



The Engineering Workforce Demands in Malaysia: Insights from The Industrial Perspective

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ABSTRACT

BACKGROUND & CONTEXT

The rapid advancement of Industry 4.0 technologies and global challenges such as climate change and digitalization has prompted a reassessment of engineering education. Traditional curricula are increasingly viewed as insufficient for developing interdisciplinary problem-solving skills. While global reports emphasize integrating technical knowledge with ethics, sustainability, and innovation, gaps remain in effective implementation. This study contributes to efforts to redefine engineering education.

PURPOSE OR GOAL

This study aims to identify essential attributes of future engineers and propose curriculum reforms aligned with Industry 4.0. It explores how engineering education can better prepare graduates for emerging challenges. The goal is to determine key competencies and strategies for effective curriculum transformation.

APPROACH OR METHODOLOGY

A qualitative approach was used, involving semi-structured interviews with six global engineering education leaders. Participants included academic leaders, accreditation experts, and curriculum developers. Data were transcribed, coded using Atlas.ti, and analyzed thematically based on established curriculum standards.

OUTCOMES

Five key themes emerged: strong fundamentals, digital and data literacy, sustainability and ethics, project-based learning, and incremental curriculum transformation. The findings highlight the importance of interdisciplinary skills, experiential learning, and the role of both grassroots and institutional leadership.

CONCLUSIONS

Engineering education reforms should emphasize learner-centered approaches and integration of theory with real-world applications. The findings align with global frameworks while offering practical insights for implementation.

KEYWORDS

Engineering curriculum; Industry 4.0; engineering education.

Introduction

Global challenges such as climate change, sustainability, infectious diseases, artificial intelligence, and ethical concerns highlight the urgent need for innovative problem-solvers (National Academy of Engineering, 2016). Engineers, trained to analyze complex problems and apply technology to improve lives, must continually be prepared through evolving education to address these pressing issues. Industry 4.0 is reshaping industries and societies through the convergence of digital, biological, and physical technologies. This era demands engineers with interdisciplinary knowledge, adaptability, and the capacity to thrive amid AI, big data, automation, and advanced manufacturing. Such rapid advancements; from AI and digital twins to 3D printing, nanotechnology, and VR; require engineers to be not just operators but creators of new technologies (Ministry of Higher Education Malaysia, 2024). This paper examines whether current engineering education adequately prepares graduates for these transformations. It situates the evolving needs of engineers in the context of Industry 4.0, tracing historical, contemporary, and future perspectives, and draws on key reports, including a Ministry of Higher Education Malaysia (MOHE) study, to outline directions for engineering programs in the country.

Literature Review

Efforts to improve engineering education have long involved professional bodies, faculty, and industry stakeholders. Since the 19th century, organizations such as the Institution of Civil Engineers, Engineers Ireland, and ASCE regulated engineering practices (International Engineering Alliance, 2015). This led to accreditation bodies worldwide, culminating in the Washington Accord (1989), which set global standards. The International Engineering Alliance (IEA) later published 11 graduate attributes (International Engineering Alliance, 2021). ABET introduced 12 criteria in 2000, revised to 7 in 2022, while Malaysia's Engineering Accreditation Council (EAC) defined 12 graduate outcomes in its 2020 standards (Engineering Accreditation Council, 2020).

Engineering education societies have also advanced reforms. Since the late 19th century, the American Society for Engineering Education (ASEE) has advocated faculty development, collaboration, relevance, and periodic assessments to drive innovation (American Society for Engineering Education, 2012). The National Academy of Engineering (NAE) report, *The Engineer of 2020*, envisioned professionals with leadership, interdisciplinary skills, and adaptability to address sustainability and global challenges (National Academy of Engineering, 2004). Similarly, the Royal Academy of Engineering (RAE) emphasized integrating technical excellence with ethics, leadership, and inclusivity (*Educating Engineers for the 21st Century*, 2007; *The UK's Engineering Future*, 2020).

Other influential works include Sheppard et al.'s (2008) *Educating Engineers*, which stressed design-centered, human-focused curricula; Rogers' (2016) *Digital Transformation Playbook*, highlighting digital fluency and agile innovation; and ACED's reports (*Engineering Change*, 2017; *Engineering 2035*, 2021), which emphasized teamwork, lifelong learning, and Industry 4.0 competencies (Australian Council of Engineering Deans, 2017; 2021). Graham's MIT study (2018) identified global best practices in experiential and entrepreneurial learning. Corporate perspectives, such as Dassault Systèmes' *Universal Registration Document* (2021), emphasized virtual collaboration and sustainability, while Malaysia's *Industry4WRD* policy stressed digital literacy, data analytics, and resilience (Economic Planning Unit, 2004).

