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Engineering education at the age of Industry 5.0 - higher education at the crossroads

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ABSTRACT: The nature of work is rapidly evolving, mainly driven by digital technologies, underpinned by Industry 5.0. It is more important than ever that engineering education, in particular, disciplines such as computer science and engineering must adapt to these changes. As witnessed by the changes over the past decade, enormous technological advancements have taken place in both hardware and software domains. Some of the outstanding industrial advancements in disruptive technologies include the Internet of Things (IoT), intelligent systems and artificial intelligence (AI) - enabled paradigms. The difference is shrinking and it is becoming harder to draw a fine line between various engineering disciplines. In this article, the author explores and emphasises the need for skill-oriented, project-based learning rather than classical engineering education with an intense focus on theoretical concepts. This approach has the potential to meet the societal demands of the engineering profession underpinned by the Industry 5.0 and Education 5.0 frameworks.

INTRODUCTION

In the coming years, technology will play a key role where advanced technologies, such as Internet of Things (IoT) and virtual reality will dominate in higher education in developed, as well as developing countries. These technologies hold great potential to enhance learning outcomes by offering a more engaging learning experience, improving organisational efficiency and equipping graduates with the knowledge and skills they require to meet the emerging industry requirements. Some of these technologies hold great promise to ascertain real-time insights into student performances and interventions required at an earlier stage [1].

In 2017, the concept of Society 5.0 was shared by Japan, wherein it was defined as:

> *…a human-centred society that balances economic advancement with the resolution of social problems by a system that highly integrates cyberspace and physical space* [2].

With the evolution of Industry 5.0, humans will work alongside semi-autonomous machines to build a sustainable human-centric ecosystem that makes the higher education sector even more dynamic, exciting and challenging.

Industry 5.0 is a driving force for the future higher education sector; however, it is not simply a continuation of Industry 4.0 as such. Industry 5.0 complements human beings by making them a central point and integrating technological advancements around to improve the quality of life in a sustainable society. Industry 5.0 is very well aligned with the United Nations sustainable development goals [3] and has a much greater potential to transform higher education institutions. By adopting the policies and practices of Industry 5.0 in the higher education sector, one can fully unfold the potential and benefits of such transformation.

In this article, the author explores the framework of Industry 5.0 and its corresponding succession to Education 5.0. The envisioned smart society will entail transformative education, which is likely to lead to a world, where the human-machine interface will be an essential part of everyday life and collaborative tasks will be performed by both humans and machines. Also, the author investigates and demonstrates a case study where certain aspects of Industry 5.0 were incorporated into a project-based task and the results were quantified. The author emphasises the need for such incremental transformation in engineering education to make alignment and gradually achieve the goals and objectives of Industry 5.0.

Contrary to the common perception, engineering very much includes both hard and soft skills, such as design conception, actual design implementation, working in teams, communication skills, social integration, interfacing and prototyping at the system level to predict behaviour using science and engineering principles, to name a few. As defined by the US accreditation body, the Accreditation Board for Engineering and Technology (ABET):

> …*Engineering is the profession in which knowledge of the mathematical and natural sciences gained by the study, experience, and practice is applied with judgment to develop ways to utilize, economically the materials and forces of nature for the benefit of mankind* [4].

To complement this accreditation requirement in a true sense, a project-based learning approach was designed and outcomes were quantified for a better understanding in respect to Industry 5.0.

Project-based learning entails several advantages and various professional bodies, such as the Association for Computing Machinery and the IEEE Computer Society, in computing [4], and the American Society of Mechanical Engineers (ASME) recommend including project-based learning to give students hands-on experience in real-life industrial projects [5]. It is emphasised in this article that the computing and engineering education be re-thought and calibrated such that students learn how to work in teams and understand the design cycle, while working in a multicultural environment.

Recent advancements in technologies, such as IoT, virtual learning and smart automation have significantly influenced the higher education sector. With the advent of Industry 5.0, where creativity is the main aspect, it is envisaged that the higher education sector will have a much bigger impact. The industry currently demands that fresh engineering graduates are well equipped with digital transformation tools with a human-centric AI-enabled perspective. Arguably, the present educational system is not fully capable to capture the aspirations of Industry 5.0 unless certain aspects were not transformed, such as project-based learning, human-machine interface and incorporation of applied artificial intelligence. Hence, Industry 5.0 must be aligned with Education 5.0 to create job opportunities and prepare the workforce needed to advance future technologies. An overview of the progress of industry, education and their corresponding characteristics are summarised in Table 1.

Table 1: Progress of industry, education and their corresponding characteristics.

