion of a circular economy where waste is minimized, and materials are reused.

Pollution, in its many forms, poses significant risks to human health and the environment. Air pollution from industrial activities and transportation contributes to respiratory diseases and climate change. Water pollution from agricultural runoff, industrial discharges, and inadequate wastewater treatment contaminates drinking water sources and harms aquatic ecosystems. Engineers play a crucial role in developing pollution control technologies, such as advanced filtration systems, wastewater treatment processes, and cleaner production methods. Additionally, they work on monitoring and mitigating the impact of pollutants through environmental engineering practices.

Biodiversity is essential for maintaining ecosystem services that support human life, including food production, water purification, and disease regulation. However, habitat destruction, climate change, pollution, and overexploitation of species are leading to a significant loss of biodiversity. Engineers can contribute to biodiversity conservation through the development of sustainable land-use planning, habitat restoration projects, and the design of eco-friendly infrastructure that minimizes impacts on natural habitats.

Rapid urbanization poses challenges related to the provision of adequate infrastructure, housing, and services for growing populations. Urban areas are often characterized by high levels of pollution, traffic congestion, and inefficient energy use. Engineers are essential in designing smart and sustainable cities that optimize resource use and improve the quality of life for residents. This includes the development of green buildings, sustainable transportation systems, and resilient infrastructure that can withstand environmental stresses such as flooding and earthquakes.

Water is a critical resource for human survival, agriculture, and industry. However, many regions around the world face severe water scarcity due to over-extraction, pollution, and climate change-induced alterations in hydrological cycles. Engineers are tasked with developing innovative solutions for water management, including efficient irrigation systems, desalination technologies, and advanced water recycling and purification methods. These solutions are crucial for ensuring a reliable supply of clean water for all.

Sustainable development also involves addressing social and economic inequities that exacerbate environmental challenges. Disadvantaged communities often bear the brunt of environmental degradation and have limited access to resources and opportunities. Engineers must consider social justice in their work, ensuring that technological solutions are accessible and beneficial to all segments of society. This includes designing affordable and inclusive technologies, engaging with communities in the decision-making process, and promoting equitable distribution of resources.

Engineers have a multifaceted role in addressing these global challenges. Their responsibilities extend beyond technical problem-solving to include ethical considerations, interdisciplinary collaboration, and a commitment to sustainability. Key aspects of their role include:

Engineers are trained to think critically and creatively to solve complex problems. This skill set is crucial for developing innovative solutions that address the root causes of global challenges. By leveraging new technologies and materials, engineers can design systems and processes that are more efficient, sustainable, and resilient.

Sustainability challenges are inherently interdisciplinary, requiring collaboration across various fields such as environmental science, economics, and social sciences. Engineers must work closely with professionals from other disciplines to develop integrated solutions that consider all aspects of sustainability. This collaborative approach ensures that engineering solutions are comprehensive and effective.

Engineers must adhere to a strong code of ethics, ensuring that their work serves the public good and minimizes harm to the environment and society. This involves making decisions that prioritize long-term sustainability over short-term gains and considering the broader impacts of their projects on communities and ecosystems.

As thought leaders, engineers have the responsibility to educate and advocate for sustainable practices. This includes mentoring the next generation of engineers, promoting sustainability within their organizations, and engaging with policymakers and the public to raise awareness about environmental challenges and solutions.

In conclusion, the role of engineers in addressing global challenges is indispensable. Their expertise, innovative mindset, and ethical commitment are essential for developing sustainable solutions that can secure a viable future for our planet. Transforming engineering education to emphasize sustainability is a critical step towards empowering engineers to fulfill this vital role effectively.

2.2 Gaps in Current Engineering Education

Despite the critical role engineers play in addressing global sustainability challenges, current engineering education often falls short in equipping students with the comprehensive skills and knowledge necessary for this task. Several key gaps exist within traditional engineering programs that hinder the development of engineers capable of creating holistic and sustainable solutions.

Traditional engineering education places a heavy emphasis on technical skills and specialized knowledge within specific disciplines such as civil, mechanical, electrical, and chemical engineering. While technical proficiency is essential, this focus often comes at the expense of broader, interdisciplinary understanding. Engineers trained primarily in technical aspects may lack the ability to integrate environmental, social, and economic considerations into their work, which is crucial for sustainable development.

Sustainability topics are often treated as peripheral within engineering curricula. They may be offered as elective courses or specialized tracks rather than being integrated into the core curriculum. This limited exposure means that many engineering students graduate without a deep understanding of sustainability principles or the ability to apply these concepts in their professional practice. As a result, they may be ill-prepared to address the multifaceted challenges of sustainability in their careers.

Sustainable solutions require an interdisciplinary approach, combining insights from engineering, environmental science, economics, social sciences, and other fields. However, engineering education typically operates within disciplinary silos, with limited opportunities for students to engage in interdisciplinary learning and collaboration. This siloed approach hinders the development of integrated solutions that consider the full spectrum of sustainability issues.

Systems thinking is essential for understanding and addressing complex, interconnected sustainability challenges. It involves recognizing the interdependencies within systems and considering the broader impacts of engineering decisions. However, many engineering programs do not emphasize systems thinking, instead focusing on solving discrete technical problems. This gap in education can lead to solutions that are effective in one aspect but have unintended negative consequences in others.

Engineering decisions have significant ethical and social implications, yet traditional engineering education often lacks a strong emphasis on these aspects. While some programs include courses on engineering ethics, these are frequently treated as standalone topics rather than being integrated throughout the curriculum. This approach can result in engineers who are technically proficient but insufficiently aware of the broader social and ethical dimensions of their work.

Practical experience is crucial for applying theoretical knowledge to real-world problems and developing critical thinking and problem-solving skills. However, many engineering programs offer limited opportunities for hands-on learning, internships, and engagement in real-world projects. This gap can leave graduates unprepared for the practical challenges they will face in their professional careers, particularly in the context of sustainable development.

The field of sustainability is dynamic, with new technologies, methodologies, and best practices continually emerging. Engineering education often does not emphasize the importance of lifelong learning and continuous professional development. Graduates may not be equipped with the mindset or resources to stay current with advancements in sustainability, limiting their ability to innovate and adapt to evolving challenges.

A typical traditional engineering curriculum might include a strong focus on foundational sciences (such as physics, mathematics, and chemistry), technical courses specific to the discipline (such as thermodynamics, fluid mechanics, and structural analysis), and design projects. While these components are essential, they often lack integration with sustainability principles. For instance, a civil engineering program might focus heavily on the mechanics of materials and structural design without adequately addressing sustainable construction practices, life cycle analysis, or the environmental impact of building materials.

To address these gaps and better prepare engineers for the sustainability challenges, engineering education must undergo significant transformation. This involves integrating sustainability into the core curriculum, promoting interdisciplinary learning, emphasizing systems thinking, and fostering a strong sense of ethical and social responsibility. Additionally, providing ample opportunities for practical experience and encouraging continuous professional development are essential for ensuring that engineers remain at the forefront of sustainable innovation.

By rethinking and redesigning engineering education to address these gaps, we can develop a new generation of engineers who are not only technically proficient but also equipped to lead the way towards a sustainable future.

3. Key components of a sustainability-focused engineering education

To address these gaps, engineering education must evolve to incorporate sustainability at its core. The following components are essential for this transformation:

3.1 Curriculum Integration

Incorporating sustainability principles into the engineering curriculum is fundamental. This involves embedding topics such as renewable energy, sustainable materials, life cycle analysis, and environmental impact assessment into core engineering courses. Additionally, offering specialized courses on sustainability and interdisciplinary projects can enhance students´ understanding and application of sustainable practices.

Curriculum integration is a crucial component in transforming engineering education to prioritize sustainability. By embedding sustainability principles throughout the engineering curriculum, educational institutions can ensure that all graduates, regardless of their specific field of study, possess a foundational understanding of sustainable practices and are equipped to apply these principles in their professional work. This holistic approach to curriculum design involves several key strategies and components.

One of the most effective ways to integrate sustainability into the engineering curriculum is to embed relevant concepts and practices into core courses. This can be achieved by incorporating modules on sustainability within existing courses, ensuring that students encounter these ideas throughout their education rather than in isolated electives. For example:

- **Introduction to Engineering**: Early courses can introduce students to the principles of sustainable development, the environmental impacts of engineering projects, and the importance of ethical decision-making.
- **Materials Science**: Courses on materials can cover sustainable material selection, the environmental impacts of different materials, and recycling and lifecycle analysis.
- **Thermodynamics and Fluid Mechanics**: These courses can include discussions on energy efficiency, renewable energy technologies, and the environmental impacts of various energy systems.
- **Civil and Structural Engineering**: Core courses can integrate sustainable building practices, green infrastructure, and the use of environmentally friendly materials.