Across these reports, a clear trajectory emerges. Early 2000s priorities centered on analytical rigor and leadership (National Academy of Engineering, 2004). By the 2010s, collaboration, adaptability, and globalization came to the fore (Australian Council of Engineering Deans, 2017; Royal Academy of Engineering, 2007). Looking toward 2035, reports stress resilience, systems thinking, and digital fluency (Australian Council of Engineering Deans, 2021). Studies by Graham (2018), Sheppard et al. (2008), and Dassault Systèmes (2021) reinforce experiential, innovation-driven approaches as critical for Industry 4.0.

These global insights align with calls for curricula revision to produce Industry 4.0-ready engineers (Australian Council of Engineering Deans, 2021). This study builds on these perspectives by exploring expert views on designing future engineering curricula, generating recommendations for Malaysian universities (Ministry of Higher Education Malaysia, 2024).

Methodology

In this qualitative study, interviews with several key informants via purposive sampling were conducted. The key informants' narratives provide a qualitative aspect that has meaning, significance, and rich understanding (Tashakkori et al., (2020). The interviews were conducted with six global experts/leaders in engineering education that comes from education and industrial background (Table 1) to get their insights on the future of engineering education, particularly in relation to the curriculum, attributes of prospective engineers, and the distinctiveness of the engineering programme to produce Industry 4.0 ready engineers. The interviews were recorded and later transcribed. These transcripts were then meticulously coded, categorized, and themed using Atlas.ti version 8 software. The thematic analysis was grounded in the attributes expected of future engineers as outlined in the engineering curriculum.

Table 1. List of engineering education experts involved in interviews

Name		Position
1.	E1	Engineering Faculty Academic and Centre for Engineering Education Leader, United Kingdom
2.	E2	Global Education Director of an International Engineering Company, France
3.	E3	Engineering Education Innovation and Research Academic Leader, Australia
2.	E4	Engineering Accreditation Leader, United States
4.	E5	Director of Engineering Education of an Engineering Academy, United Kingdom
5.	E6	Engineering Faculty Trainer and Curriculum Development International Network Leader, Sweden

Results

Preliminary data extraction from the interviews have been broadly categorized into 11 segments, that include (i) technical skills, (ii) mathematical and computer skills, (iii) management, (iv) entrepreneurial skills, (v) sustainability and ethics, (vi) adaptability, (vii) teaching and learning, (viii) transformation, (ix) educators' development, (x) Accreditation and recognition, and finally (xi) Stakeholders' involvement. However, some of the points stated above were grouped together to ease the discussion. Hence, the points above have been organized into five important major elements, which are (i) Strong fundamentals (ii) Project-Based learning using real world problems (iii) Digital knowledge & skills, mathematical knowledge & data management (iv) Entrepreneurial, sustainability & professional ethics, and (v) Transforming engineering education

Strong Fundamentals

All experts agree that the fundamentals in engineering programs will always be rooted in science, mathematics and technical knowledge. These are the fundamental knowledge in engineering that must be mastered by engineering students at a deep level. E3 said,

“I think in some ways, you know, a lot of the fundamentals have already been defined. They're in our accreditation guidelines.” (20.34).

Other areas of advanced knowledge such as programming, artificial intelligence and data science are important as well in the context of Industry 4.0, but it could evolve from time to time.

In addition to the fundamentals mentioned, there are two other branches of knowledge or skills that need to be mastered by engineering students. They are the digital knowledge and skills (computer simulation currently coined as the digital twin of physical processes, Artificial Intelligence and machine learning, as well as data science) and soft skills or transferable skills (project management, problem-solving, teamwork, ethics, sustainability mindset, etc.). These will be further discussed in the next sections.

E3 described them as a Y-shape,

“Yeah, we, we like to talk about the T shaped graduate, but I like to say it's really a Y shaped graduate. There are three arms. There's obviously the technical issues, technical fundamentals. There's the, what you might call the generic skills, you know, ethics, teamwork, communication, innovation. Probably put project management in that category. And I say they're, they're the skills that absolutely every graduate in the university needs, not just those in the engineering faculty, the technical skills distinguish the discipline, whether you're a civil, mechanical or whatever, and the third, the third arm is, is design and systems engineering. It's that ability to actually solve problems, which you don't actually solve problems by wheeling up your your technical skills, until you've understood what the problem is. So there's a process of problem identification with the client.” (15.55).