Industrial progression	Educational progression	Characteristics and technologies used
Industry 1.0	Education 1.0	Information gathering with basic means of reading/writing
Industry 2.0	Education 2.0	Knowledge-based understanding with printable knowledge means, such as books
Industry 3.0	Education 3.0	Skills-based knowledge of computing and communication technologies
Industry 4.0	Education 4.0	Research-based learning with IoT based technologies
Industry 5.0	Education 5.0	Intelligence-based mass automation with technologies, such as AI, nano-computing and virtual reality.

OBJECTIVES

- To investigate and present an engineering case study, where students' learning experience based on a hands-on project in a multicultural team was investigated;
- Quantify learning outcomes in both hard and soft skills and students' overall understanding of the engineering design process;
- Develop a broader range of skills that underpins Industry 5.0 and assesses their suitability for higher education engineering programmes;
- Analyse a successful learning strategy in the context of Industry 5.0.

METHODOLOGY

For students to successfully progress in their engineering programmes, their courses must provide opportunities to help them learn the fundamentals of engineering, and be engaging, motivating and hands-on. Engineering programmes must make the graduates market-ready for successful transition and progression into their professional careers. The latest research in pedagogy reflects that many higher education institutes are trying to adopt project-based learning in engineering courses [6]. However, quantifiable research is required to understand the dynamics of project-based learning aligned with the requirements of accreditation bodies and the emerging digital industry's needs.

This article offers an insight to help faculty and staff involved with engineering programmes, in particular, programmes such as electrical, electronic and computer engineering. The following case study demonstrates and elaborates on how an integrated project is conceptualised and designed for engineering students. The study was evaluated by assessing students' overall performance in the course to help understand further improvements and interventions required.

Based on this case study and the author's personal experience in teaching and learning, this article argues that project-based learning is no longer an option, rather, it must be included as part of the curriculum design. Such engineering projects should have features that include activities, such as design conceptualisation, development of hardware and software, working in teams, appreciating multicultural collaboration, and finally end product development and testing.

CASE STUDY

A case study was designed, where a cohort of 40 students in a postgraduate module was given a task to reverse engineer and design an integrated platform for environmental sensing. This project was carefully designed and included several design aspects requiring applied hardware and software skills and working in small multicultural teams. The project involved addressing present-day concerns, such as sustainability and the effective utilisation of renewable resources. The task included conceptualising and modifying the existing design by reverse engineering and developing a viable solution to power up environmental sensing with a solar panel and make interfaces with the hardware circuits. This bespoke design task also required students to look at the task from a system perspective. Finally, a microcontroller was required to be interfaced and programmed to perform a hand-shaking protocol between different hardware entities. The input sensor was required to sense environmental data, convert analogue signals into the digital domain and display information for data analysis purposes. An overview of the design project is shown in Figure 1.

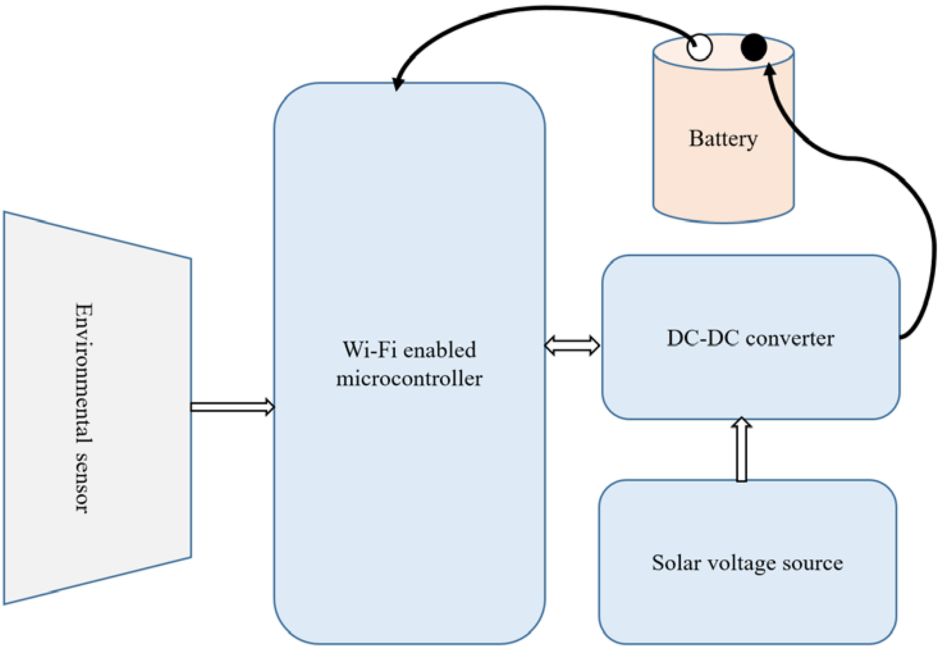

Figure 1: Overview of the design project.

