The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
ASEE
Paper ID #41384

Stakeholders analysis for future Materials Engineering education – from good to great

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Abstract

In the twenty-first century, meeting technological demands requires educational excellence that is ready for the critical challenges society faces. In the ever-advancing engineering industry, how would our Materials Engineering education system adequately prepare our students with the essential knowledge and skills necessary to adapt and excel in their career? What are the learning outcomes that are required to support such excellence?

To design these learning outcomes in our curriculum, gathering and analysing relevant stakeholders' input is crucial. This paper presents our endeavour in partnering the stakeholders (students, educators/faculty, alumni and employers) to understand the gaps and needs of Materials Engineering education. Consultations with the stakeholders were designed to rally around three main focus areas namely (i) to evaluate the existing curriculum and validate good elements that should be retained, (ii) to identify missing gaps and areas that need improvement, and (iii) to address emerging trends and match future needs of Materials Engineering graduates with that of Materials Engineering industry. This study forms the basis for curriculum revamp of Materials Engineering undergraduate programme in our institution – from good to great.

While thorough analysis that looks into equipping our graduates with fundamental skills, agility and adaptability, collaboration skills, and innovation and enterprise mindset has reflected relatively positive feedback, several domains that require more development were highlighted too. They include the demand for more programming proficiency and data analytics, hands-on/practical experience, knowledge on Solidworks/CAD and ability to apply technical knowledge in real life applications. Such demands are now addressed in the new curriculum by introducing new courses and/or revising existing courses. A new laboratory course was introduced with greater emphasis on student-directed experimental design and practical work. A new course is offered to introduce students to various engineering digital tools like Solidworks and CAD. An existing engineering design course was thoroughly revamped to allow students work on real engineering problems brought up by industry partners. The industry partners also serve as direct mentors to our students and work closely with them for an entire semester to test, validate and refine the solutions proposed by our students.

Finally, key technological trends in the Materials Science industry in the next 5 – 10 years' time were consolidated into materials simulation, machine learning and Artificial Intelligence (AI), materials and sustainability, biomaterials for ageing population, semiconductor with new materials, nanomaterials and nanotechnology and advanced/flexible/wearable electronics. While most of the future trends have been addressed in the present curriculum, two new specialisation areas were introduced. First, Materials and AI specialisation was introduced to cater to students who wish to deepen their knowledge on how AI and machine learning contribute to materials simulation and new materials discovery. Second, Materials and Sustainability was introduced to prepare students to better meet the needs of various industries towards a circular economy and sustainable Earth.

We strongly believe that the newly revamped curriculum will prepare Materials Engineering students with essential knowledge and skills necessary to adapt in the ever-advancing engineering industry and excel in their career.

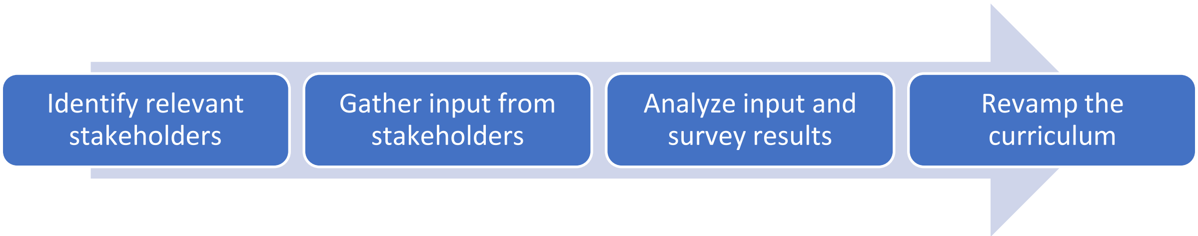
1. Background

The fast-paced advancement in science and technology means timely revision of existing curriculums is important to avoid instances where learners gain obsolete skills that lack global competitiveness [1], [2]. In 2020, we embarked on a curriculum review for Materials Engineering undergraduate programme. We are determined to ensure that our curriculum adequately prepare our students with the essential knowledge and skills necessary to excel in the ever-advancing materials engineering industry. The collective curriculum review exercise sought to evaluate the existing curriculum, identify gaps and areas for improvement and address future needs of the materials engineering industry.

Gathering relevant stakeholders' input is a crucial element to guide this endeavour. Supported by an education grant, this project, thus, aimed to survey and consult various stakeholders including students, educator (faculty), alumni and employers on their feedback about the existing Materials Engineering curriculum and their views of the future developments in Materials Engineering industry. Subsequently, this study forms the basis for curriculum revamp of Materials Engineering programme in our institution – from good to great.

2. Methodology

We believe that a great curriculum is not a sole responsibility of a singular academic unit or department in a university. Rather, a great curriculum should take into consideration the inputs from all stakeholders. Therefore, planning and execution of our curriculum review and revamp exercise involves four key phases, as shown in Scheme 1.



Scheme 1. Phases of curriculum review and revamp exercise

In the first phase, four groups of relevant stakeholders were identified, namely students, educators (faculty), alumni and employers. Targeted students group is graduating students who have completed at least one stint of internship during their course of study. They should be able to provide input based on their work experience during internships. The educators group refers to 30-35 faculty staff who actively teach various courses in the Materials Engineering programme. The alumni group refers to recent graduates who obtained their degrees in Materials Engineering within five years of this study while employers group refers to industry partners that actively recruit Materials Engineering graduates. During this phase, an application was also filed with our Institutional Review Board (IRB) to seek permission for this study. The Institutional Review Board (IRB) conducts ethical reviews on all research proposals involving human research participants, including the use of their personal data.

Once the list of relevant stakeholders was finalised and IRB approval was granted, the second phase began. To gather input from the stakeholders, survey forms and several focus group discussions were originally planned. Unfortunately, Covid-19 pandemic struck and restricted our approach to mainly online surveys. As such, survey forms were prepared and sent to respondents using “Verint” online survey system that allowed each respondent to receive a unique survey link via email. The response generated from each link was stored on the system safely.

Despite the challenges presented by the pandemic, relatively good participation was obtained from our target groups (students, faculty, alumni and employers), as recorded in Table 1 below. It is noted that a slightly lower participation from employers and alumni groups could be attributed to the lack of interactive, in-person sessions restricted by the pandemic.

Table 1. Number of responses gathered from various stakeholders

Students	Educators (faculty)	Alumni	Employers
104	23	48	24

The third phase of the study began by compiling and analysing the survey results. Comprehensive data analysis revealed valuable insights about the existing curriculum as well as the emerging trends in Materials Engineering industry. Thorough discussions about the survey results is presented in section 3 of this paper.

Finally, the last phase of the study involved revamping the existing curriculum to address findings and inputs from the stakeholders analysis. Discussion on the ideas and suggestions for Materials Engineering curriculum revamp can be found on section 4 of this paper.

The approach taken for our curriculum review exercise in Scheme 1 is somewhat similar to the process of curriculum change in engineering education proposed by Walkington [3], that envisions curriculum reform as a process that circles around four stages involving establishment (data collection and discussion), dissemination (consultation and refinement), design and development of curriculum and finally, implementation (teaching and evaluation).