Project-based Learning Using Real World Problems

All of the experts agreed that it is not the knowledge itself, but how the fundamental knowledge is designed in the curriculum and how it is learned by the students through more student-centred approaches. The ways that these fundamentals were being taught in the first two years of their studies are not helpful for students in the later stage of their engineering program when they undergo their engineering projects, as well as in their future workplace. Although students learned the fundamentals and may have passed the courses with excellent results, many of them usually struggle when given projects or real engineering problems that require the fundamentals, indicating a lack of deep understanding of the fundamentals. E1 said,

“And you know, we, we spent a lot of time saying, you know, you gotta learn this math, you gotta learn that science. You gotta learn this technical thing, that technical thing. And then, you know, well, you maybe did when you got to the third year. The, you know, good students saw it in the projects and make those connections, but they'd forgot a lot of it by then” (11.41).

Project-based learning has been mentioned by all the experts for the teaching and learning in engineering education to help students learn through experiential learning and become creative applying their technical knowledge. E4 said,

“And then, you know, everybody knows the best way to learn is by doing, right? You learn by doing. That's why I like, sort of like the project based learning approach, also because there's more of that involved” (13.07).

This is agreed by E3, who said,

“And, but it kind of brings us back to our early conversation about fundamentals... most of that's finished by the end of second year. And third and fourth year should be a time of exploration and possibilities, and that's where I think the project based learning really, really has a big part to play. I think almost everything in third and fourth year should be project based, because students want to get on and do real things. They don't want to sit around learning textbooks anymore...” (28.04).

E5 mentioned,

"design led project based learning approaches are embedded in undergraduate degrees" (11.14).

The project-based learning must be using real world problems to ensure that the learning of the fundamentals can be strengthened. E3 said,

"Project I mean, ... put them in teams from mixed up, from across departments, and then bring in some mainly Non Governmental Organizations, charities, to set challenges, real world challenges, things they don't know the answer to, based on new and sustainability goals" (21.14).

Digital Knowledge and Skills, Mathematical Knowledge & Data Management

Digital knowledge and skills, mathematical knowledge, and data management have emerged as indispensable competencies for modern engineers, as highlighted by all experts interviewed. These skills are crucial for addressing the demands of emerging technologies, which are advancing at an unprecedented pace.

E1 emphasized the importance of digital tools and coding knowledge, stating,

"A good working knowledge of Python and understanding data analysis is going to be something that will pervade all engineering jobs" (02.21).

Similarly, E4 pointed out,

"Everything is driven by software now, especially in the tool side. Everything's simulated" (51.44).

He added,

"It's critically important to expose students to some of these modern tools and techniques" (52.34).

E2 asserted the prominent role of digital twins that renders the communication from the management, optimization and planning decisions to the manufacturing operation and line seamlessly. He emphasized that driving digital transformation requires a blend of technical expertise, particularly in digital technologies, and strong organizational and procedural skills. This integration of technical knowledge with digital capabilities is crucial for successful implementation. Thus, this scenario supports the needs for engineers who are well-versed in these modern computing tools and approaches.

E2's insights further underscore the critical nature of digital fluency in an era of rapid industrial evolution driven by Industry 4.0. He highlighted how digital transformation is not confined to any specific sector but spans manufacturing, infrastructure, and life sciences. The engineering company, a major player in digital tools for engineering internationally, has emphasized the need for "pivotal" skills such as simulation, data science, systems engineering, and digital supply chain management. E2 noted that digitalization not only reshapes engineering methodologies but also necessitates a rethinking of roles for technicians and operators, illustrating how connectivity between engineers and shop-floor workers is becoming increasingly important.

Statistics, as a foundation for data analysis, was highlighted by multiple experts. E4 noted,

"Statistics is hugely important... There's so much data now... every student should have it because they'll probably use it so much" (58.50).

E3 echoed this sentiment, stating,

"We have abundant data now, and in the digital age, the capacity to analyze it. However, we've always taught statistics poorly unless someone needs it in their role and relearns it again" (22.55).

Another expert, E5 emphasized the importance of statistics by stating the following precautionary statement about the risk of misinterpreting results, saying,

"Graduates may use big data analytics tools without really understanding why the results are what they are" (11:00).

The role of digital tools, such as computer-aided design (CAD) and simulation software was also discussed. E3 said,

"We have this amazing design software that does a lot of the work for us. But students still need to understand stress, strain, and other fundamentals" (18:51).

