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Editorial Brief

The pandemic that has interrupted the world since early 2020 has progressively seen sign of positive recovery and improvement. The world is progressively working its way to new normality. For the sixth volume (Issue 1), ASEAN Journal of Engineering Education (AJEE) has successfully published 8 engineering education manuscripts. Four of the manuscripts were related to Covid-19 effects in issues related to academic performance evaluation, engineering assessment for service learning and final year project implementation. On top of the engineering assessment mentioned earlier, another manuscript discusses on sustainable assessment that aims to produce sustainable engineering graduates while also reducing the burden of programme outcomes assessment on academic staffs.

A systematic literature review on engineering employability factors was one of the manuscripts included in this publication where it listed four critical factors where engineering graduate need to focus to secure a professional job. A narrative inquiry analysis manuscript based on personal reflections and learning portfolio written by a first-year undergraduate engineering student is an interesting episode that should be read by engineering undergraduates in order to comprehend what they will go through and how to excel as a new engineering student in the first academic year. It should also be read by engineering lecturers to immerse themselves in what engineering students are going through. Finally, AJEE Vol. 6, Issue 1, presents a manuscript that discusses on the phenomenological approach to identify mathematical competency in an engineering industry context.

It is our intention that the papers published in this volume can shed some light on the current issues in engineering education and lead to further development and studies for quality teaching and learning.

Editorial Boards

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Making the First Semester Your Own: Personal Experience and Lessons from a Chemical Engineering Freshman

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Abstract

There lies a sea of reviews and experiences on the progression from engineering students to diverse careers and countless other pursuits. Yet, less is mentioned about the actual student First Year Experience (FYE), in particular: relating to the context of engineering, and towards becoming advanced learners. In order to stimulate awareness and strengthen confidence among future learners entering undergraduate engineering programs, especially chemical engineering, this paper integrates three key aspects: a genuine reflection from an undergraduate engineering student on the first semester; how to benefit as much as possible from the very beginning at University, and most importantly, making the learning process suited to one's abilities. This is to explore more about how first year students can identify learning methods suited to their own strengths and a growing factor to their weaknesses. In addition, this paper intends to showcase a brief process in crafting and developing an initial engineering identity as a student, and advance to what is hoped to be a successful engineering education and career. I personally found my first semester at University of Technology Malaysia (UTM) to be inspirational and a boost to my love for all facets relating to elementary engineering know-how. Hence, through my writing, I share "true to life" experiences in my personal learning journey through the first semester at UTM. This will be entwined with lessons I learnt on how to gain the most from the start, shaping a mature mindset and much more. Ultimately, it aims to motivate fresh engineering students of the future, and display to them that in every step of the undergraduate journey, lies lessons, whether it be in their failures or successes.

Keywords: Developing an Engineering Identity, First Year Experience (FYE), Learning Process, Undergraduate, Education

Introduction

How can first year engineering students develop a suited identity, to rightfully explore the world of engineering from an early stage? This paper aims to investigate ways to answer this question. Around 30 million practicing engineers globally and 10 million Science, Technology, Engineering & Mathematics (STEM) students graduated in only China, India and the USA combined, for 2016 alone (McCarthy, 2017). This shows the incredible relevance, importance and popularity of the engineering and STEM-based disciplines. With the number of engineering graduates having grown by 1.44% in just one year (from 4.48 million in 2018 to 4.54 million in 2019) in the USA alone (Data USA, 2020), one question arises: Why choose an engineering degree, in a field which appears to be saturated?

The reason is because engineering prospects, in reality, are far from becoming saturated. Being one of the most diverse professions, engineers have been key players in both technological and mankind's advancements since the beginning of the industrial era to what is now being called the fourth industrial revolution of connected, digitized technology (Xu et al., 2018). Meanwhile, numerous types of engineering disciplines are present today (Elmogahzy, 2020), they include: aerospace; chemical and process; civil and environmental; electrical and electronics; software; medical; and bioengineering among others (Cebr, 2016). Engineering interweaves STEM, economics, physical, natural and social sciences, humanities and much more. So, engineering truly means to build, construct & design things, and constantly improve their functioning and efficiency to solve societies' biggest challenges, while ensuring a sustainable route is followed (Rosen, 2012).