In addition to integrating sustainability into core courses, offering specialized courses focused entirely on sustainability is essential. These courses can provide deeper knowledge and skills that are critical for addressing complex sustainability challenges. Examples of specialized courses include:

- **Renewable Energy Systems**: Covering the design, implementation, and maintenance of renewable energy technologies such as solar, wind, and hydroelectric power.
- **Sustainable Design and Manufacturing**: Focusing on principles of sustainable design, eco-friendly manufacturing processes, and the lifecycle assessment of products.
- **Environmental Impact Assessment**: Teaching methods for evaluating the environmental impacts of engineering projects and developing strategies to mitigate negative effects.
- **Climate Change Mitigation and Adaptation**: Exploring engineering solutions for reducing greenhouse gas emissions and adapting to the impacts of climate change.

Interdisciplinary projects and capstone experiences provide students with hands-on opportunities to apply sustainability principles in real-world contexts. These projects encourage collaboration across different engineering disciplines and with other fields such as environmental science, economics, and social sciences. Key aspects of these projects include:

- **Team-Based Projects**: Students work in diverse teams to tackle sustainability challenges, fostering interdisciplinary collaboration and broadening their perspectives.
- **Industry Partnerships**: Collaborations with industry partners can provide practical experience and expose students to current sustainability practices and challenges in the professional world.
- **Community Engagement**: Projects that involve working with local communities on sustainability initiatives can enhance students´ understanding of social dimensions and ethical considerations.

Life Cycle Analysis (**LCA**) and systems thinking are essential tools for understanding the full environmental impact of engineering projects. Integrating these concepts into the curriculum helps students develop a holistic view of sustainability. Strategies for incorporation include:

- **Case Studies and Examples**: Using real-world case studies to illustrate the application of LCA and systems thinking in engineering projects.
- **Simulation and Modelling**: Incorporating software tools and simulations that allow students to conduct lifecycle assessments and analyse complex systems.

- **Problem-Based Learning**: Engaging students in problem-based learning activities that require them to apply LCA and systems thinking to solve sustainability challenges.

To ensure the effectiveness of sustainability integration, continuous assessment and improvement of the curriculum are necessary. This involves:

- **Feedback Mechanisms**: Regularly collecting feedback from students, faculty, and industry partners to identify areas for improvement and to stay current with evolving sustainability challenges and technologies.
- **Curriculum Review Committees**: Establishing committees that include sustainability experts to review and update the curriculum regularly.
- **Professional Development for Faculty**: Providing ongoing training and resources for faculty to enhance their knowledge of sustainability and effective teaching methods for integrating these concepts into their courses.

Integrating sustainability into the engineering curriculum is essential for preparing engineers to meet the complex challenges of the era. By embedding sustainability concepts in core courses, offering specialized sustainability courses, promoting interdisciplinary projects, incorporating life cycle analysis and systems thinking, and continuously assessing and improving the curriculum, educational institutions can ensure that graduates are well-equipped to develop innovative and sustainable engineering solutions. This comprehensive approach to curriculum integration is a critical step towards building a more sustainable world.

3.2 Interdisciplinary Learning

Sustainability challenges are inherently complex and multifaceted, requiring knowledge from various disciplines. Engineering education should promote interdisciplinary learning by encouraging collaboration with fields such as environmental science, economics, and social sciences. This approach fosters a more comprehensive understanding of sustainability issues and enhances the ability to develop integrated solutions.

Interdisciplinary learning is an essential component of transforming engineering education to address sustainability challenges effectively. Sustainability issues are complex and multifaceted, requiring knowledge and approaches from various disciplines. By fostering interdisciplinary learning, engineering programs can prepare students to develop comprehensive and integrated solutions. This section explores the importance of interdisciplinary learning, strategies for implementation, and examples of successful interdisciplinary programs.

Sustainability challenges such as climate change, resource depletion, and pollution are interconnected and cannot be addressed through a single-disciplinary approach. Interdisciplinary learning enables students to understand these problems from multiple perspectives, leading to more holistic and effective solutions. For example, addressing climate change requires knowledge of engineering, environmental science, economics, public policy, and social sciences.

Combining knowledge from different disciplines fosters innovation and creativity. Students exposed to diverse perspectives and methodologies are more likely to think outside the box and develop novel solutions to sustainability challenges. Interdisciplinary collaboration encourages creative problem-solving by blending technical expertise with insights from other fields.

In the professional world, engineers often work in multidisciplinary teams. Interdisciplinary learning in an academic setting helps students develop collaboration and communication skills essential for effective teamwork. These skills are critical for working with professionals from various backgrounds to address complex sustainability issues.

Sustainability challenges have significant social and ethical dimensions. Interdisciplinary learning exposes engineering students to these aspects, ensuring they consider the broader impacts of their work on society and the environment. Courses in ethics, sociology, and public policy can help students understand the societal implications of engineering decisions and promote responsible practices.

Developing courses and programs that explicitly focus on interdisciplinary learning is a key strategy. These can include:

- **Integrated Sustainability Courses**: Courses that combine elements of engineering, environmental science, economics, and social sciences to provide a comprehensive understanding of sustainability issues.
- **Dual-Degree Programs**: Programs that allow students to earn degrees in engineering and another discipline, such as environmental science, public policy, or business administration.
- **Sustainability Minors and Concentrations**: Minors or concentrations in sustainability that require coursework from multiple disciplines.

Interdisciplinary projects and capstone experiences provide practical opportunities for students to apply knowledge from various fields. These projects should involve:

- **Team-Based Approaches**: Students from different disciplines working together to solve real-world sustainability problems.
- **Industry and Community Partnerships**: Collaborations with industry and community organizations to address practical challenges and develop solutions that consider technical, environmental, and social aspects.
- **Faculty Collaboration**: Involving faculty from different departments to guide and mentor students, providing diverse expertise and perspectives.

Encouraging students to participate in interdisciplinary research projects can deepen their understanding of sustainability challenges and solutions. Strategies include:

- **Research Centres and Institutes**: Establishing centres focused on sustainability that bring together researchers from various disciplines to work on collaborative projects.
- **Undergraduate Research Programs**: Providing opportunities for undergraduate students to engage in interdisciplinary research, often through summer programs, internships, or thesis projects.
- **Cross-Departmental Seminars and Workshops**: Offering seminars and workshops that address sustainability topics from multiple disciplinary perspectives.

Designing curricula that integrate interdisciplinary learning throughout the program is essential. This can be achieved by:

- **Interdisciplinary Modules in Core Courses**: Embedding interdisciplinary content and perspectives in core engineering courses.
- **Thematic Learning**: Organizing the curriculum around sustainability themes that require input from various disciplines.
- **Problem-Based Learning**: Using problem-based learning approaches that present students with complex, real-world problems requiring interdisciplinary solutions.

Interdisciplinary learning is crucial for preparing engineers to address the complex and multifaceted challenges of sustainability. By integrating knowledge from various disciplines, fostering collaboration, and emphasizing the ethical and social dimensions of engineering work, interdisciplinary learning equips students with the skills and perspectives needed to develop holistic and effective solutions. Implementing interdisciplinary courses, collaborative projects, research opportunities, and integrated curricula can transform engineering education and ensure that graduates are ready to lead the way towards a sustainable future.

3.3 Ethics and Social Responsibility

Engineering decisions have significant ethical and social implications. Incorporating ethics and social responsibility into engineering education ensures that future engineers consider the broader impact of their work on society and the environment. Courses and discussions on engineering ethics, corporate social responsibility, and public policy can help instil a strong sense of accountability.

As engineers are at the forefront of developing and implementing technologies that significantly impact society and the environment, ethics and social responsibility become integral components of their education and professional practice. By embedding ethical considerations and a sense of social responsibility throughout engineering curricula, educational institutions can prepare future engineers to make decisions that prioritize the well-being of both people and the planet. This section explores the importance of ethics and social responsibility in engineering, strategies for integrating these principles into education, and examples of successful implementation.

Engineers often face complex ethical dilemmas where they must balance technical feasibility, cost, safety, and environmental impact. Ethical decision-making involves evaluating the consequences of engineering actions on stakeholders and making choices that align with moral and professional standards. A strong ethical foundation helps engineers navigate these dilemmas and make decisions that promote the public good.

Engineering projects can have profound effects on communities, particularly marginalized and vulnerable populations. Social responsibility in engineering entails considering the social and economic implications of engineering decisions and striving to achieve equitable outcomes. This includes ensuring that engineering solutions do not disproportionately harm disadvantaged groups and that they contribute to social justice.