3. Input from Stakeholders

The survey questions were designed to rally around three main focus areas namely (i) to evaluate the existing curriculum and validate good elements that should be retained, (ii) to identify missing gaps and areas that need improvement, and (iii) to address emerging trends and match future needs of Materials Engineering graduates with that of the industries. The stakeholders’ input for each focus area was thoroughly analysed and summarised here.

3.1 Evaluation of the present curriculum

First, input from stakeholders was sought on the overall sentiment about the preparedness of recent graduates in the Materials Engineering industry. Figure 1 shows that the stakeholders namely alumni, employers and students agree that Materials Engineering graduates are rather well prepared for jobs in the industry. This indicates that our present curriculum has met the needs of the industry well. While close to 80% alumni and employers rated this favourably, the students scored slightly lower, close to 70%. It is worth noting that students surveyed here drew their experience based on a short stint of internship. They had not completed the entire Materials Engineering degree programme and hence, underwent the internship with an incomplete mastery of Materials Engineering skills and knowledge.

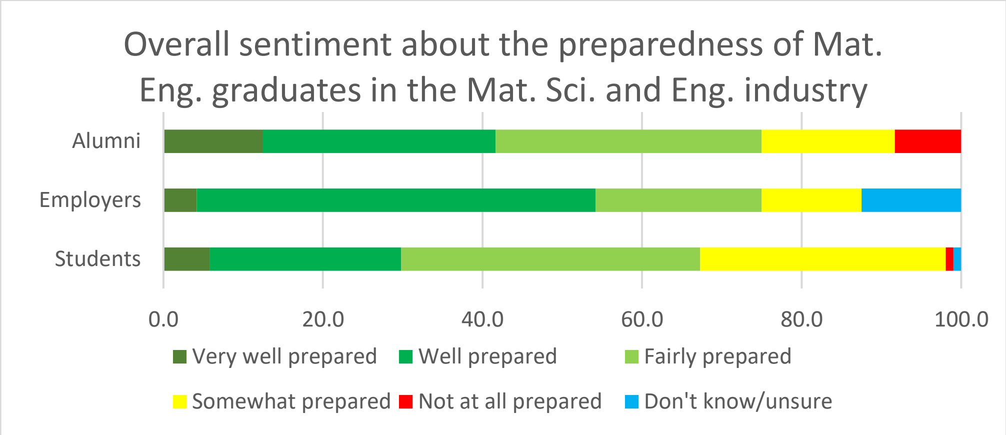
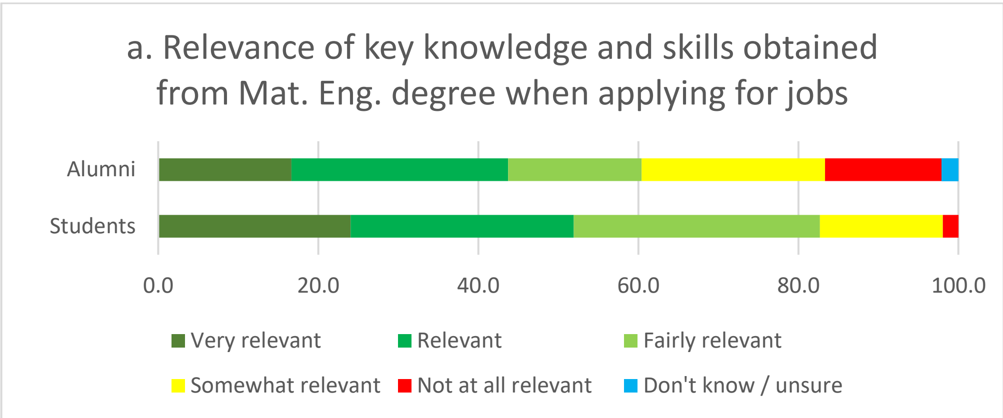


Figure 1. Overall sentiment about the preparedness of Materials Engineering graduates in the Materials Science and Engineering industry

The stakeholders were further asked to reflect on the relevance of key knowledge and skills obtained from Materials Engineering degree (i) when applying for jobs and (ii) in relation to the actual duties performed in their roles.



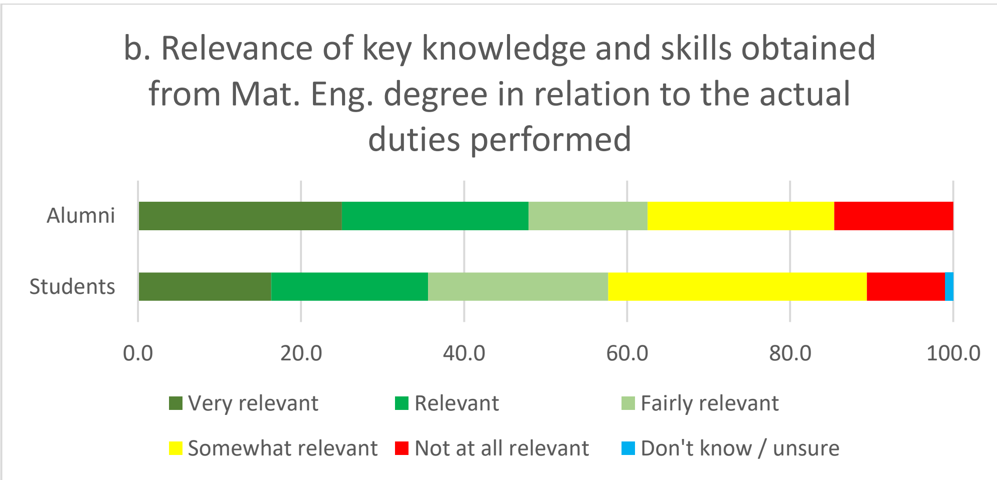


Figure 2. Relevance of key knowledge and skills obtained from Materials Engineering degree (a) when applying for jobs and (b) in relation to the actual duties performed

The alumni and students could relate the key knowledge and skills obtained from their degree when applying for jobs and in relation to the actual duties performed in their roles. In Figure

2a, more than 80% students could draw the relevance of their skills with the job requirement when applying for jobs. However, this number drops to close to 60% in relation to performing actual duties. Students added remarks in the survey citing that they would only learn certain skills and knowledge required to perform their duties well upon returning to school to complete their last two semesters of study prior to graduation. Thus, this is not a great source of concerns. The input from the alumni for Figure 2a and Figure 2b does not differ much, albeit at a slightly lower level that hovers around 60%. It is worth noting that not all Materials Engineering alumni eventually pursued a career in Materials Engineering industry; thus, certain group of alumni would not see the direct relevance.