To put it into a clearer perspective, engineering can be defined as creatively applying a vast range of scientific principles in the real-world climate, and to "invent, design, build, maintain, and improve structures, machines, devices, systems, materials and processes" (Rosemberg et al., 2015). This not only allows capable engineering graduates to almost always transcend to another career, but also succeed in a variety of work environments, anywhere in the world. It is also because engineering-based applications integrate almost all types of proficiencies in the bigger picture of scientific formulations, design and practicability. Furthermore, with ever-growing technological efficiencies and development (Çalışkan, 2015), upcoming research prospects, combined with the cruciality towards controlling climate change, investing in space exploration, advancing in healthcare, creating more effectively designed machinery and systems that make life exponentially more secure amongst countless other missions, engineers are required to work across all these projects. In addition, it has proliferated the need for innovative solutions to intricate issues, thus the need for engineers in the global industrial, economic, agricultural, environmental and all other sectors (Rosemberg et al., 2015).

So, the initial story of an engineering student, which almost all engineers have been through in the beginning of their education, training and career, needs to be studied and explored. This is to raise awareness on the central, yet delicate process of developing an engineering identity, which has to match and be molded individually. As a result, molding a finely tuned engineering identity, which differs person-to-person, is crucial in the way great engineering and scientific innovations arise. Most importantly, knowing about the learning processes that will help shape exceptional engineers of the future, with a diverse skill-set, all sharpened to suit the different and difficult scenarios, is necessary. Besides, the development of such skills, that successful future engineers require from the learning stage as students, entails much more than building knowledge and fundamental know-how, but stretches to psychological, ethical and other aspects. This training of mental stability and emotional intelligence is correlated to handling pressure and obstacles in the future workplace with self-control and resilience (Serrat, 2017) and is of foremost importance. Eventually, it could assist in the development of a proper engineering identity on an individual basis, wherein each student understands the role they play in engineering and beyond (Rodriguez et al., 2018).

Based on these elements, this paper looks at a personal account of my engineering story for the first semester at UTM, the learning growth I went through, the corresponding challenges and far more. Subsequently, one chief mission of this study is to raise alertness on the importance of student learning experiences in the first semester, and how writing about such personal accounts may offer prospects of progressive research into refining teacher and student philosophies (Reber, 2011), within and beyond the classroom. It also aims to enhance opportunities for research into how learners, from the very beginning, can develop this properly suited engineering identity that works towards their advantages and enriches their caliber.

Methods

The preliminary source of information in terms of reflection and structuring used in this study was from typed Reflection Journals, made over the first semester in the Industrial Seminar and Profession (ISP) course. This series of journals I wrote include reviews, thoughts, feedback, evaluation and details on all learning curves that occurred. It also contains every stage of my personal development relating to certain learning outcomes, which was applied across all seven courses I took. The journals were recorded regularly over 3-week periods, with a total of 4 journals encapsulating the first twelve weeks and the META Reflection Journal (Zakaria et al., 2020) covering the final 3 weeks of the semester. All journals were digitally completed using Microsoft Word. Secondly, for the Introduction to Engineering (ITE), Mathematics and implementation-based courses, the primary details were synthesized from my Learning Portfolio created at the end of the semester, with additional guidance received from lecturers. This learning portfolio remains a written record of my goals, reflection, feedback and analysis in identifying weaknesses and strengths over the course of the first semester. An attempt was made to meticulously cover all specifics and recollections across every assignment and topics on a weekly basis. This was to assure a detailed narrative study would be possible in future research and works.