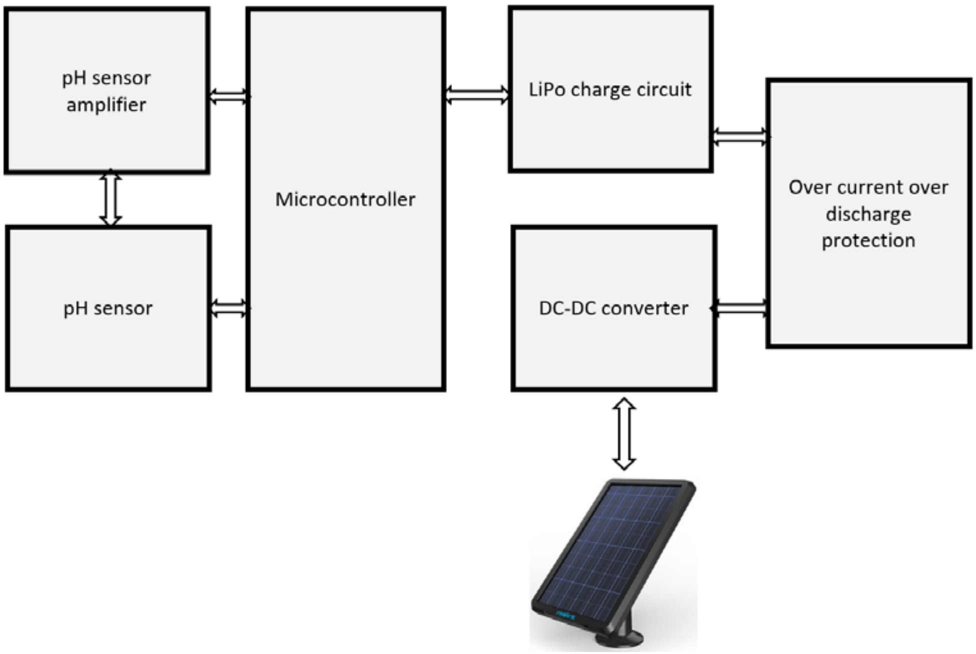

Figure 2: Hardware design blocks.

Further breakdown of tasks required project management skills, where the main task was further sub-divided into hardware and software as shown in Figure 2 and Figure 3, respectively. As shown in Figure 2 above, the hardware design consisted of six sub-tasks; namely, the LiPo solar charge circuit, the over current over-discharge protection circuit, the boost converter circuit, supply inverter, pH sensor amplifier and a microcontroller. These tasks required hardware skills as were outlined in the course learning outcomes.

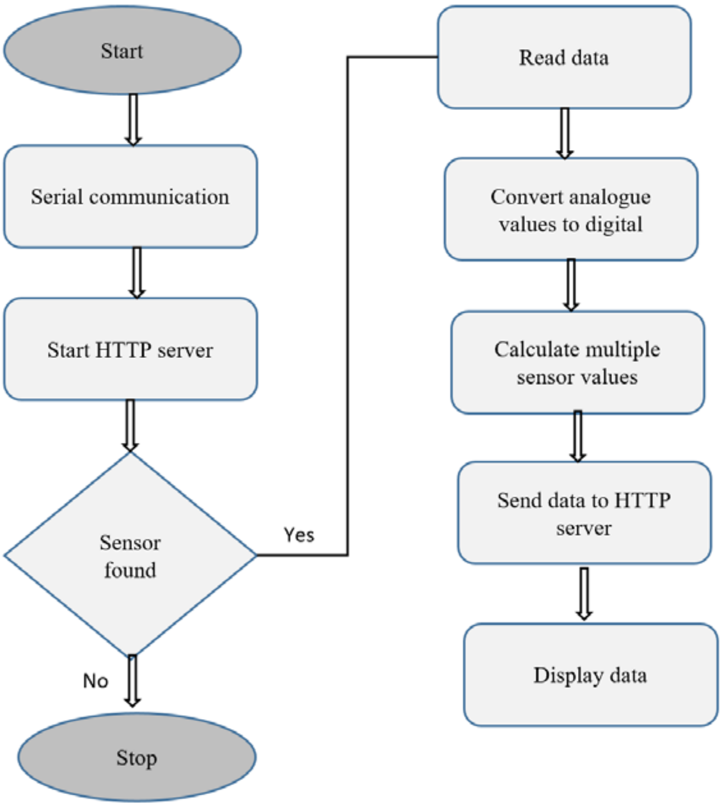

Figure 3: Software flowchart.