E5 stressed the need for foundational and advanced knowledge in digital tools, stating,

"You need to teach the fundamentals of AI and advanced digital tools" (11:02).

Entrepreneurial, Sustainability & Professional Ethics

Entrepreneurial thinking, sustainability, green solutions, sustainable development goals (SDGs), human values, and ethics are core components of modern engineering curricula. These elements are essential in shaping engineers who can address contemporary challenges while fostering responsible innovation. Graduates must understand societal needs, operate ethically and sustainably, and navigate diverse cultural contexts in modern workplaces. E1 emphasized this, stating,

"We will need graduates that understand society much better, understand the role of engineers in society. They need to know how to operate ethically, how to operate sustainably, and how to operate in the diverse cultures of modern workplaces" (01:31).

Project-based learning must play a pivotal role in contextualizing technical knowledge within real-world applications. By integrating projects as central components of education, students can develop a holistic understanding and drive innovation. E1 highlighted this approach, noting,

"We wanted something... that they saw this thread of projects as very central, and that the technical learning was all supporting, contributing to the projects... Projects provide a focus, a backbone, that binds all the loose ends together" (11:41).

Sustainability is a critical theme in engineering education, focusing on fostering a mindset aligned with global goals. Students must develop innovative solutions that minimize environmental impact, conserve resources, and promote social equity. E4 reinforced this, stating,

"I do think, for example, one of the things I talk about all the time... is the support of sustainability and getting students to think about, you know, as they go through their education, and coming up with designs and so forth about sustainable solutions" (05:00).

Additionally, E3 remarked,

"...getting that life cycle thinking into our design tasks. So it's not a very big shift, but it's just making that happen" (56:25).

Insights from E2's interview highlight the importance of digital and green transitions in addressing contemporary challenges. Employers are increasingly prioritizing engineers who possess a combination of technical expertise, systems thinking, and a focus on sustainability. He said digitalization extends beyond traditional engineering domains, requiring practices that align engineering activities with sustainable and transformative approaches to drive systemic innovation. Emerging practices such as virtual twin technology, which simulate and optimize processes before implementation, demonstrate how engineers can reduce environmental impact, conserve resources, and enhance energy efficiency while improving functionality and user experience.

Engineers must adopt a paradigm shift to reverse environmental impacts and prioritize interdisciplinary collaboration. This involves embedding broader perspectives into engineering education. E5 emphasized,

“Over the last 250 years... all our engineered products have been contributing to ever-increasing carbon emissions... In 20 years, we have to entirely reverse that trend... requires potentially an entirely different mindset: of how we think about our engineered products, why we’re designing things, why we’re developing things in the very first place” (05:12).

He also noted,

“...embedding much greater levels of interdisciplinarity into our engineering degrees... with geography, politics, economics, history... so engineers have a much broader understanding of the work they’re doing and how they fit into society” (06:12).

Integrating engineering ethics into curricula is crucial for preparing students to navigate complex moral dilemmas. Ethics education fosters critical thinking, accountability, and professionalism by addressing safety, environmental impact, and societal well-being. E3 stated,

“The job of the studios is that you bring realistic tasks in and you get students to understand that the decisions they make are not just technical and economic, but they’re social and environmental as well” (54:00).

E2 also further stressed that engineers must understand not only the “how” but also the “why” behind their actions to ensure socially and environmentally responsible outcomes.

Transforming Engineering Education

Having mentioned all the attributes of future engineers for the era of Industry 4.0, it is clear that the way how these attributes should be taught must be student-centred. All the experts mentioned project-based learning that uses real world engineering problems. This leads to the next concern on how to ensure that engineering educators are able to use the student-centred approach in developing the attributes among the engineering students. All of them also agree that institutions should start on a small scale first.

All the experts agreed that making changes or transforming engineering education is the most difficult task. However, there are some proven and effective experiences practiced by the experts in making the transformation. E1, E3 and E6 suggested changes can start from a small group of engineering educators who are willing or “ready to shift” (E3, 38.40). Furthermore, E1 suggested that the small group can be those who are enthusiastic to change and they are usually the senior faculty members,

“I think you, you know, if you're looking at making a change in the university. You need to capitalize on those enthusiasts. You need to capitalize on senior staff with a vision to make a change.” (29.37)

The senior faculty members were mentioned particularly because the junior and new faculty members are pressured to focus on research excellence such as getting research grants and publication, but the pressure is less for the senior faculty members, especially when they have reached a “very senior position” (E1, 30.07).