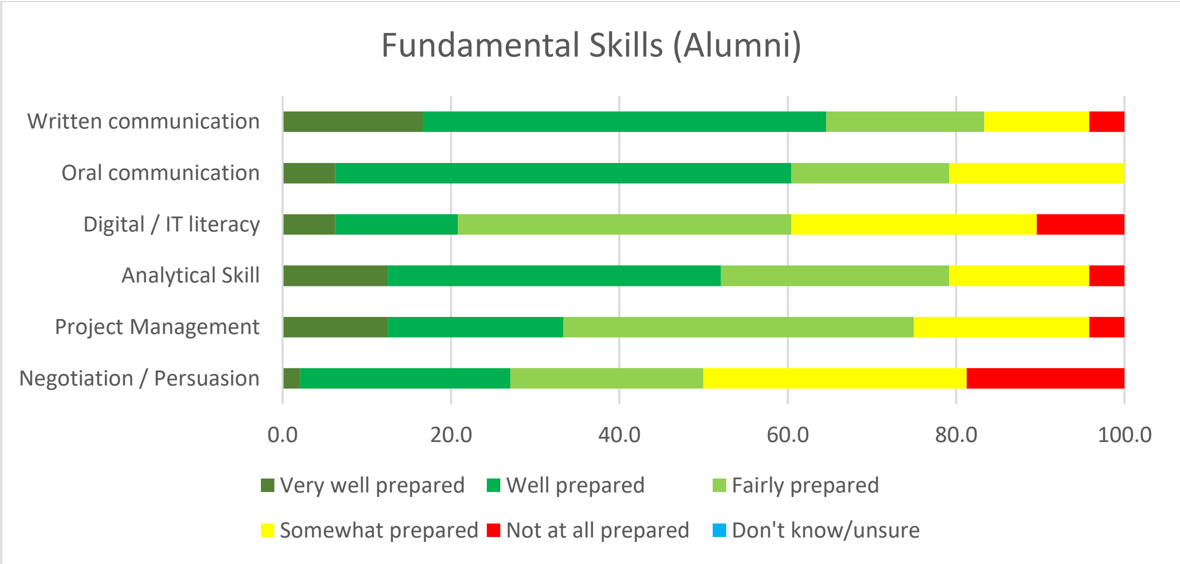
Figures 3, 4, 5 and 6 provide the stakeholders' opinions on how well the present curriculum equipped Materials Engineering students and alumni with different skillsets to perform well in their roles. A total of 19 specific skills and competencies were grouped into four main categories: (i) fundamental skills, (ii) agility and adaptability, (iii) collaboration skills, and (iv) innovation and enterprise mindset. This evaluation is crucial to ensure that our graduates' skills and attributes continue to be aligned with the employers' expectations [4], [5].

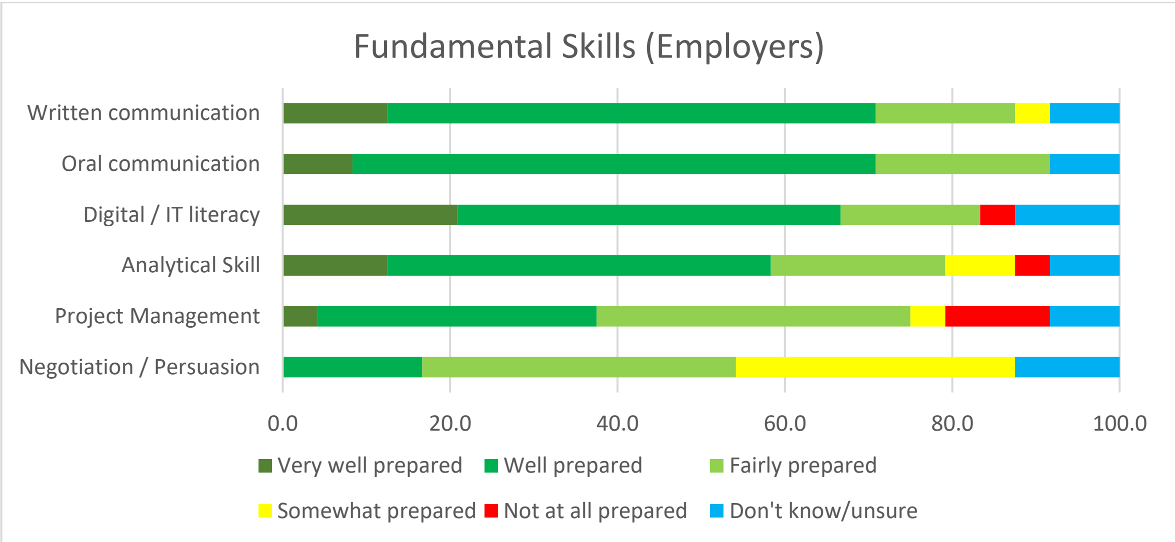
As seen from Figure 3, the present curriculum has equipped the students/graduates well with written and oral communication skill, analytical skill and project management. Digital literacy and negotiation/persuasion skill are two fundamental skills that were viewed as the least prepared by the present curriculum. The need for greater digital literacy is echoed again when respondents were asked to identify areas or skills that need improvement in the present curriculum. Clearly, this is a missing gap that must be addressed in phase 4 (curriculum revamp) of this study. Suggestions for the curriculum revamp exercise are presented in section 4 of this paper.

Figure 4 assesses the agility and adaptability of Materials Engineering graduates/students, which includes ability to apply knowledge and skillsets in different contexts, ability to develop innovative ideas and identify new opportunities, ability to thrive in situations with no determinate solutions, ability to work autonomously and be resourceful when required and capacity to work under pressure. While the alumni and employers have given a relatively high rating on all aspects surveyed, the students were slightly less confident. This is understandable as students had less opportunity to express these traits during their relatively short stint of internships, typically lasting for 20 weeks only.

Evaluation results on collaboration skills are shown in Figure 5. It is obvious that the present curriculum has done well to equip students/graduates with ability to engage with team members, capacity to listen and understand different perspectives, teamwork and ability to interact with coworkers of diverse backgrounds. While ability to communicate across all levels within the organisation was viewed favourably by alumni and employers, the students were less confident. This could again stem from the limited interaction opportunity students had during their short internship stints.

Finally, Figure 6 provides insight into innovation and enterprise mindset of Materials Engineering graduates/students in terms of ability to identify new opportunities, ability to develop innovative ideas to solve problems and ability to observe professional industry codes and general ethical standards. All stakeholders (alumni, employers and students) provided favourable feedback on this set of skills.