Engineers play a critical role in environmental conservation and sustainability. Ethical engineering practices require minimizing environmental degradation, conserving resources, and promoting sustainable development. By prioritizing environmental stewardship, engineers can contribute to the health and longevity of ecosystems and the overall sustainability of the planet.

Ethics and social responsibility are foundational to the credibility and trustworthiness of the engineering profession. Engineers must adhere to professional codes of conduct that emphasize honesty, transparency, and accountability. Upholding these principles enhances public trust in engineering solutions and the profession as a whole.

Ethics and social responsibility should be integrated into the core engineering curriculum rather than confined to standalone courses. This approach ensures that ethical considerations are consistently addressed across all areas of engineering education. Strategies include:

- **Case Studies**: Incorporating case studies that highlight ethical dilemmas and social impacts of engineering projects in core courses.
- **Ethics Modules**: Embedding ethics modules within technical courses to discuss the ethical implications of specific technologies and engineering practices.
- **Interdisciplinary Courses**: Offering courses that combine engineering with philosophy, sociology, and public policy to provide a broad perspective on ethical issues.

In addition to integrating ethics into the core curriculum, offering dedicated courses on engineering ethics and social responsibility provides students with in-depth knowledge and critical thinking skills. These courses can cover:

- **Professional Codes of Conduct**: Examining the ethical guidelines and codes of conduct established by professional engineering organizations.
- **Ethical Theories and Principles**: Introducing students to ethical theories and principles that underpin ethical decision-making in engineering.
- **Social Impact Analysis**: Teaching methods for assessing the social impacts of engineering projects and developing strategies to mitigate negative effects.

Service learning and community engagement projects provide students with hands-on experience in applying ethical principles and social responsibility. These projects can involve:

- **Community-Based Projects**: Collaborating with local communities to address real-world challenges, such as improving infrastructure, enhancing sustainability, or providing access to clean water and sanitation.
- **Non-profit Partnerships**: Partnering with non-profit organizations to work on projects that benefit underserved populations and promote social justice.
- **Volunteer Opportunities**: Encouraging students to participate in volunteer activities that align with their engineering skills and contribute to the public good.

Promoting ethical leadership and mentorship within engineering programs helps cultivate a culture of integrity and responsibility. Strategies include:

- **Ethics Workshops and Seminars**: Organizing workshops and seminars on ethical leadership, featuring guest speakers from industry, academia, and non-profit organizations.
- **Mentorship Programs**: Pairing students with mentors who exemplify ethical behaviour and social responsibility in their professional practice.
- **Leadership Training**: Providing training in leadership skills that emphasize ethical decision-making, social justice, and sustainability.

Continuous reflection and improvement are crucial for maintaining high ethical standards and social responsibility in engineering education. This involves:

- **Feedback Mechanisms**: Collecting feedback from students, faculty, and industry partners to identify areas for improvement in ethics education.
- **Ethics Committees**: Establishing ethics committees within engineering departments to review and update curricula, ensuring they remain relevant and effective.
- **Professional Development**: Offering ongoing professional development opportunities for faculty to enhance their understanding of ethical issues and effective teaching methods.

Integrating ethics and social responsibility into engineering education is essential for preparing engineers to address the complex challenges. By embedding ethical considerations in the curriculum, offering dedicated courses, promoting service learning and community engagement, fostering ethical leadership and mentorship, and ensuring continuous reflection and improvement, educational institutions can develop engineers who are not only technically proficient but also committed to the public good, social justice, and environmental stewardship. This comprehensive approach to ethics and social responsibility ensures that engineers are well-equipped to lead the way toward a sustainable and equitable future.

3.4 Practical Experience and Problem-Solving

Hands-on experience is crucial for applying theoretical knowledge to real-world problems. Engineering programs should provide opportunities for students to engage in sustainability-focused projects, internships, and research. This practical experience helps students develop critical thinking and problem-solving skills, essential for creating innovative and sustainable engineering solutions.

Practical experience and problem-solving are critical components of engineering education, particularly when preparing students to address sustainability challenges. These elements ensure that students can apply theoretical knowledge to real-world situations, develop essential skills, and innovate effectively. This section explores the importance of practical experience and problem-solving in engineering education, strategies for their integration, and examples of successful programs.

Practical experience allows students to apply the theoretical concepts learned in the classroom to real-world scenarios. This hands-on approach deepens understanding and helps students grasp the complexities of engineering problems. It bridges the gap between theory and practice, making learning more relevant and impactful.

Engaging in practical projects and problem-solving activities helps students develop essential skills such as critical thinking, creativity, teamwork, and communication. These skills are crucial for addressing sustainability challenges, which often require innovative solutions and collaboration across various disciplines and stakeholders.

Practical experience fosters innovation and creativity by exposing students to real-world problems that require novel solutions. Working on these problems encourages students to think outside the box, explore different approaches, and develop unique solutions that are sustainable and effective.

Hands-on experience builds confidence and prepares students for professional practice. By working on real projects, students gain a better understanding of the engineering process, from problem identification to solution implementation. This experience makes them more prepared to tackle complex challenges in their careers.

Practical experience often involves collaboration with industry and community partners. These interactions provide students with insights into the professional world, expose them to current industry practices and challenges, and foster a sense of social responsibility by working on projects that benefit the community.

Laboratory courses and workshops are foundational elements of engineering education that provide hands-on experience in a controlled environment. Strategies include:

- **Experimentation and Simulation**: Conducting experiments and using simulation tools to understand engineering principles and their real-world applications.
- **Prototyping and Testing**: Building and testing prototypes to learn about design, manufacturing, and troubleshooting processes.
- **Interactive Learning**: Utilizing interactive learning modules that combine lectures with hands-on activities to reinforce theoretical concepts.

Capstone projects are comprehensive, culminating experiences that challenge students to apply their knowledge to real-world problems. Key aspects of effective capstone projects include:

- **Interdisciplinary Collaboration**: Encouraging students to work in interdisciplinary teams to tackle complex, multifaceted problems.
- **Industry Partnerships**: Partnering with industry organizations to provide real-world challenges and mentorship.
- **Project Management**: Teaching students project management skills, including planning, execution, and evaluation of engineering projects.

Internships and cooperative programs offer students practical experience in professional settings. These programs should:

- **Provide Real-World Experience**: Allow students to work on actual projects and gain exposure to industry practices and standards.
- **Offer Mentorship**: Pair students with industry professionals who can provide guidance, feedback, and insights into the profession.
- **Encourage Reflection**: Include structured reflection activities where students analyse their experiences and learn from successes and challenges.

Service learning and community projects integrate practical experience with social responsibility. These initiatives can include:

- **Community-Based Engineering Projects**: Engaging with local communities to identify and solve engineering problems that improve quality of life and sustainability.
- **Nonprofit Collaboration**: Partnering with nonprofit organizations to work on projects that address social and environmental issues.
- **Global Service Programs**: Offering opportunities for students to participate in international projects, addressing global sustainability challenges and gaining cross-cultural experience.

Engineering competitions and challenges stimulate practical problem-solving and innovation. These events can:

- **Promote Creativity**: Encourage students to develop creative solutions to predefined problems or open-ended challenges.
- **Foster Teamwork**: Require collaboration in teams, enhancing communication and teamwork skills.
- **Provide Recognition and Feedback**: Offer opportunities for students to showcase their work, receive feedback from experts, and gain recognition for their achievements.

Involving students in research projects provides practical experience in solving cutting-edge engineering problems. Strategies include:

- **Undergraduate Research Programs**: Offering structured programs that involve students in faculty-led research projects.
- **Research Internships**: Providing internships at research institutions, allowing students to work on advanced engineering problems.
- **Publication and Presentation**: Encouraging students to publish their research findings and present at conferences, enhancing their communication skills and professional development.

By incorporating laboratory courses, capstone projects, internships, service learning, competitions, and research opportunities, educational institutions can ensure that students develop the skills, knowledge, and confidence needed to create innovative and sustainable engineering solutions. This comprehensive approach to practical experience and problem-solving not only enhances students´ learning but also prepares them to make meaningful contributions to society and the environment in their professional careers.

3.5 Continuous Professional Development

The field of sustainability is dynamic, with new technologies and methodologies continually emerging. Engineering education should emphasize the importance of lifelong learning and continuous professional development. Providing resources and opportunities for ongoing education ensures that engineers remain current with the latest advancements and best practices in sustainability.

Continuous Professional Development (**CPD**) is an ongoing process that ensures engineers remain competent, skilled, and knowledgeable throughout their careers. In the context of sustainability and the rapidly evolving technological landscape, CPD is critical for engineers to stay current with new advancements, regulations, and best practices. This section explores the importance of CPD, key components, strategies for implementation, and examples of successful CPD programs.