The software design is shown in Figure 3, which included tasks, such as data collection from the environmental sensor node and data logging and display. According to the flowchart several tasks were performed, where the software was required to establish a serial communication interface through a predefined communication protocol. Once the sensor node interface was established, the environmental data was collected.

A backend server was designed for data integration and logging. The input data was further converted into a digital domain through an analogue to digital converter and a data display. These tasks required software development skills including microcontroller programming and data server interface with the underlying hardware components. These tasks helped students to understand software programming skills by implementing them on hardware platforms. Hence, this activity bridges the gap between hardware and software domains and developed a deeper understanding of the theoretical concepts.

ASSESSMENT

To ascertain the impact of project-based learning in the context of Industry 5.0, certain assessment tools were adopted to gain insight and make further improvements. The course project run for seven weeks in total, where regular meetings took place to keep track of the project's progress and solve problems at an earlier stage rather than late.

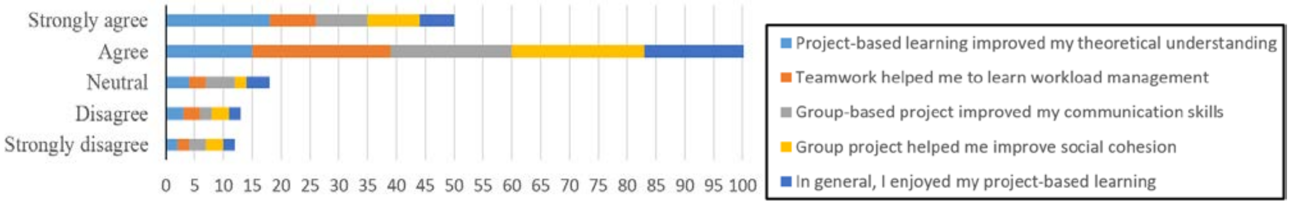

Figure 4: Student satisfaction survey results.

Two short surveys were created to get students' feedback on the knowledge obtained and their understanding of the theoretical engineering concepts, while working with multicultural design teams. In total, 40 students participated in the study, where they were asked specific questions about their understanding of the topic with a project-based approach, workload management skills, communication skills, social cohesion and overall satisfaction with the course delivery.

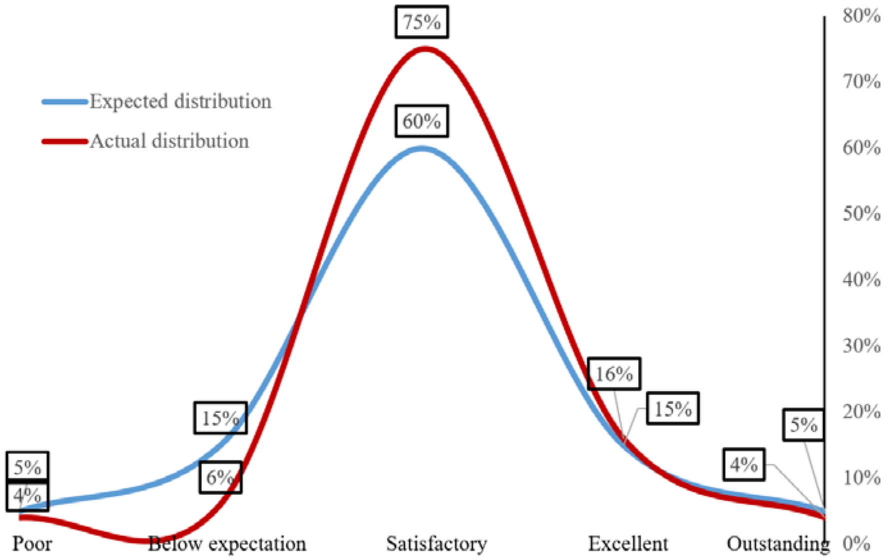

Figure 5: Students' performance distribution.

The final satisfaction survey was compiled and the findings are reported in Figure 4 and Figure 5, respectively. A normal distribution chart between expected and actual student performance is shown in Figure 5. As seen in Figure 5, students' actual performance was relatively better than the expected performance. As reflected in Figure 4, students found it easier to work in teams, understand theoretical concepts, and reproduce and implement hardware and software for real-life applications. As Industry 5.0 emphasises a human-centric approach, students learned and appreciated the value of working with a team of multicultural backgrounds, which also helped them improve their communication skills.