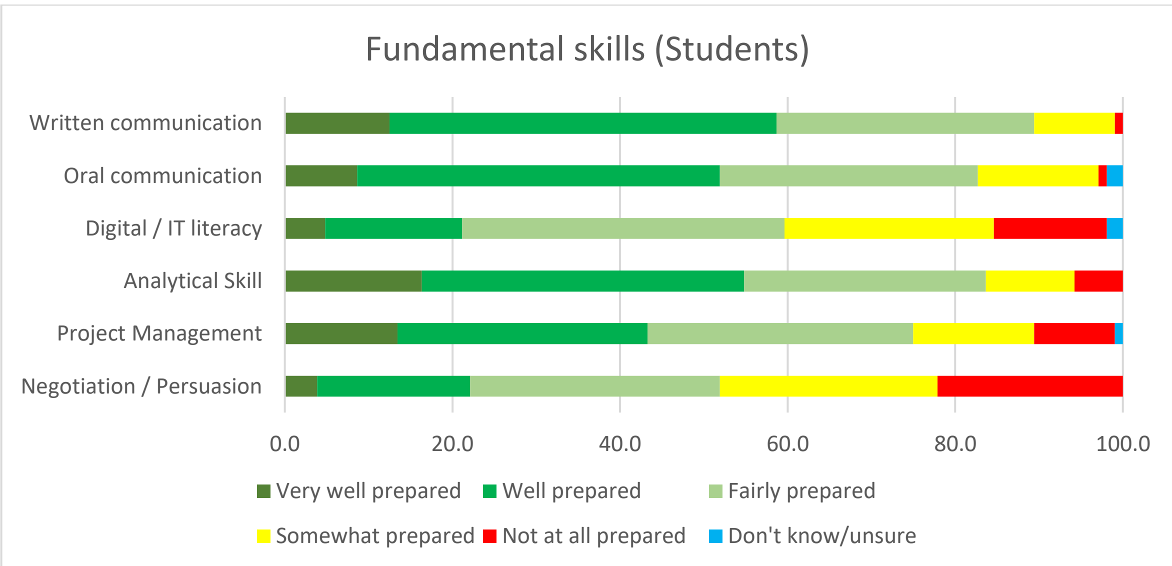
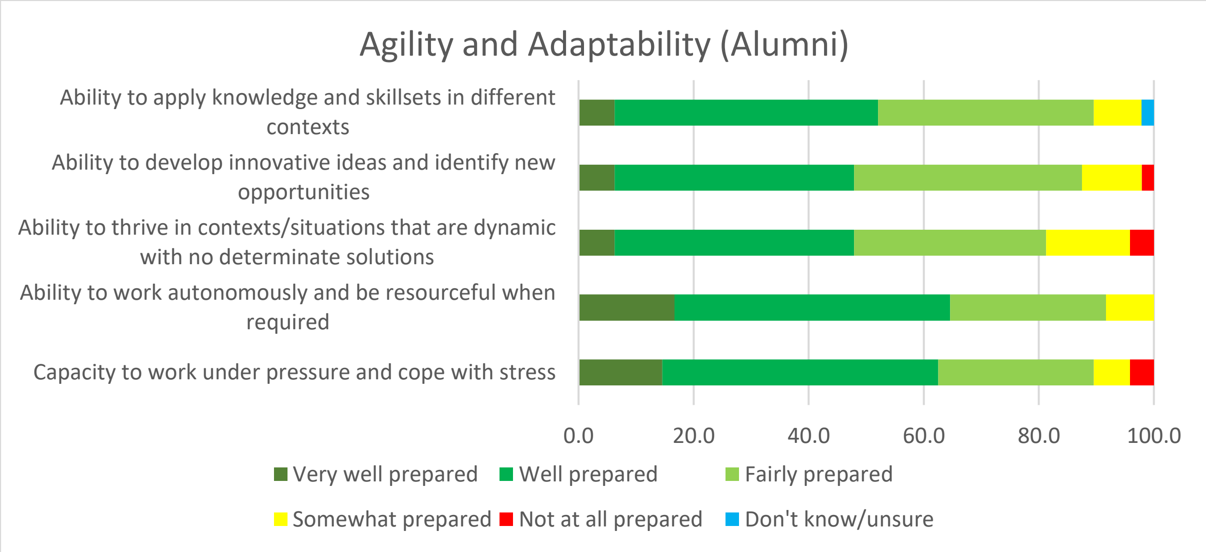
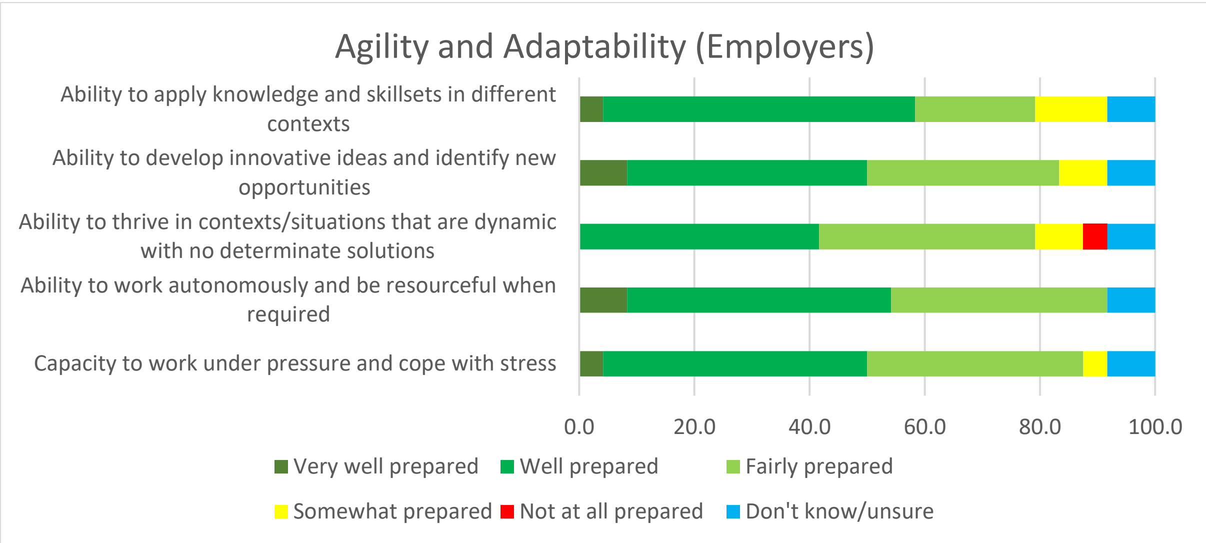


*Figure 3. **Fundamental skills** of Materials Engineering graduates/students as evaluated by alumni (top), employers (middle) and students (bottom)*