The field of engineering is constantly evolving, with new technologies and methods emerging regularly. CPD ensures that engineers remain up to date with the latest advancements, enabling them to implement cutting-edge solutions and maintain their professional relevance.

Engineering practices are often governed by regulatory standards that evolve to address new challenges, including sustainability and environmental protection. CPD helps engineers stay informed about these changes, ensuring compliance and enhancing their ability to contribute to sustainable practices.

CPD provides opportunities for engineers to develop new skills and refine existing ones. This continuous learning process is essential for maintaining high standards of practice, fostering innovation, and enhancing problem-solving abilities.

Ethical considerations and social responsibilities are integral to engineering practice. CPD programs can reinforce these principles, providing training on ethical decision-making, social justice, and sustainability to ensure engineers contribute positively to society.

Engaging in CPD can lead to career advancement and greater professional recognition. Engineers who demonstrate a commitment to continuous learning are more likely to be considered for promotions, leadership roles, and professional awards.

Formal education and training are foundational elements of CPD. These can include:

- **Advanced Degrees**: Pursuing further education such as master´s or doctoral degrees to gain specialized knowledge in areas like sustainability, renewable energy, or environmental engineering.
- **Professional Certifications**: Obtaining certifications that demonstrate expertise in specific areas, such as *Leadership in Energy and Environmental Design* (**LEED**) accreditation for sustainable building practices or certification in project management.

Workshops and seminars provide opportunities for engineers to learn about new technologies, methods, and industry trends. These events can be organized by professional organizations, universities, or industry groups and often feature expert speakers and hands-on training sessions.

Online learning platforms and webinars offer flexible and accessible options for CPD. These resources allow engineers to learn at their own pace and stay updated with the latest advancements. Topics can range from technical skills and sustainability practices to ethics and leadership.

Attending industry conferences is an effective way to engage with peers, learn about new research, and participate in discussions on current challenges and innovations. Conferences often feature keynote addresses, technical sessions, and networking opportunities.

Networking with peers and industry leaders is a crucial component of CPD. Engaging in professional networks, joining engineering societies, and participating in forums and discussion groups help engineers share knowledge, exchange ideas, and stay informed about industry developments.

Mentorship and coaching programs provide personalized guidance and support. Experienced engineers can mentor younger professionals, offering insights, advice, and feedback. This relationship benefits both parties, fostering continuous learning and professional growth.

Engaging in research and contributing to publications allows engineers to explore new ideas, develop innovative solutions, and share their findings with the broader community. This practice promotes a deeper understanding of complex issues and encourages the dissemination of knowledge.

Reflective practice involves regularly assessing one´s work and identifying areas for improvement. This self-assessment process encourages engineers to critically evaluate their skills, knowledge, and performance, leading to continuous professional growth.

Employers play a significant role in supporting CPD. Strategies include:

- **Training and Development Programs**: Offering in-house training sessions, workshops, and seminars on relevant topics.
- **Tuition Reimbursement**: Providing financial support for employees pursuing further education or professional certifications.
- **Professional Memberships**: Covering the cost of memberships to professional organizations, enabling access to resources, events, and networking opportunities.
- **Mentorship Programs**: Establishing formal mentorship programs that pair less experienced engineers with seasoned professionals.

Professional organizations and societies often offer extensive CPD resources. Strategies include:

- **Accredited Courses and Certifications**: Providing accredited courses and certification programs that enhance professional skills and knowledge.
- **Continuing Education Requirements**: Implementing requirements for ongoing education to maintain professional licensure or certification.
- **Resource Libraries**: Offering access to research papers, technical guides, and other educational materials.
- Engineers should also take personal responsibility for their professional development. Strategies include:
- **Individual Learning Plans**: Creating personalized learning plans that outline goals, required skills, and steps for achieving them.
- **Self-Directed Learning**: Taking the initiative to learn new skills through online courses, reading professional journals, and participating in webinars.
- **Professional Goals**: Setting *Specific, Measurable, Achievable, Relevant, And Time-Bound* (**SMART**) goals for professional growth and development.

Partnerships between academic institutions and industry can enhance CPD by providing relevant and up-to-date training opportunities. Strategies include:

- **Collaborative Research Projects**: Engaging in research projects that address industry challenges and contribute to academic knowledge.
- **Guest Lectures and Industry Experts**: Inviting industry professionals to deliver guest lectures and share their expertise with students and faculty.
- **Internships and Cooperation**: Offering internship and co-op programs that provide practical experience and foster ongoing professional development.

Continuous Professional Development is essential for engineers to maintain their competence, adapt to technological and regulatory changes, and contribute effectively to sustainable development. By engaging in formal education, workshops, online learning, industry conferences, networking, mentorship, research, and reflective practice, engineers can enhance their skills and knowledge throughout their careers. Employers, professional organizations, and academic institutions all play critical roles in supporting CPD. A commitment to continuous learning ensures that engineers remain innovative, ethical, and capable of addressing the complex challenges of the modern world.

4. Conclusion

Engineering education must evolve to address the pressing sustainability challenges of our time. By fostering a holistic approach that integrates technical expertise with ethical, social, and environmental considerations, educational institutions can prepare engineers to develop innovative solutions for a sustainable future. This paper has explored key components of transforming engineering education, including curriculum integration, interdisciplinary learning, ethics and social responsibility, practical experience, problem-solving, and continuous professional development.

Incorporating sustainability into the core engineering curriculum ensures that students understand the relevance and importance of sustainable practices from the outset. Courses should cover a range of topics, from renewable energy to sustainable materials, and emphasize the interconnectedness of technical, environmental, and social issues.

Sustainability challenges are inherently complex and require knowledge from multiple disciplines. By promoting interdisciplinary learning, engineering programs can equip students with the skills to collaborate effectively across various fields and develop comprehensive, innovative solutions.

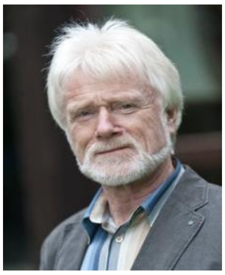
Embedding ethics and social responsibility throughout engineering education is crucial. Students must learn to consider the broader impacts of their work on society and the environment, ensuring that their solutions are not only technically sound but also ethically and socially responsible.

Hands-on experience through laboratory courses, capstone projects, internships, and service learning is essential for developing practical skills and fostering innovation. Real-world problem-solving prepares students for the complexities they will face in their professional careers and instils confidence in their abilities to address sustainability challenges.

Engineering education does not end at graduation. Continuous professional development ensures that engineers remain current with technological advancements, regulatory changes, and best practices. By engaging in lifelong learning, engineers can maintain their competence, adapt to new challenges, and continue to contribute to sustainable development throughout their careers.

To achieve a sustainable world, engineering education must be dynamic, comprehensive, and forward-thinking. It requires a commitment from educational institutions, industry, and professional organizations to support and implement these changes. By fostering a new generation of engineers who are technically proficient, ethically grounded, and socially responsible, we can develop the innovative solutions needed to create a sustainable future for all.

The transformation of engineering education outlined in this paper is not merely an academic exercise but a critical investment in our collective future. As the challenges we face grow increasingly complex, the role of engineers as problem solvers and innovators will become ever more vital. It is imperative that we equip them with the knowledge, skills, and values necessary to lead the way towards a more sustainable and equitable world.



Accreditation of Anti-corruption Course Modules as Part of the University Education Programs of Civil Engineers

Prof. Dr. Carsten Ahrens
Germany
ZDI, Munich; Jadehochschule, Oldenburg; WFEO; GIACC-DE

1. Introduction

Corruption was and still is part of human life. Ethical behaviour and education was and still is part of human life. So both, corruption and ethical behaviour, is also part of the civil engineering life and business. How to avoid corruption? Can it be done by specific ethical and accredited education? Or do we have to follow Aristotle's finding: "All earthquakes and disasters are warnings; there is too much corruption in the world." We all still suffer from earthquakes and disasters, worldwide and a lot.

Sustainability and corruption never can come together; corruption hinders long-lasting forthcoming of mankind and, thus, hinders sustainable development.

2. Reality in Construction Industry

The newest book about corruption in the construction industry is an eye-opener about the reality [1]. The author Bruce Wymond addresses in his book one of the society's greatest challenges. The author is member of the GIACC affiliate's family, and as a civil engineer with many years of praxis and experience in the construction industry knows what is the case in these working surroundings.

Just as an example, the book describes surprisingly many types of corruption and possible participant involvement, see table 1 (Table 5.1(a) in the book).