Starting small can also mean changing a few small parts of the program. E3 suggested the transformation of engineering education can be done by pulling apart a program and changing only a handful of the subjects or components with the participation from a few senior faculty members in charge of the few subjects that are willing to change. E3 said,

“...we try to change curriculum as a whole, and you don't need to, because it's just a series of parts, if you, if you pull any of your programs apart... Look, this is our civil engineering program. There are about a dozen different components in there, and each

component is made up of one, two or three subjects. So when you realize that you can actually work on just two subjects at a time. You can take the five academics who are involved in those two subjects and say, how could we do this better? And they'll be able to tell you how they can do it better. So, so you can get down to the detailed conversations at that level. You don't have to have everybody in a room, because that you'll get nowhere with that from past experience. So just have small group discussions with those involved, yeah, but you also and, and you need to get the senior people interested in the problem first." (1:03.25)

E4, however, suggested change could be sped up through accreditation exercise and incentive. E4 said,

"It's incentivizing faculty to change... faculty will get extra time credits, or however it's organized at the individual University, where they have time to try different things... if you wanted to change a course, for example, next semester, and say, Okay, we're going to, we're going to basically put aside our traditional teaching methods and go to something that's going to be more interactive with students. That's going to take a lot of, it's going to take time and effort. And so I think incentivizing is good, the support..." (16.30)

E4 further mentioned,

"Hey, you need to change, and this is what you got to do. Do it, I don't think so that'll be effective. Now, having said all that, I think this is where accreditation comes in, also, because that's part of the motivation" (19.41)

"I think the, the accreditation part helps, definitely helps. Yes, it's a pushing factor." (21.21)

Changes take years to happen. E1 said, "you have just got to remember it's going to take three years for the students to stop complaining about the fact you've changed a load of things. You know, You've almost got to watch a cycle of students to get the ones coming in fresh and then accepting it."

However, the most crucial factor to make any changes in engineering education is leadership. E4 said,

"And the pull part on the incentivize you gotta that's something I think the Deans can actually, that's something within their power. And I think incentivizing faculty, I think, is the way to go... gotta be some incentive to get people to change behaviors and how they do things" (1:03.25)

E3 mentioned,

"Because, you know, there will always be those who go, the Dean doesn't really believe in this, you know, whereas, if, if challenged, and the Dean says, Well, yes, of course, we're doing this. That's, that's all that's required eventually, eventually people will just kind of knuckle down and, and, and get started." (30.49)

E1 shared his experience to make change at his faculty can only become a reality because of his Dean. He said,

"...so when my, my dean came back from the Global Engineering Dean's Council meeting... So Sunday afternoon he writes this email saying we're going to radically change all our degree programs. This is our plan, and he was a software engineer, so he helpfully thought, just writing it in an email... He went to that extent and sent this spreadsheet out, and oh my god, it created panic and division... the next 48 hours he was being flooded with well, this can't possibly work because of this and this... It got the attention of the faculty that something was going on. And even though mostly it was to say they didn't like it, we spurred the conversation. And in a way, that was important, but it was also, I think, valuable to me, when I came in, in that, yeah, I came into the

role to then, then lead this project and make the change... and it didn't have many details, so they filled in the gaps, and then didn't like the thing, you know, didn't like what they'd filled in, but they were sort of making assumptions about what he must meant, and with their own prejudice in it, whereas at the heart of it was a set of principles of what he wanted to achieve that I could actually quite well buy into. And I think the majority of which we were, we did get done.” (1:13.03)

With the Dean’s support and instruction, engineering education could be transformed at the faculty level, not just among a few enthusiastic faculty members.

Discussion

Figure 1 provides an overarching view of the key findings and recommendations as an integrated strategy for transforming engineering education. This strategy highlights the critical attributes for engineers, transformative learning approaches, and strategies to address challenges in curriculum reform. It connects the foundational elements of engineering attributes (discussed in Section 5.1) and the broader transformation strategies (outlined in Section 5.2). By aligning these components, the strategy serves as a roadmap for equipping future engineers with knowledge, skills and qualities essential for thriving in Industry 4.0 through fostering leadership and grassroots change within institutions.