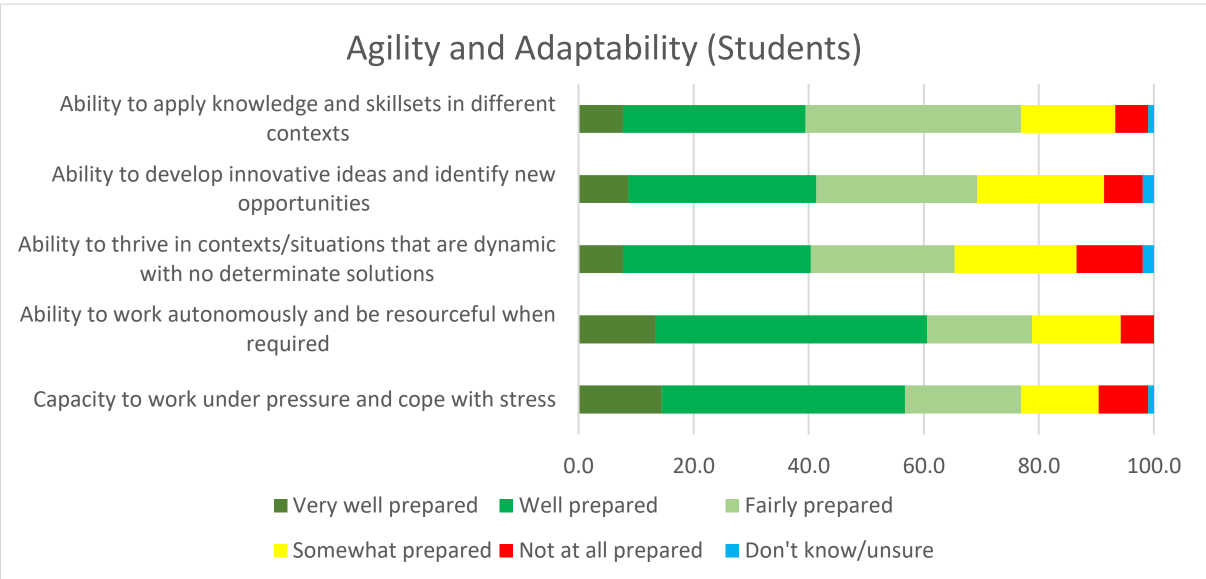
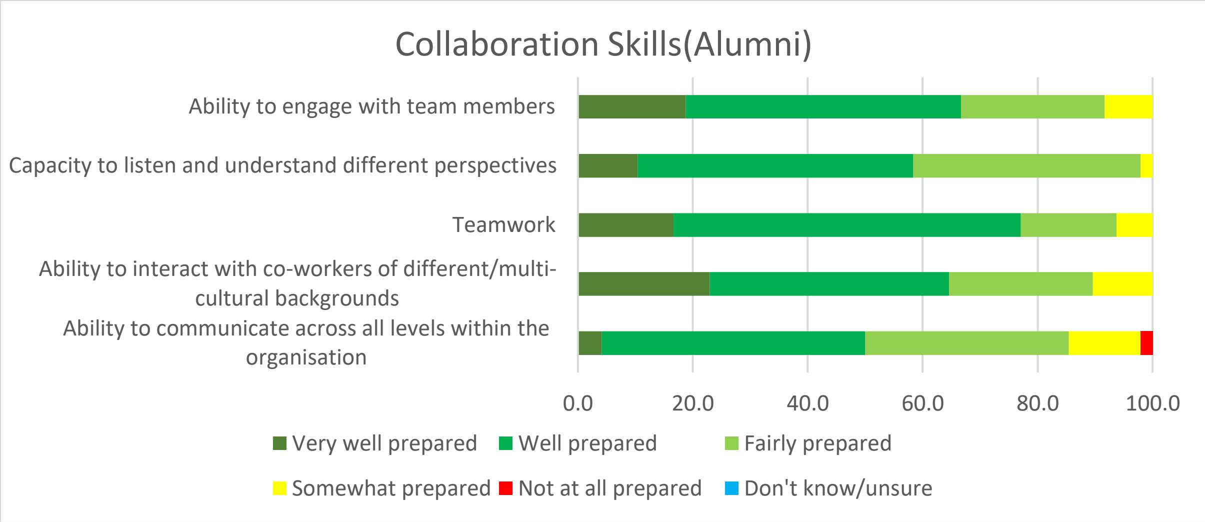
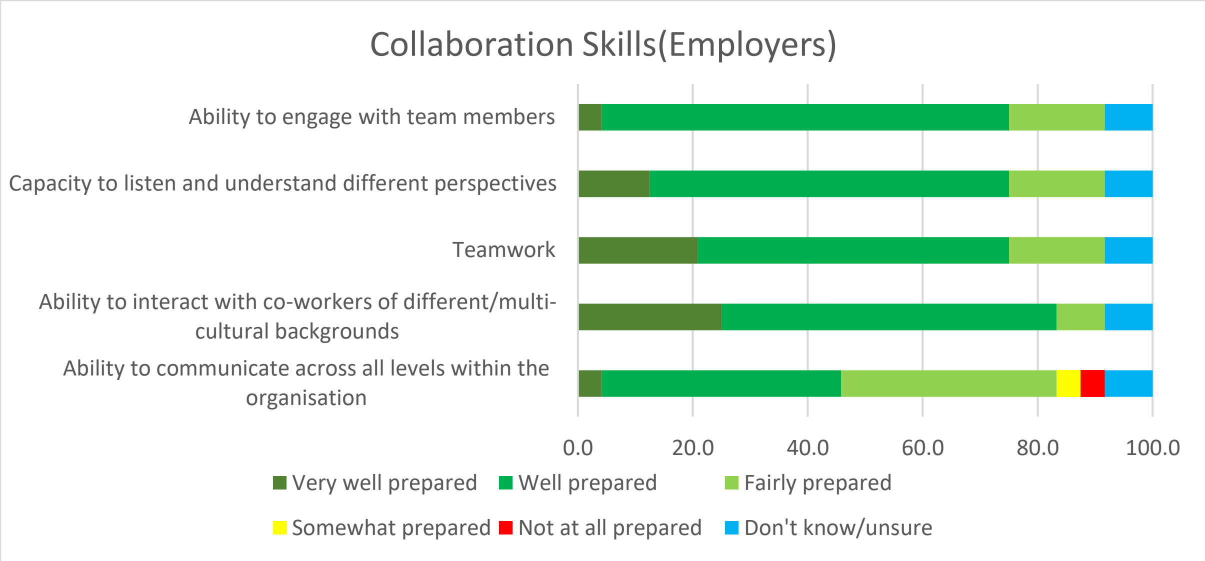


*Figure 4. **Agility and adaptability** of Materials Engineering graduates/students as evaluated by alumni (top), employers (middle) and students (bottom)*





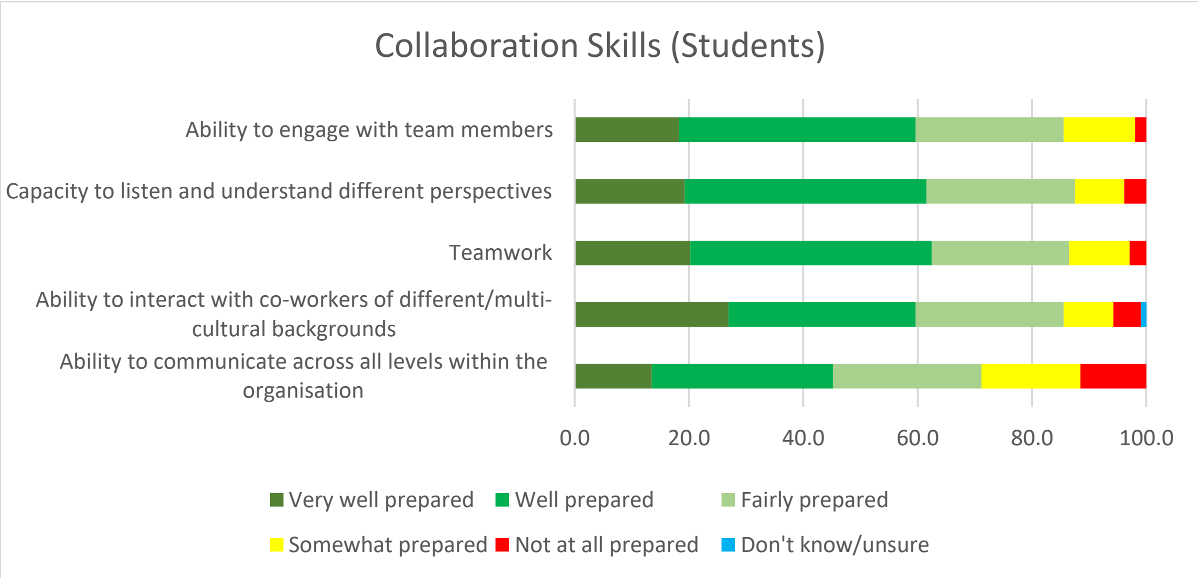


*Figure 5. **Collaboration skills** of Materials Engineering graduates/students as evaluated by alumni (top), employers (middle) and students (bottom)*