Table 5.1(a): Type of corruption and possible participant involvement

Type corruption	Authority	Client	Consultant	Contractor	Supplier
Fraudulent acts					
Fraud	*	*	*	*	*
Deception	*	*	*	*	*
Ghosting	*	*	*	*	*
Front-shell company	*	*	*	*	*
Dishonesty	*	*	*	*	*
Money laundering		*	*	*	*
Collusion		*	*	*	*
Bribery acts					
Bribery	*	*	*	*	*
Solicitation	*	*	*	*	*
Lobbying	*	*			
Facilitation payments	*	*	*	*	*
Kickbacks	*	*	*	*	*
Influence peddling	*	*	*	*	*
Extortion acts					

Table 1: Type of corruption and possible participant involvement

3. Reaction on possible acts and cases of corruption in the built environment

3.1 Engineering Associations and Ethics

Nearly all (civil) engineers associations have their own understanding of ethical behaviour in their profession.

They have guidelines how to behave "ethically".

They mostly do not have definite rules against corruption.

But, relatively early the rather demanding Code of Professional Conduct has been published by the European Council of Civil Engineers (ECCE) [2]. The wording is very clear: An engineer will reject bribery in all forms.

On the other hand since 2016 there exists the ISO 37001 Anti-bribery Management Systems [3], and later, but complementary the guide for use of it. This A-standard can be implemented into any companies management system like the "normal" ISO 9001 Quality Management Systems. It could help a lot to get out of bribery troubles within the companies' activities and co-operations with partners.

3.2 Education and Ethics

Nearly all educational institutions have their own understanding of ethical behaviour of their students and academic staff.

They offer study programs about "Ethics and Technology".

They do not really tackle questions of corruption.

Last year in the ICEEA2023 conference the author has described two different teaching approaches: A bottom-up and a top-down course.

"**Ethics in the Built Environment** (EiBE)" [4] was an international Socrates summer course, the content of which has been elaborated from the participating students (bottom-up).

The "**GIACC Anti-Corruption Course**" is a top-down course, elaborated and described by GIACC [5]. This name stands for "Global Infrastructure Anti-Corruption Centre", which is placed in London. It has been founded by the couple Cathrine and Neill Stansbury. - Neill was also the convenor of the ISO 37001 Anti-bribery standard.

This course can be taught at universities, in engineering organisations, in life-long-learning institutions etc. It has distinct sections as teaching parts as follows:

1. Introduction to Course

2. What is corruption?

3. How corruption occurs on infrastructure projects

4. Why corruption occurs on infrastructure projects

5. The cost of corruption

6. Dealing with corruption

7. Hypothetical Case Study: The Galaxy Highway

8. Detailed case studies of real life corruption cases

4. Accreditation

The first problem to teach ethics or - more effectively – anti-corruption matters, is to see the necessity to do so. Then secondly one has to "find a place" within the normal education and/or professional courses. And, thirdly, it is necessary to teach this topic in a way, that it can be accredited by the specific bodies or agencies. Otherwise students would not attend these courses. In Europe the study load and, thus, the "students' salary" is described by the ECTS-system. But this is not unique, there are other agencies and credit giving systems too, of course.

5. Summary

Corruption hinders sustainable development worldwide. The loss of money, lives and economic growth increases in a breath taking speed. Education, information, transparency, legislation and compliance within organisations could help. But how and when and where and with whome?

6. Bibliography

[1] Corruption in the Construction Industry, *www.brucewymond.com*

[2] European Council of Civil Engineers (ECCE), *www.ecceengineers.eu*

[3] *www.iso.org*

[4] *www.giacc.de/wp-content/uploads/2023/11/Euceet-Pisa-paper-10-2023-1.pdf*

[5] *www.giaccentre.org*

Cultivating Emerging Technology Engineers to Promote World Development

Professor WANG Qinglin
Chair, Standing Committee on Emerging Technologies
for Professional Development, FEIAP

Abstract: The development of emerging technology industries has opened up many new paths for the professional development of engineers. Professional engineer organizations should seize the time to formulate the classification and engineering education and engineering capability standards for emerging technology engineers in a timely manner, and promote the development of various emerging technology engineer systems. At the same time, the training of professional engineers in emerging technologies should be regarded as an important measure to bridge the gap between the development of the north and the south, and the training of emerging technology engineers in developing countries should be accelerated, so as to achieve coordinated and balanced development between developed and developing countries in the current emerging technology field and digital field.

The Pact for the Future, adopted at the 79th session of the United Nations on September 20, 2024, states that Advances in knowledge, science, technology and innovation could deliver a breakthrough to a better and more sustainable future for all. In the "Science, Technology and Innovation and Digital Cooperation" section, it is further pointed out that it is necessary to Increase efforts to support developing countries, in particular by developed countries and those developing countries in a position to do so, with capacity-building in science, technology and innovation through policy exchanges, knowledge-sharing, technical assistance, financing, joint international research and personnel training tailored to specific needs, policies and priorities of developing countries. Digital and emerging technologies, including artificial intelligence, play a significant role as enablers of sustainable development and are dramatically changing our world. They offer huge potential for progress for the benefit of people and planet today and in the future.

Emerging technologies usually refer to technologies that have emerged relatively recently, are currently under development, and have the potential to have a significant impact. These technologies are often based on new scientific discoveries or innovative engineering methods that can change the way people live and work, and have a profound impact on the economy, society and the environment.

Emerging technologies usually have the following characteristics: innovative, that is, they represent new ideas and new methods that are different from traditional technologies; uncertainty, including uncertainty in the development path of technology and its application effects and impacts; high growth potential and in the future It is expected to achieve rapid market expansion and widespread application; interdisciplinary, usually integrating knowledge and technology from multiple subject areas.

Due to the importance of emerging technologies to human economic and social development, FEIPP established the Standing Committee on Emerging Technologies for Professional Development in 2022, focusing on the impact of the development of emerging technologies and its relationship with professional development.

Our focus is on this type of emerging technologies, that is, technologies that can promote the development of a type of emerging industry. This kind of emerging technology will inevitably require and lead to the emergence of a new type of engineers who can master this emerging technology and apply it to promote the development of this emerging industry. In this way, through the development of emerging technologies and corresponding industries, corresponding talent training and career development are linked.

Currently, our Standing Committee on Emerging Technologies for Professional Development is carrying out the following work:

1. Classification of emerging technologies, study which emerging technologies in the engineering field can drive the development of an emerging independent industry. For these emerging technologies, we recommend establishing specialized majors and colleges in universities to cultivate specialized talents. At the same time, we suggest setting up professional engineer titles for such professional and technical talents to reflect their differences from other professional engineers. We also recommend establishing professional associations for such engineers in addition to existing engineer associations, such as the Society of Artificial Intelligence Engineers, the Society of Big Data Engineers, the Society of Additive Manufacturing Engineers, etc., to promote the career development of engineers in emerging technologies and safeguard their interests.

2. Establish education standards and ability evaluation standards for emerging technology engineering majors, for these emerging technology engineers, we will explore specific engineering education standards and engineering ability standards corresponding to them, and recommend organizing corresponding certification and evaluation committees to ensure that the quality standards of university engineering education and practicing engineers can meet the corresponding ability standards.

We think this is a very meaningful and necessary task. The FEIAP Standards Working Group has communicated with ISO, and ISO has expressed its willingness to support this work in terms of capacity standard building.

On August 21 this year, when WFEO President-elect Tan Seng Chuan and UNESCO Beijing Office Director Shahbaz Khan visited FEIAP CHINA office, we discussed this issue together. Both of them expressed understanding and support for the proposal to establish standards. Tan Seng Chuan said that he would consider establishing a WFEO Standards Working Group to promote this work. Director Shahbaz Khan said that in the future, UNESCO, WFEO and FEIAP should strengthen cooperation and jointly carry out this work.

3. Promote the establishment of the AAAP agreement, promote the high-quality training of engineering and technical talents in countries in the global South, and reduce the development gap between developed and developing countries.

Digital and emerging technologies, including artificial intelligence, are important drivers of sustainable development. Compared with modern agriculture and modern industry, emerging technologies that focus on digital labor are lower-cost industries. Priority development in the digital industry by developing countries may make the goal of reducing the gap with developed countries easier to achieve. India's success in software engineering and China's success in artificial intelligence are good examples.

The AAP Agreement and AAAP will adopt engineering education standards and engineering capability standards equivalent to those of developed countries, and promote them in developing countries in a more appropriate way, striving to first reduce the North-South gap in the training and capacity building of engineers in emerging technology fields.