Relating to this paper, learning theories and processes are integrated at selected parts, to correctly describe my student learning experience in connection to authentic education models that exist, largely encapsulating the sphere of engineering and STEM. Such theories include: Mezirow's Transformative Learning Theory; The Constructivist Learning Theory; Curriculum and Thinking Mathematics; Alderfer’s ERG Theory of Motivation; and The Cognitive Learning Theory among others. Primarily, I decided to display my complete learning growth by merging Daniel Goleman’s Emotional Intelligence theory and model (Goleman, 1995) of my personal emotional development (Chopra et al., 2010), throughout the semester. Simultaneously, it was interesting and valuable because it aided in building my sense of an initial engineering identity using systems of self-awareness, self-management, and seasoning my own characteristics such as a personal identity (Godwin, 2016). Figure 1 is a representation of this model.

Furthermore, a systematic approach using revitalized explanations of the personal learning process and reflection was used. It allowed me with a particular method of writing using the storytelling approach, by means of an active and personal voice. This also facilitated me to identify the lesser efficient methods in my unique learning process, and work on aptitude development as a preparation for the semesters that will follow. Hence, the dominant style used in the reflection journals and learning portfolio, which is consequently implemented in this paper, is the Narrative Inquiry analysis method. It embodies a qualitative data analysis approach, wherein a personal story of the learning experience is told, to best represent my unique journey to learners and readers of tomorrow. The reason narrative enquiry, and chiefly autobiographical narrative inquiry, is chosen is to present observations from the student angle accurately and its ability to correctly express an honest viewpoint through storytelling (Clandinin, 2006) from the writer's plane of thought and aims to make a connection with the reader (Bullough et al., 2001). Furthermore, the primary qualitative data sources and input in this paper has been carried out through the process of observation and using diachronic data. This assisted in reaching beyond a limit of chronological sequences in learning, and rather analyzing each part in a more dynamic and communicative manner (Polkinghorne, 1995).

Figure 1: Goleman's Emotional Intelligence Model (2002)

Findings and Discussion

Why I Chose Chemical Engineering

A life changing question was when I asked myself: "What do I want to dedicate my undergraduate degree towards?". Given my early curiosity in the STEM and humanities areas, there were four things I was genuinely passionate about: Writing; Chemical properties and structures of molecules and atoms in matter; Nature; and the Inner workings of the brain of living organisms. Such fascinations translated to four turfs of undergraduate programs I desired to choose from: Literature; Chemistry; Environmental Science and Neuroscience. After times deep thought, long nights awake and several honest conversations with my parents and high school teachers close to me, I felt that having the basis of a chemical engineer in the beginning of my higher education, would best suit my future missions and potential to contribute to society.

These aspirations include: doing both further studies and research into Neuroscience, which is largely dependent on the processes controlled by countless chemicals and compounds within the body of living organisms; becoming an environmental engineer, where I could apply and contribute towards designing and improving the efficiency of renewable technologies and materials of the future; and finally, writing and publishing a book, which has been a personal longing of mine.

Thus, the only course I felt was fitting to such long-desired ambitions would be Chemical Engineering. Honestly, I tend to be an explorer in terms of what I like to study and may get bored with one certain subject, but love the next. Hereafter, given I comprehended what I loved, Chemical Engineering became like an opening door to a variety of career and educational choices for the future, which I admire and continue to value.

Accordingly, to all future learners considering an undergraduate engineering degree, sculpt a sense of clarity for why you really want to do engineering. It does not mean to have the whole picture and life plan already in mind, but rather your long-term and personal intentions, hopes and dreams. Moreover, before choosing an engineering program, consider having true conversations about your plans with people you trust, ranging from parents and teachers, to senior friends and siblings.

More vitally, after you have some opinions and thoughts, try finding contacts for practicing engineers to have meetings or discussions with, which will guide you in getting a bigger picture of what your future might involve in the engineering line. However, the ultimate decision should be one's own calling, what your heart tells you, like it told me to choose Chemical Engineering at UTM.