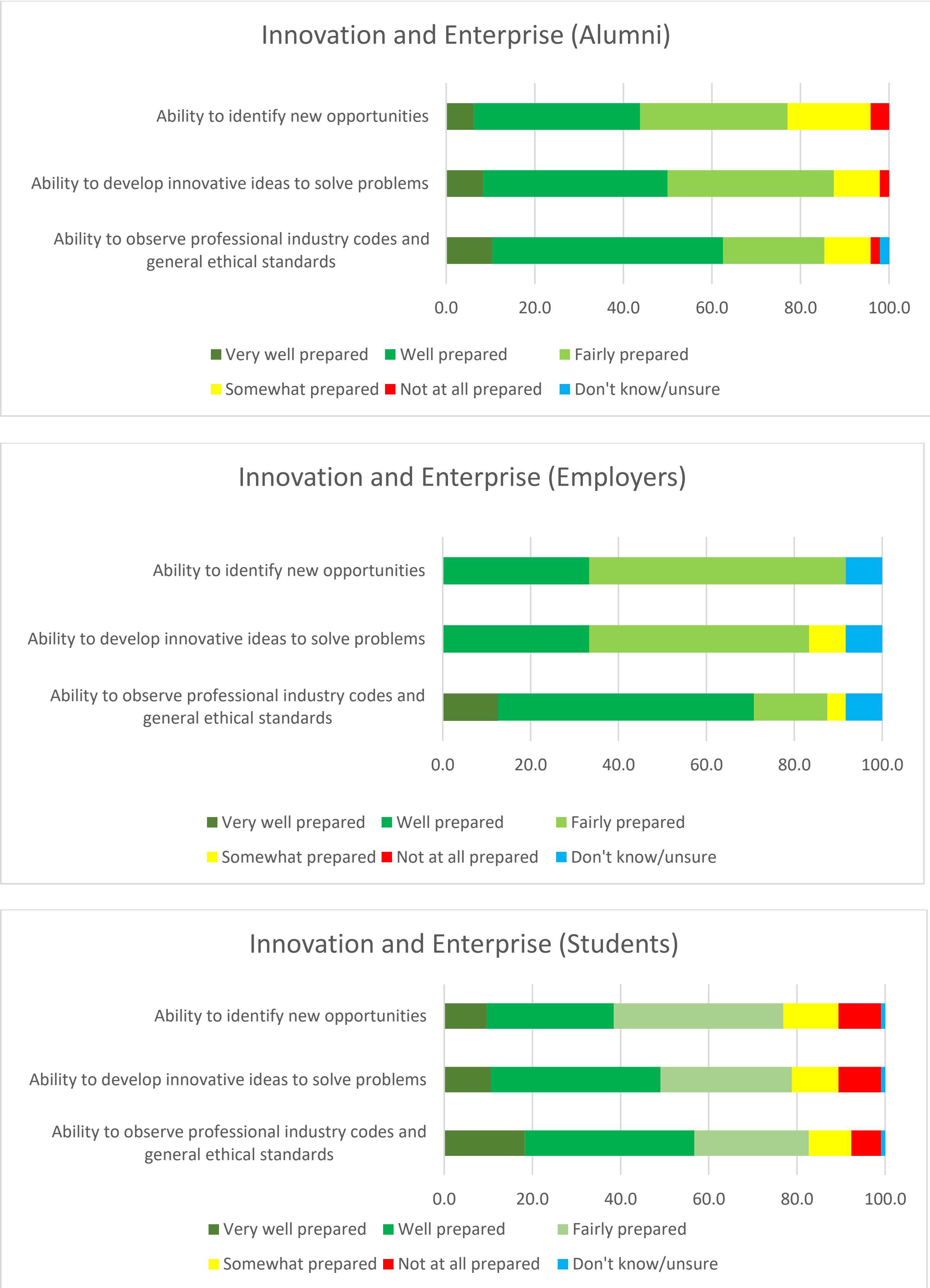


Figure 6. ***Innovation and enterprise mindset*** *of Materials Engineering graduates/students as evaluated by alumni (top), employers (middle) and students (bottom)*

3.2 Skills that require more development

Apart from evaluating the present curriculum, the survey also provided stakeholders with opportunities to share their opinions on the missing gaps and knowledge/skills that require more development. Myriad responses, ranging from specific to more general skills, were obtained and analysed.

Recurring responses were identified, grouped and summarised into the following top four:

i. Programming proficiency and data analytics
ii. Hands-on/practical experience
iii. Solidworks/CAD/AutoCAD
iv. Applying technical knowledge in real life applications

Measures to address these missing gaps were proposed in the next phase of this study involving curriculum revamp.

3.3 Emerging trends in Materials Engineering industry

Finally, the survey was designed to be forward-looking too. Stakeholders like educators (faculty), alumni and employers were invited to share their views on the key developments or technological trends in the Materials Science and Engineering industry in the next 5 – 10 years' time. Such input is critical to ensure that the new curriculum addresses the emerging trends and matches future needs of our graduates with that of Materials Engineering industry.

During the survey, the stakeholders were allowed to express their opinions freely and many of them provided more than one input. A total of 58, 103 and 48 entries were collected from 23 faculty (educators), 48 alumni and 24 employers respectively. While a wide variety of opinions were gathered across different classes of materials and applications, the responses were sorted and grouped to identify recurring themes. Table 2 provides summary of the responses gathered from alumni, employers and faculty (educators).

Table 2. Emerging trends in Materials Engineering industry as stated by alumni, employers and faculty (educators)

	Recurring themes	Faculty^{+}	Alumni*	Employers$^{\#}$	Cumulative^
i.	Material simulation, machine learning and AI	28%	7%	15%	14%
ii.	Materials and sustainability (green energy, electric vehicle, battery, photovoltaic, food sustainability)	28%	25%	21%	25%
iii.	Biomaterials for ageing population	7%	21%	4%	13%
iv.	Semiconductor with new materials	3%	9%	19%	10%
v.	Nanomaterials and nanotechnology	3%	13%	10%	10%
vi.	Advanced/flexible/wearable electronics	5%	4%	10%	6%
vii.	Others (non-recurring themes)	26%	21%	21%	22%

$^{+}$ is calculated as a percentage of 58 entries, * is calculated as a percentage of 103 entries, $^{\#}$ is calculated as a percentage of 48 entries and $^{\wedge}$ is calculated as a percentage of 209 entries.

Six recurring themes were identified from Table 2 and they made up to about 78% cumulatively of all entries submitted by our stakeholders (faculty/educators, alumni and employers). For clarity, each theme is briefly described here by providing a summary of the entries supporting each theme. Theme (i) refers to leveraging on AI and machine learning to predict, simulate, develop and optimize new materials. AI and machine learning may also be extended to materials characterization and analysis such as alloy composition and failure analysis. Theme (ii) encompasses materials' roles in achieving sustainability goals in areas like green energy, conservation and harvesting of energy, recycling and upcycling of waste, renewable materials and food sustainability. Theme (iii) looks into biomedical materials to support ageing population, targeted drug delivery for treatment of cancer, diabetes, HIV and other chronic diseases, vaccine creation and delivery (as seen during pandemic), tissue engineering and other related applications in life sciences (wellbeing, health and pharmaceutical). Theme (iv) focuses on the use of new semiconductor materials such as gallium nitride (GaN) and silicon carbide (SiC) in manufacturing processes, development of graphite wafer, semiconductor device scaling and next generation transistors. Theme (v) comprises nanomaterials and nanotechnologies in electronics and energy storage, additives for multi-functional coatings, nanomedical technology and nanomaterials that enable quantum technology. Lastly, theme (vi) represents flexible/wearable electronics that not only revolutionize electronics industries but also explore the use of embedded sensors to create smart materials.