To achieve this goal, FEIAP designed and organized the 2024International Engineering Congress (2024IEC) (Taizhou, China). This congress focuses on cooperation among countries in the global South in the field of engineering and North-South dialogue, and builds a new model of multilateral cooperation with the support of UNESCO, WFEO and IEA. 1) Invite engineering organizations from countries in the global South to effectively participate in global decision-making in the multilateral system and better incorporate the voices of developing countries into global decision-making. Engineer organizations from nearly 30 southern countries confirmed their participation in this meeting, including 19 Presidents of national engineering organizations. The meeting will form a Taizhou Declaration on "International Cooperation for Sustainable Engineering Development"(Professor Chuah Hean Teik drafted and will preside over the adoption of this document), and strive to reach a consensus on the AAAP agreement. 2) Form a mechanism platform for North-South dialogue in the engineering field. Fifteen international organizations have confirmed their participation in this congress, including 15 Presidents of international engineering organizations. The participation of important international organizations in the engineering field representing global standards laid a good foundation for North-South dialogue and later North-South cooperation.

In order to improve the quality of engineering education and engineering capabilities in the Global South, FEIAP considers promoting new projects

1) Encourage and support southern countries to establish specialized engineer schools or establish specialized programs in universities focusing on artificial intelligence and digital and emerging technologies to cultivate specialized engineers in emerging technology fields. France is a country with a specialized engineer degree. In recent years, China has also established National Superior Colleges for Engineers in 24 universities. We hope that France and China can share their experiences with countries in the South.

2) In countries and regions that are willing to give support , FEIAP and WFEO may establish joint training centers for international engineering education and engineering capabilities to support the training of international standard engineers locally and support the training of engineering talents in developing countries.

Emerging technologies are not only the main factor supporting the development of the world economy, but also the main factor changing human lifestyles and the world's development pattern. At the same time, emerging technologies have also opened up new paths for the career development of engineers. The International Organization of Engineers and the Organization of Engineers of various countries should attach great importance to them, give full play to their own advantages, and take active actions to Strengthen North-South cooperation, South-South and triangular cooperation, while taking into account different national circumstances, in accordance with the requirements of the United Nations "Pact for the Future", to build capacity for and improve access to science, technology and innovation, and to increase resources for the implementation of technical and scientific initiatives; so as to contribute to reducing and eliminating the North-South development gap and promoting sustainable development in the world.

Enhancement of Course-based Undergraduate Engineering Research Experiences (CUERE) towards the implementation of Outcome-based Education at Yangon Technological University

Hla Myo Tun
Research Department, Yangon Technological University
Gyogone, Insein PO, 11011, Yangon, Republic of the Union of Myanmar
kohlamyotun.ytu@gmail.com

Abstract—The paper presents the Enhancement of Course-based Undergraduate Engineering Research Experiences (CUERE) towards the implementation of Outcome-based Education at Yangon Technological University (YTU). This study emphasizes the crucial role of undergraduate research in the capacity building of engineering higher education, concentrating on enhancing academic, experimental and practical skills, addressing accreditation, internationalization and globalization challenges, and integrating innovative teaching methods. The paper brings rich experience in academia, research and development, and curriculum innovation to highlight how research underpins the development of a responsive and technologically professional engineering education system. This study insight aims to inspire advancements in engineering higher education, preparing students to meet the challenges of the 21st century with an all-inclusive skill set, a global perspective, and a commitment to sustainability. The ultimate goal of this study is to cultivate an environment where research and education converge to produce not just engineers, but innovators and leaders in the field.

Keywords- Course-based Undergraduate Engineering Research Experiences (CUERE), OBE, Research Activities, Research-based Education System, Quality Education

1. Introduction

Course-based Undergraduate Engineering Research Experiences (CUEREs) engage students in addressing engineering research questions or problems that are of interest to the academic or research community. These represent scalable laboratory learning or experiential learning that allow a whole class of students to experience the excitement of research within an engineering discipline. There are five keys elements of CUERE:

- **Iteration:** cycles of inquiry and critical evaluation of data and information, repeating and revising as necessary
- **Collaboration:** students mimic the engineering research process by engaging with other students and/or TAs and instructors in conversations to clarify and progress ideas
- **Discipline-based process:** students learn practices of the engineering discipline by engaging in an investigation
- **Relevance:** outcomes of engineering student research have implications, applications, or other outcomes that are relevant and interesting beyond the course
- **Discovery:** engineering students work with information to answer questions or develop ideas that are new to the other engineering students, instructor, and broader community.

CUERE can be implemented based on the PODS system as a pedagogical model. PODS is one of the learning cycle used for design active learning teaching module. In PODS learning cycle, students are encouraged to make a prediction about the result of a particular engineering experiment before any treatment. The experiment is then performed and the students are encouraged to make a quantitative or qualitative observation of the experimental results. And then, students can discuss and share their predictions and observations with group or class; whether the same or not from any conflict between their predictions and observations can be solved during the discussion phase. After discussion, students come to be a better understanding about the specific courses underlying the observations amongst themselves and or with the facilitators. Finally, students are encouraged to synthesize their newly learned ideas and conclusions into the more general framework of their knowledge on the whole content.

Figure.1 shows the block diagram of PODS learning cycle that always start with the Prediction. In the case of improving the students' understanding on specific courses, the researcher has implemented and utilized the PODS learning cycle based on hand-on activities. This is because it is more suitable for the topic and students who learn in the specific courses. All students have a chance to discuss, share their ideas and experience between their predictions and observations in this study. Moreover, it is important that all students are encouraged to synthesize what they have learnt. This can reflect how their understanding of a particular topic has been evolved to try to identify the critical issues that need to be addressed for meaningful learning to occur. As they progress in their investigation of specific courses, the researcher can be given many opportunities to express their ideas [1-5].

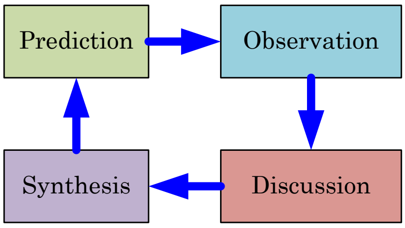


Figure.1. Strategies of YTU [1]

2. Undergraduate Research Activities at YTU

Booth explains that the research cycle starts with basically a practical problem: one must be clear what the problem being attempted to solve is and why it is important. This problem motivates a research question without which one can tend to get lost in a giant swamp of information. The question helps one zero in onto manageable volume of information, and in turn defines a research project which is an activity or set of activities that ultimately leads to result or answer, which in turn helps to solve the practical problem that one started with in the first place as shown in Figure.2.

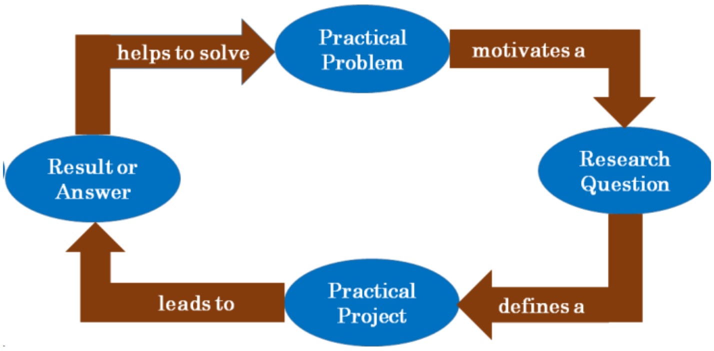


Figure.2. Research Flow Diagram

The researcher not only selects a qualitative, quantitative, or mixed methods study to conduct; the inquirer also decides on a type of study within these three choices. Research designs are types of inquiry within qualitative, quantitative, and mixed methods approaches that provide specific direction for procedures in a research design. Others have called them strategies of inquiry. Quantitative strategies have involved complex experiments with many variables and treatments (e.g., factorial designs and repeated measure designs). There are two focuses on two designs: surveys and experiments. In qualitative research, the numbers and types of approaches have also become more clearly visible during the 1990s and into the 21st century. Narrative research is a design of inquiry from the humanities in which the researcher studies the lives of individuals and asks one or more individuals to provide stories about their lives. Phenomenological research is a design of inquiry coming from philosophy and psychology in which the researcher describes the lived experiences of individuals about a phenomenon as described by participants. Mixed methods involves combining or integration of qualitative and quantitative research and data in a research study. Figure.3 illustrates the designing engineering research.