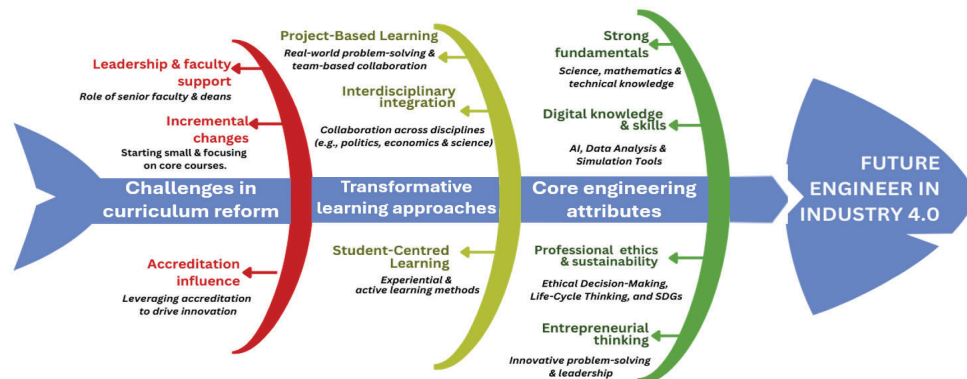


Figure 1: Strategic Attributes for Future Engineers in Industry 4.0

Attributes for Engineers

Engineering education has long emphasized fundamentals in science, mathematics, and technical knowledge, forming the basis for accreditation standards and ensuring analytical rigor (National Academy of Engineering, 2004). With Industry 4.0, additional competencies such as programming, AI, and data science are essential, while statistics is now regarded as a core requirement (Australian Council of Engineering Deans, 2021). The Educating Engineers for the 21st Century report also stresses broader skills like communication, teamwork, and problem-solving, reinforcing the Y-shaped graduate model (Royal Academy of Engineering, 2007).

Project-based learning (PBL) is increasingly recognized as a transformative approach. Reports by ACED (2017), Graham (2018), and Sheppard et al. (2008) highlight PBL’s role in fostering creativity, systems thinking, and experiential learning. The UK’s Engineering Future underscores how real-world projects linked to societal goals enhance student motivation and innovation (Royal Academy of Engineering, 2020). Accordingly, recommendations for Malaysian universities include strengthening fundamental teaching through problem- and project-based learning, with emphasis on real-world contexts (Ministry of Higher Education Malaysia, 2024).

The rising importance of digital tools and data management reflects Industry 4.0 demands. Dassault Systèmes (2021) highlights digital twins and simulation tools, while experts stress

coding, data analytics, and software proficiency (E1, E4). These align with the Engineer of 2020 (National Academy of Engineering, 2004) and Engineering 2035 (Australian Council of Engineering Deans, 2021), which emphasize digital fluency and seamless integration of technical skills. Graham (2018) adds that embedding statistics and data literacy into curricula is crucial for accurate analysis and decision-making.

Modern engineering education must also integrate entrepreneurial thinking, sustainability, and ethics. The RAE reports (2007; 2020) emphasize embedding sustainability and inclusivity, while ACED (2017) and Graham (2018) highlight life-cycle thinking and interdisciplinary approaches. Sheppard et al. (2008) further stress ethics and accountability. These insights suggest curricula should embed sustainability, digital skills, and professional ethics without adding new standalone subjects, but rather by integrating them across courses (Ministry of Higher Education Malaysia, 2024).

Transformation of Engineering Education

While many reports identify what to transform in engineering education, fewer detail how (Australian Council of Engineering Deans, 2017, 2021). Leadership is a key driver, as noted by Graham (2018), and faculty support is crucial (American Society for Engineering Education, 2012). Incremental change at small scales, through motivated academics and selected courses—has proven more effective than wholesale reforms (Graham, 2018). ACED (2021) notes that smaller institutions like Olin College illustrate how gradual transformation can succeed.

In line with these insights, the Ministry of Higher Education Malaysia (2024) recommends capacity building and mentoring for educators within communities of practice. This dual approach, leadership-driven institutional support combined with grassroots initiatives, can cultivate champions of change, embedding Industry 4.0-relevant skills and pedagogy into engineering programs.

Conclusion

Comparing the study's findings to established reports by various engineering education organizations, the engineering education experts believe that engineering fundamentals, digital skills, sustainability, and professional ethics must be emphasized in the curriculum. through implementation of effective learner-focused teaching strategies for meaningful learning. Teaching methods should foster a deep understanding through real applications, such as project-based learning with real-world problems, ensuring future engineers can solve complex issues in the Industry 4.0 era. Both top-down (leadership) and bottom-up (grassroots) incremental approaches should be used to transform engineering education, initiating and sustaining changes to ensure quality programs that prepare future engineers for Industry 4.0.

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