DISCUSSION AND CONCLUSION

It is not an overstatement that society is going through tremendous change in this time, which is both exciting yet demanding. In early 1965, Gordon Moore predicted that the density of computational logic on an integrated circuit will double almost every 18 months [7]. It later turned out to be the case and hence, became a so-called Moore's law. Similarly, Buckminster Fuller describes in his book Critical Path that new knowledge had doubled every century until 1900 [8]. He described in his book, the famous, *knowledge-doubling curve* and postulated that knowledge will double every 18 months. However, mankind is witnessing one of the fastest paces of technology and the pace of growth is continuously increasing.

Project-based learning has been well practised and is considered a student-centred approach for engineering programmes all over the world. This approach is still valid and very well aligned with the Industry 5.0 and Education 5.0 frameworks, albeit with some evolution. Both the focus and topics selected to make incremental alignment with Education 5.0, must be relevant from a technology, sustainability and ethical behaviour perspective. It is important that project-based learning addresses certain core concerns, such as educational equity through the use of open-source hardware and software. To make a seamless transition into Industry 5.0, in the author's opinion, project-based learning should consider certain aspects, such as knowledge and skills that are equitable, sustainable, modular, collaborative, open-sourced and ethical. In doing so, projects would require continuous evolution by making modifications to the project specifications and their learning outcomes.

Industry 5.0 advocates personalisation, which underpins cutting edge technologies, such as machine learning, artificial intelligence (AI) and computer vision. Therefore, such activities must address industrial requirements by including certain skillsets in the project-based learning approach. By including machine learning and AI concepts into project-based learning, students will gain immediate insight and will learn hands-on skills. As AI holds immense potential, it is not optional anymore, but rather imperative that all engineering programmes include skills to help facilitate students learning of how to code, as well as understand the social and ethical implications of artificial intelligence in engineering disciplines. The role of AI in Education 5.0 is thoroughly discussed and predicted in [9-11].

From the author's personal experience of working in the higher education sector in countries, such as Pakistan, Denmark, the UK and currently the United Arab Emirates (UAE), the project-based learning approach has proven to be one of the most successful techniques in explaining subtle engineering concepts.

In the author's most recent experience, while working in the UAE higher education sector, it is encouraging that the government recognises and is committed to adopting digital technologies as a driving force for economic growth and sustainability. Hence, the UAE is perhaps best placed in the Gulf Cooperation Council (GCC) to improve its higher education sector and embrace both Industry 5.0 and Education 5.0 frameworks in the true sense. It has both the will and resources to improve and provide a sustainable workforce to meet the demands of this digital transformation. It is indeed not an option, but rather a requirement for a well-resourced forward-looking country to develop an academia-industry ecosystem for sustainable growth. However, as investigated through this case study that higher education is at the crossroads, where transformation is needed to take a leadership role in higher education and fulfil the ambitious goals of the Industry 5.0 and Education 5.0 frameworks.

REFERENCES

1. Pusca, D. and Northwood, D.O., The impact of positive change in higher education. *World Trans. on Engng. and Technol. Educ*., 18, **4**, 427- 432 (2020).
2. Cabinet Office, Society 5.0, 20 May 2022, http://www8.cao.go.jp/cstp/english/society5_0/index.html
3. United Nations 17 Sustainable Development Goals, 18 May 2022, https://sdgs.un.org/goals
4. ABET, Inc. 2021. Criteria for Accrediting Computing Programs, 10 April 2022, https://www.abet.org/wp-content/uploads/2021/01/C001--21--22-CAC-Criteria.pdf
5. ABET Criteria for Accrediting Engineering Programmes (2021-22), 20 May 2022, https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2021-2022/.
6. Guo, P., Saab, N., Post, L.S. and Admiraal, W., A review of project-based learning in higher education: student outcomes and measures. *Inter. J. of Educational Research*, 102, **1**, 1-13 (2020).
7. Moore, G.E., Cramming more components onto integrated circuits. *Electronics Magazine*, 38, **8**, 114-117 (1965).
8. Fuller, R.B. and Kuromiya, K., *Critical Path*. St. Martins Press, MacMillan (1982).
9. Pedro, F., Subosa, M., Rivas, A. and Valverde, P., Artificial Intelligence in Education: Challenges and Opportunities for Sustainable Development. UNESCO (2019).
10. Cope, B., Kalantzis, M. and Searsmith, D., Artificial intelligence for education: knowledge and its assessment in AI-enabled learning ecologies. *Educational Philosophy and Theory*, 53, **12**, 1229-1245 (2021).
11. Nagao, K., *Artificial Intelligence in Education*. In: Artificial Intelligence Accelerates Human Learning. Singapore: Springer, 1-17 (2019).