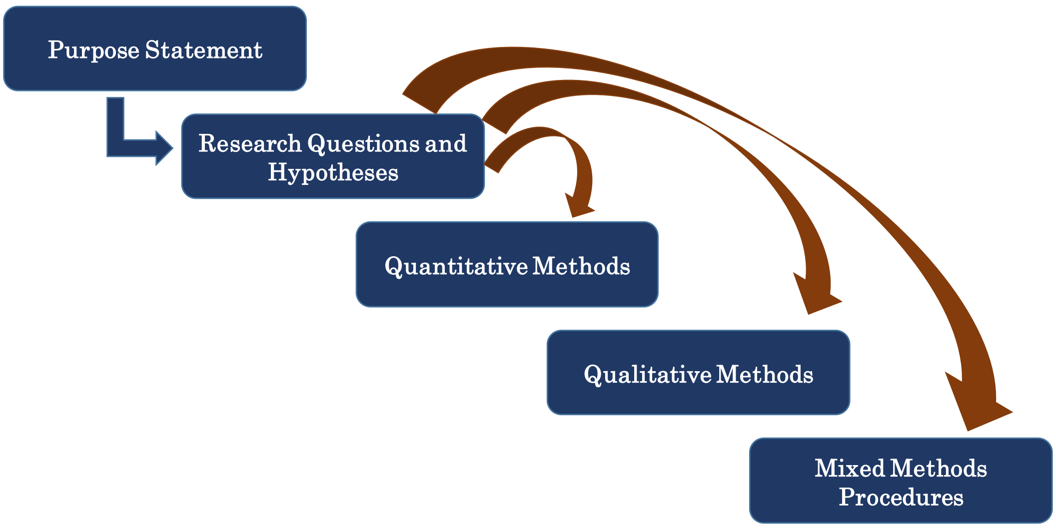


Figure.3. Designing Engineering Research

In proposals, researchers need to distinguish clearly between the purpose statement, the research problem, and the research questions. The purpose statement sets forth the intent of the study, not the problem or issue leading to a need for the study. The purpose is also not the research questions—those questions that the data collection will attempt to answer. Instead and again, the purpose statement sets the objectives, the intent, or the major idea of a proposal or a study. This idea builds on a need (the problem) and is refined into specific questions (the research questions). Figure.4 shows the purpose statement for engineering research.

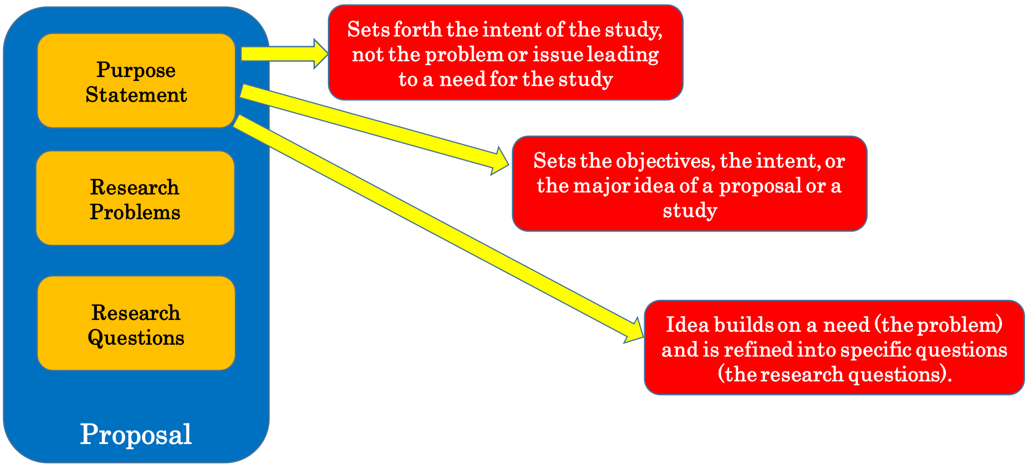


Figure.4. Purpose Statement for Engineering Research

In a qualitative study, inquirers state research questions, not objectives (i.e., specific goals for the research) or hypotheses (i.e., predictions that involve variables and statistical tests). These research questions assume two forms: (a) a central question and (b) associated subquestions. The central question is a broad question that asks for an exploration of the central phenomenon or concept in a study. The inquirer poses this question, consistent with the emerging methodology of qualitative research, as a general issue so as to not limit the views of participants. Several subquestions follow each general central question; they narrow the focus of the study but leave open the questioning. Figure.5 demonstrates the research questions and hypotheses.

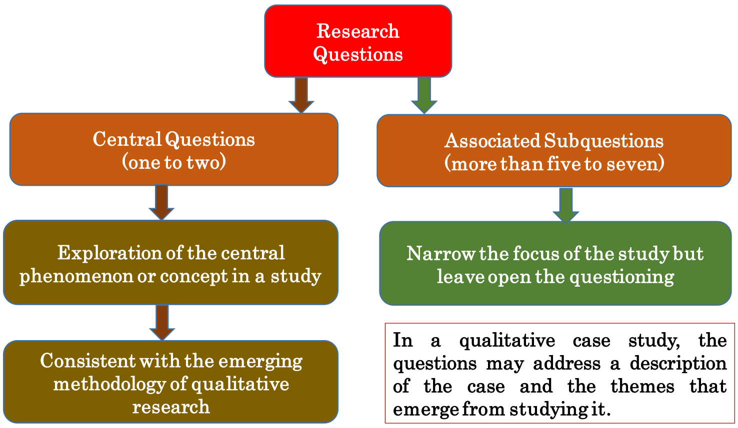


Figure.5. Research Questions and Hypotheses

3. CUERE Implementation at YTU

The target of Research University has followed the activities of research groups at the university. Figure.6 offers the important activities of a research group at YTU. The research publications are one of the credits for the establishment of Research University. In this model, the first level is the final year or sixth year (B6) students, and the second level is the first year and second-year master (M1 and M2) students, the third level is the first year to third-year doctoral (D1 to D3) students, and the top-level is the teachers. At first, teachers announced their research themes and topics for creating their research groups. The different levels of research topics are provided by the respective supervisor or teacher at YTU. The leader is that teacher, and he/she introduced his/her research works in front of the B6, M1, M2, D1, D2, and D3 students. That teacher always creates research group seminars every week. All research group members have to present their understanding of research findings and knowledge sharing at the research group seminars. That teacher always gives valuable advice to his/her research group members. The research group members follow the suggestions of that teacher. Finally, they have got their research achievements after completing the research activities based on different levels. The teachers shall have to transform their research outcomes into research publications and teaching material. In this regard, the teachers have the dominant teaching qualifications based on the research achievements by researching with research groups at university. The consequence of research-based education is directly affected by the Outcome-Based Education system with research university establishment [2].

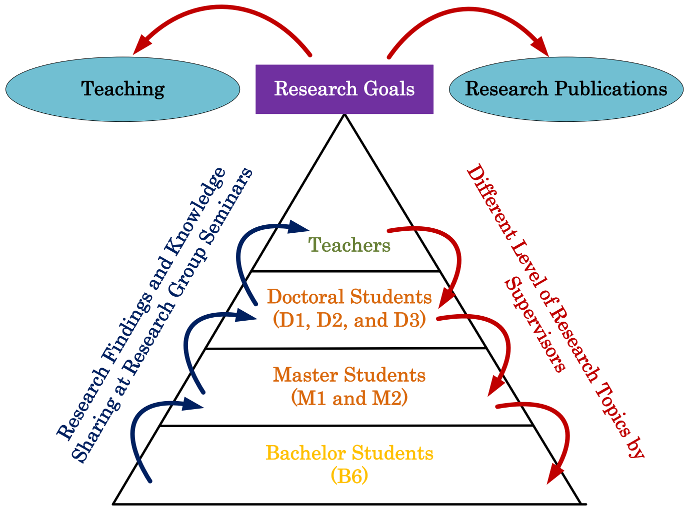


Figure.6. Formulation of Research Groups Activities at YTU [2-3]

4. CUERE through Research and Innovation

The model for engineering research practices through research and innovation system is shown in Figure.7. The idea after that block diagram is very similar to basic closed-loop control system design. There are eight elements to operate that model. The first one is the inputs of the system and it is called "Research Inputs". Those inputs could be "Problems from Societies", "Problems from Industries", and "Problems from Research Laboratories". The second one is summing point which function is the difference between Research Inputs and the Feedback portion that comes from the Sustainable Research Works and Evaluation. The third one is the Error Signal after the summing point. The fourth one is called the "Controller of the Control System" and it shall be "Researchers from Universities and Industries" and the function is to control the Research University. The fifth one is the "Disturbance of the Control System" and it shall be "Boundary of Scientific Researches". The combination of the output of "Researchers from Universities and Industries" and "Boundary of Scientific Researches" shall be the inputs of the "Research University" that includes the two research activities of "Basic Research" and "Applied Research". The sixth one is the output of the control system called "Research Outcomes" which consists of "Knowledge", "Publications", and "Products". The last one is feedback portions. In this model, there are two feedback system. The inner feedback is to compensate the "Boundaries for Scientific Researches" and its must be "Collaborations with Local and International Organizations". If we have great amount of collaborations with different organizations, the disturbance of "Boundary of Scientific Researches" could be reduced. The outer feedback should be "Sustainable Research Works and Evaluation". We could control the model with stable condition after utilizing the two feedback system for undergraduate engineering research practices [5].