It is worthwhile noting that the themes listed are not mutually exclusive. As complex engineering solutions are mostly interdisciplinary in nature, it is no surprise that some themes may cross over one another. Nanotherapeutics, for example, are nanomaterial products that provide promising solution to cancer treatment. In our quest for sustainability, clean energy (photovoltaics) and battery (energy storage) often draw knowledge from nanomaterials and semiconductors technologies.

Apart from the recurring themes, non-recurring entries were documented too. Many of the non-recurring entries are too generic and lack explanation or details. Some examples of such generic entries include comments like "groundbreaking and out of the box innovation that is able to fulfil daily functional needs in life, exploration of new materials, alloy development, improvement of current materials and with materials science development, many traditional raw materials could be more innovative and widely used in industry which we never expected before". On the other hand, some non-recurring entries are too specific or are applicable to a particular industry/application only. Some examples include comments like "materials usage in power electronics for aerospace, faster memories, passive fire protection for batteries and aerospace materials". The non-recurring entries made up the remaining 22% cumulatively of all entries submitted by our stakeholders, as seen in the last row of Table 2.

Themes (iii) to (vi) have been long recognised and included in the present curriculum through various specialisations such as Medical Materials, Industrial Materials Engineering and Nanoscience and Nanotechnology. However, themes (i) and (ii) are emerging areas that should be incorporated in the new curriculum.

4. Curriculum Revamp – from good to great

This section of the paper is focused on two areas. The first discusses the actions taken to address the missing gaps and skills that require more development. The second discusses the new initiatives introduced to the new curriculum to meet the future needs of Materials Engineering industry.

4.1 Revision to existing courses and/or introduction of new courses

As highlighted in section 3.2 of this paper, four sets of knowledge/skills were identified as areas that require improvement.

4.1.1 Digital literacy, programming proficiency and data analytics

The need for better digital literacy, programming proficiency and data analytics is addressed by the addition of several new core courses such as Introduction to Computational Thinking, Introduction to Data Science and Artificial Intelligence and Navigating the Digital World.

These new courses would serve as the foundation for our students who wish to broaden their knowledge by picking up a minor or a second major in computing and/or data analytics during their undergraduate study.

4.1.2 Hands-on/practical experience

While the present curriculum has included some laboratory courses, these experiments were run largely as equipment demonstrations and/or operations. The design of experiments (DOE) concept was absent and students were merely acting as operators. Thus, the older laboratory courses were retired and/or integrated as laboratory demos during tutorial classes of relevant core courses. New laboratory courses ought to be designed where students are trained to perform their own Design of Experiments (DOE). In one of the new laboratory courses proposed, students are required to prepare their own samples, identify the types of testing and characterisations required, plan their own experimental flow/sequence, choose appropriate machines/equipment for testing and conduct analysis of their own results. Students work in groups and are given 12 – 13 weeks to complete the given task independently. We believe that this shift from a traditional, passive learning approach towards an active learning will not only increase students' engagement and achievement of learning outcomes but also train our students to take ownership of their learning and embrace self-directed learning practices [6], [7], [8].

4.1.3 Solidworks/CAD/AutoCAD

A new Digital Design Lab was proposed during the curriculum revamp exercise. It aims to familiarise students with design concepts and digital tools that are available in virtual design of engineering parts or components. Apart from learning how to use Solidworks and CAD for engineering drawing, students also learn how to perform geometric modelling, finite element analysis and simulation in engineering analysis. Lastly, students are also presented with opportunities to convert the model drawing into actual prototypes via 3D printing.

4.1.4 Applying technical knowledge in real life applications

To allow students apply their technical knowledge in real life applications, a new course called Industrial Design was introduced. The Industrial Design course introduces students to the process of design thinking and how to apply it in designing a solution or a new product that will potentially tackle materials engineering problems. The concepts and principles are further enhanced by an intensive team-based project, in which the students are asked to propose a solution to a real problem raised by our industry partners. As a team, students apply design thinking principles in proposing and testing their solutions through several rounds of iterations and refinement process. This project also serves as a platform that allows students hone their ability to negotiate and persuade industry partners to support their ideas or solutions. Each team of students is guided by one faculty member and one industry mentor that provide weekly feedback/consultations on their progress. Given that students receive immediate validation of their proposed solutions from industry partners directly, this is certainly a pinnacle of authentic, experiential learning in real life applications. We strongly believe that exposure to such authentic learning experiences will benefit our students greatly, as documented well in literature [9], [10].

4.2 Introduction of new specialisations

Two new areas of Materials Engineering specialisations were proposed to address the emerging trends in Materials Engineering industry put forth by our stakeholders in section 3.3.

4.2.1 Materials and Artificial Intelligence (AI)

The specialisation in Materials and AI is needed to breed new graduates that meet the future demand of Materials Engineering industry. This specialisation is suitable for students who are interested to deepen their understanding on how AI and machine learning may revolutionize materials engineering industries. New interdisciplinary courses are needed, and students should be given an opportunity to work on a capstone project or final year dissertation thesis specifically in the area of materials and AI/machine learning. In fact, whenever possible, collaboration with a computing department or a computing school should be pursued. Such collaboration will enrich students' experience and expand the selection of courses students can read in order to specialise and be competent in this niche field.

4.2.2 Materials and Sustainability

Materials sustainability is cited as one of the emerging trends in materials engineering industry through our stakeholders' analysis. It is rightfully so as materials engineering is certainly right in the centre of circular economy and global sustainability drive. Thus, it is important that Materials Engineering curriculum evolves and keeps up with the United Nation's / UN's sustainability goals and various nations' mission to maintain the health and biocapacity of the environment. Sustainability will support the well-being of communities and promote a better economy with lesser waste and pollution and fewer emissions. The Materials and Sustainability specialisation places emphasis on how the right materials can be engineered to make them reusable and recyclable. It also focuses on the materials for renewable energy, photovoltaic applications, sustainable farming/aquaculture and more. Such training will prepare our students and graduates in meeting the needs of various industries that are gearing towards a more sustainable Earth.

5. Summary

In this paper, we presented the curriculum review exercise in our institution. This exercise was motivated by the importance of keeping Materials Engineering curriculum relevant and responsive to the ever-changing needs of Materials Engineering industry. While curriculum reforms undertaken by other engineering institutions [11], [12], [13] may have different basis of actions, our exercise took a more holistic approach whereby we consulted various stakeholders and gathered their input towards updating the curriculum. Similar holistic curriculum updates in other engineering disciplines were previously reported for mechanical engineering [14] and aerospace engineering [15].