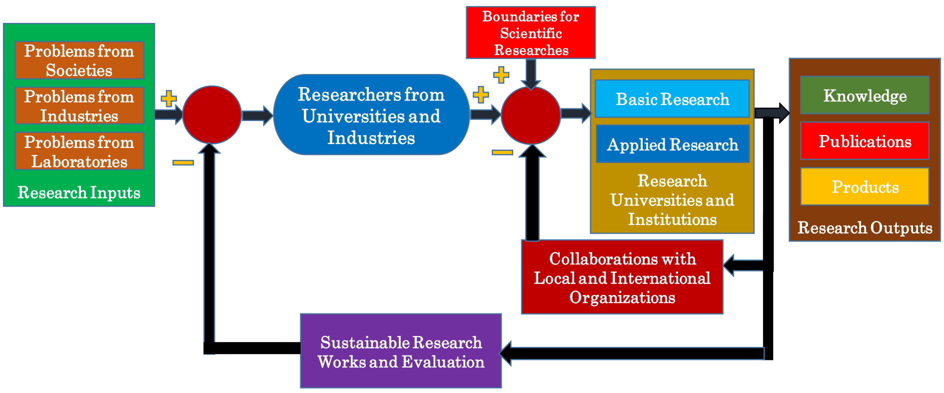
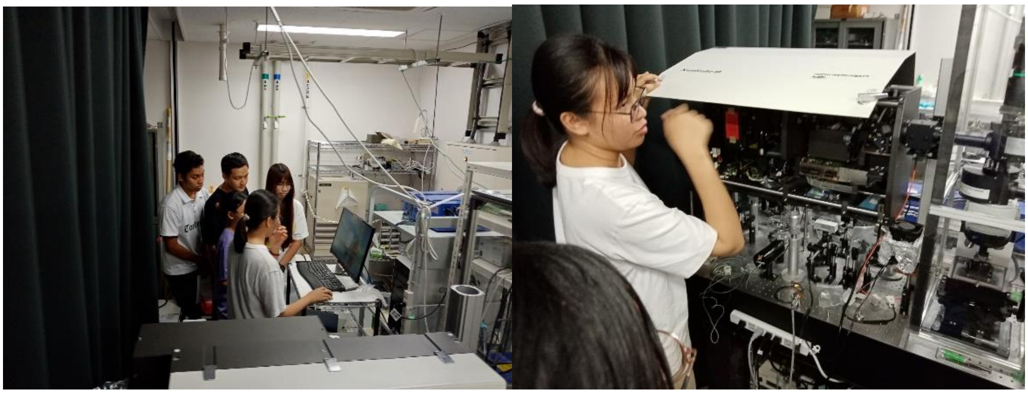


Figure.7. Model for Engineering Research Practices through Research and Innovation System [5]

5. CUERE Practices at YTU

YTU has two important research centres of Myanmar-Japan Technological Development Centre (MJTDC) 1 and 2 for research activities of undergraduate and postgraduate studies. Figure.8 illustrates the Undergraduate Research Activities at Research Centre (MJTDC 1) of YTU.



(a) (b)

Figure.8. Undergraduate Research Activities at Research Centre of YTU

After completing the research activities for undergraduate students, the research work presentations are offered by all undergraduate students for their graduations. Figure.9 shows the research work presentations offered by undergraduate students of YTU in 2023.

(a) (b)

Figure.9. Research Work Presentations offered by Undergraduate Students of YTU in 2023

6. Some Research Outcomes

There are several research activities for undergraduate studies. The most well know activities are integrated design project and graduation research. The integrated design projects are for the fifth year courses and the graduate researches are for the final year courses. Figure.10 shows the Undergraduate Research on Wall Climbing Robot at YTU. Figure.11 demonstrates the Undergraduate Research on Vertical Takeoff and Landing Unmanned Aerial Vehicle at YTU.

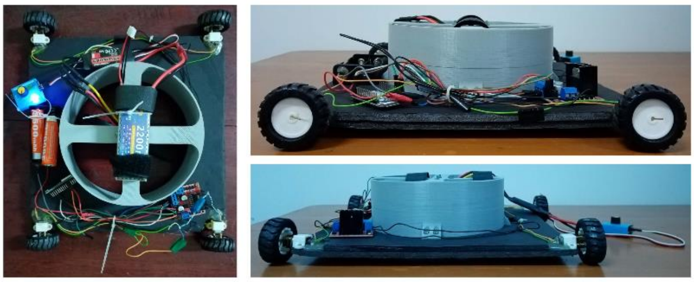


Figure.10. Undergraduate Research on Wall Climbing Robot at YTU

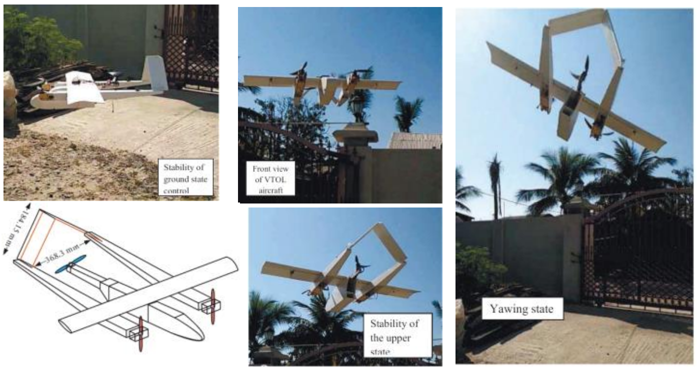


Figure.11. Undergraduate Research on Vertical Takeoff and Landing Unmanned Aerial Vehicle at YTU

7. Benefits of CUEREs for Students and Instructors

Figure.12 shows some lecture notes from research outcomes from experiences of YTU. CUEREs have several benefits for both students and instructors. CUEREs could help the level of understanding on courses could be improved by all students. The research activities could reflect the deep understanding on the engineering practices for sustainable development and lifelong learning of the graduates. And also, CUEREs could motivate the teaching staff for their education and research qualifications based on their research activities. The experimental-driven lecture notes could be the outcomes of the CUEREs at YTU.

The Benefits of CUEREs for Students are as follows:

- Gain knowledge in course content and research technical skills in several engineering disciplines
- Demonstrate gains in communication, organization, time management, and information literacy
- Gain confidence and self-efficacy
- Get exposed to and explore new and exciting career opportunities

The Benefits of CUEREs for Instructors are as follows:

- Advance their skills in developing instructional materials, incorporating active learning strategies, and managing engineering research projects
- Advance original engineering research with a timeline for completion
- Develop relationships with new researchers and recruit engineering students for internships and other opportunities

Figure.12. Some Lecture Notes from Research Outcomes

8. Conclusion

The undergraduate engineering curriculum should be necessarily modified to meet the outcome-based education through CUERE. The outcomes of CUERE are based on the following points such as (1) students' gaining a mastery of some specialized techniques and/or a broader knowledge of the content area covered, (2) experience conducting research, (3) developing a greater capacity for self-confidence in doing research work, (4) the ability to apply for further research opportunities in higher academic pursuits.

9. References

[1] Hla Myo Tun, Thida Than, Myint Myint Than, Khin Sandar Tun, Zaw Min Naing, Maung Maung Latt, Win Khaing Moe. Analysis on Research and Education for Electromagnetic-Applied Subjects with Finite Difference Time Domain Theory. American Journal of Electromagnetics and Applications. Vol. 6, No. 1, 2018, pp. 6-16. doi: 10.11648/j.ajea.20180601.12.

[2] Hla Myo Tun, "Improvement of Teaching Staff Qualification in line with Research-Based University and Outstanding Laboratory Facilities Fulfillment for Quality Engineering Education towards Outcome-Based Education System", International Conference on Engineering Education Accreditation (ICEEA) 2021, January 14-16, Yangon, Myanmar.

[3] NAM S&T Newsletter, A Quarterly of the Centre for Science and Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre), Vol. 32, No. 2, July - September 2022, https://www.namstct.org/DOCU/newsletters/Newsletter-July-September-2022.pdf

[4] Hla Myo Tun, "Formulation of Discipline Based Criteria for Electronic Engineering Programme through Mathematics Topics to Implement the Outcome Based Education System at Yangon Technological University", International Conference on Engineering Education Accreditation 2023 (ICEEA 2023 Myanmar), 27th July to 28th July 2023.

[5] Hla Myo Tun, Sustainable Development for Engineering Practices through Research and Innovation, 31st General Assembly and 7th Special Distinguished Lectures 11-13 September, 2023 Nay Pyi Taw, Myanmar

မြန်မာနိုင်ငံအင်ဂျင်နီယာကောင်စီ
Myanmar Engineering Council

WFEO-CEIE

ISBN 978-99986-0-252-6
9 789998 602526