Planning and execution of the curriculum revamp exercise involves four key phases that include identifying relevant stakeholders, gathering input from stakeholders, analysing input and survey results and finally revamping the curriculum. Four important groups of stakeholders were identified as students, alumni, employers and educators (faculty). Comprehensive survey was conducted to evaluate the present curriculum, identify gaps and areas for improvement and address emerging trends in Materials Engineering industries.

While thorough analysis that looks into equipping our students/graduates with fundamental skills, agility and adaptability, collaboration skills, and innovation and enterprise mindset has reflected relatively positive feedback, several skills/knowledge domains that require more development were highlighted too. They include the demand for more programming proficiency and data analytics, hands-on/practical experience, knowledge on Solidworks/CAD and ability to apply technical knowledge in real life applications. Such demands are now addressed in the new curriculum by revising existing courses and/or introducing a series of new courses in digital literacy, computing and data analytics. A new laboratory course was introduced with greater emphasis on student-directed experimental design and practical work. A digital design course is proposed to introduce students to various engineering tools like Solidworks, CAD and more. A new Industrial Design course allows students work on real engineering problems brought up by industry partners. The industry partners also serve as direct mentors to our students and work closely with them for an entire semester to test, validate and refine the solutions proposed by our students.

Finally, with the input of our stakeholders, key developments or technological trends in the Materials Science industry in the next 5 – 10 years' time were consolidated into materials simulation, machine learning and AI, material sustainability, biomaterials for aging population, semiconductor with new materials, nanomaterial and flexible/wearable electronics. While most of the future trends have been addressed in the present curriculum, two new specialisation areas are introduced. First, Materials and AI specialisation was introduced for students who wish to deepen their knowledge on how AI and machine learning contribute to materials simulation and/or new materials discovery. Second, Materials and Sustainability was introduced to prepare our students to better meet the needs of various industries that are gearing towards circular economy and a more sustainable Earth.

We strongly believe that the newly revamped Materials Engineering curriculum will adequately prepare our students with essential knowledge and skills necessary to adapt in the ever-advancing engineering industry and excel in their career. Our curriculum review journey will not end here as we believe constant feedback from our stakeholders is critical to monitor and evaluate the implementation of the new curriculum. Various consultation strategies can be explored such as students' surveys, focus group discussions with different stakeholders (alumni, students, faculty staff and employers) as well as consultations with our industrial advisory committee.

6. Acknowledgement

This project was successfully completed with a generous support from Nanyang Technological University (NTU), Singapore EdeX Teaching and Learning grant (Mar 2020–Aug 2022). Special thanks are extended to Dr Lim Fun Siong (Centre of Teaching, Learning and Pedagogy, NTU) for his input on questionnaire and survey design, Mr Leo Tan (Career

& Attachment Office, NTU) for his support in relation to industry engagement, Ms Christina Cheng (Theory of Constraint for Education Inc, Singapore) for her advice on this study and Mr Tan Kek Koon (School of Materials Science and Engineering, NTU) for his contribution in setting up Verint survey system.

7. References

[1] C. K. Howson and M. Kingsbury, “Curriculum change as transformational learning,” *Teaching in higher education*, vol. ahead-of-print, no. ahead-of-print, pp. 1–20, 2023, doi: 10.1080/13562517.2021.1940923.

[2] M. Y. Law, “A review of curriculum change and innovation for higher education,” *Journal of Education and Training Studies*, vol. 10, no. 2, pp. 16-23, 2022y, doi: 10.11114/jets.v10i2.5448

[3] J. Walkington, “A process for curriculum change in engineering education,” *European journal of engineering education*, vol. 27, no. 2, pp. 133–148, 2002, doi: 10.1080/03043790210129603.

[4] S. Monteiro, L. Almeida, and A. García-Aracil, “(Mis)matched perceptions: Graduates and employers’ views about competencies in professional activities,” in *Edulearn’19 Proceedings*, 2019, pp. 8662-8666, doi: 10.21125/edulearn.2019.2147

[5] G. Rayner, and T. Papakonstantinou, “Employer perspectives of the current and future value of STEM graduate skills and attributes: An Australian study,” *Journal of Teaching and Learning for Graduate Employability*, vol. 6, no.1, pp. 100-115, 2015, doi: 10.21153/jtlge2015vol6no1art576

[6] S. Freeman *et al.*, “Active learning increases student performance in science, engineering, and mathematics,” *Proceedings of the National Academy of Sciences - PNAS*, vol. 111, no. 23, pp. 8410–8415, 2014, doi: 10.1073/pnas.1319030111.

[7] J. Michael, “Where's the evidence that active learning works?” *Advances in physiology education*, vol. 30, no. 4, pp. 159-167, 2006, doi:10.1152/advan.00053.2006

[8] R. Barnett, G. Parry, and K. Coate, “Conceptualising Curriculum Change,” *Teaching in higher education*, vol. 6, no. 4, pp. 435–449, 2001, doi: 10.1080/13562510120078009

[9] G. Tembrevilla, A. Phillion, and M. Zeadin, “Experiential learning in engineering education: A systematic literature review,” *Journal of engineering education (Washington, D.C.)*, vol. 113, no. 1, pp. 195–218, 2024, doi: 10.1002/jee.20575.

[10] S. M. S. Al Arefi, “Avenues for Authentic Learning in Engineering Education through Reflection and Co-Creation,” in *2022 IEEE World Engineering Education Conference (EDUNINE)*, 2022, pp. 1–6. doi: 10.1109/EDUNINE53672.2022.9782320.

[11] S. L. Toh, “Revamped Biomedical Engineering Curriculum for Future-Ready Graduates,” in: *XIV Mediterranean Conference on Medical and Biological Engineering and Computing 2016. IFMBE Proceedings,* E. Kyriacou, S. Christofides, and C. Pattichis, Eds. 2016, vol 57, pp. 1317-1319, doi:10.1007/978-3-319-32703-7_251

[12] J. P. Jarosz and I. J. Busch-Vishniac, “A Topical Analysis of Mechanical Engineering Curricula,” *Journal of engineering education (Washington, D.C.)*, vol. 95, no. 3, pp. 241–248, 2006, doi: 10.1002/j.2168-9830.2006.tb00896.x.

[13] J. T. Luxhøsj and P. H. K. Hansen, “Engineering Curriculum Reform at Aalborg University,” *Journal of engineering education (Washington, D.C.)*, vol. 85, no. 3, pp. 183–186, 1996, doi: 10.1002/j.2168-9830.1996.tb00231.x.

[14] G. Tryggvason, M. Thouless, D. Dutta, S. L. Ceccio, and D. M. Tilbury, “The New Mechanical Engineering Curriculum at the University of Michigan,” *Journal of engineering education (Washington, D.C.)*, vol. 90, no. 3, pp. 437–444, 2001, doi: 10.1002/j.2168-9830.2001.tb00624.x.

[15] B. K. Walker, S.-M. Jeng, P. D. Orkwis, G. L. Slater, P. K. Khosla, and G. J. Simitses, “Redesigning an Aerospace Engineering Curriculum for the Twenty-First Century: Results of a Survey,” *Journal of engineering education (Washington, D.C.)*, vol. 87, no. 4, pp. 481–487, 1998, doi: 10.1002/j.2168-9830.1998.tb00382.x.