Early Lessons from the Mistakes I Made

When beginning the transition to an undergraduate engineering program, there will come waves of anticipation, nervousness and self-questioning, especially in the first semester. After successfully completing the documentation processes to become an official undergraduate student, arrives the moment of real work. Congratulations for coming this far to become a student at your respective learning institution; so, what next? Herein begins the vivacious learning journey, with the start of lectures and classes for your respective courses and subjects. My voyage began with the interesting experience of introducing myself to lecturers across all courses, meeting new students and peers who will be taking the same degree as me: Bachelor of Chemical Engineering with Honors.

I felt valued from the start of my undergraduate journey, as in a welcoming meeting held by the Chair of our School of Chemical and Energy Engineering at UTM, I asked on sincere advice to do well throughout our time as undergraduates. To my surprise, the question was praised for being greatly important and this was my first authentic graceful moment in the program. All I can say is that I was fortunate enough to experience such a rich instant of interaction with professors, lecturers, staff and students from the very start. As a result, it helped me cultivate confidence; which formed a huge portion of the engineering identity I continually aim towards: Becoming an effective global communicator and leader in the field of engineering. As mentioned in the book How to Win Friends and Influence People (Carnegie, 2009), it is necessary and highly advisable to start becoming a good listener. Furthermore, you must begin to practice an encouraging and positive temperament, and truly hear what others have to say. If peers are initially conserved or quiet, motivate your surrounding students to have conversations and find out more about each other.

Similarly, this motivation can be branched towards Alderfer's ERG Theory of Motivation, where the three aspects of: Existence (which I relate to asking about a person's wellbeing); Relatedness (forming a common ground for talking and communicating to form closer relations); and Growth (commend others on their potential and achievements) all help in forming strong bonds with others from the very start of your time at university (Yang et al., 2011). You will realize the immense value of this later on. Similarly, another noteworthy aspect of education research that has been beneficial to my performance is slowly becoming an active learner. This idea of active learning is valuable and says that active learners go above the normal step in the classroom by asking questions, discussing, debating, brainstorming than simply listening and viewing (Felder et al., 1988). Hence, I benefited from forming student discussion groups, working with others during exercises and before tests, to retain information more effectively and elevate my proactiveness as an active learner.

Now, some of the most enjoyable courses in the first semester for an engineering program will involve on building the conceptual way of thinking, and on the larger aspect of uses of engineering. Courses that enhance such perspectives for me included Introduction to Engineering, Industrial Seminar and Profession, Introduction to Computer Programming, Engineering Drawings and similarly structured courses. To perform to the best of your abilities, give your best efforts to participating actively in the lecturing sessions and ask questions you really need answers to, without any hesitation. Often, a common fear among fresh undergraduates is the fear of a lecturer condemning a student of one wrong question, and even the fear of facing embarrassment amongst peers. However, this remains far from reality as it is assured that lecturers at higher education institutes are exceedingly knowledgeable and mature. It is my observation that lecturers constantly encourage and prefer active student groups that ask vital questions and interact well with them. Hence, often more times than not, the question you ask stimulates every student to participate more attentively during the lecturing session.

Asking well-formed questions will also help in establishing a good relation with your lecturers when others in class tend to be more reserved. Hence, as you practice the art of critically thinking and then asking well-rounded questions, peers and friends will also gain confidence to ask better questions themselves, which is bound to be advantageous to each and every learner, building trust (Brooks et al., 2018), and a key player in becoming fruitful in academia, STEM, engineering and beyond (Vale, 2013). Swiftly, to become an exceptional learner and develop an engineering identity that matches to you, growing your emotional intelligence must be equally matched to the process of performing well academically, and both should balance each other harmoniously. A student can do this by understanding their feelings and thoughts after a class, reviewing what they understood, and if it was not to their liking, then considering on improvements to change their emotions towards something more productive (Goleman, 1995).

With the ever-evolving technological era and the availability of countless smart devices, it is beyond useful to become "tech-savvy" and learn about any new devices and functions as opportunities arise. It will be supportive in the long-run to have a voice or even a video recorder, fully charged, with you at all times. Recording entire lecture sessions for future use (Groen et al., 2016) will not only allow you to rerun and absorb certain parts for strengthening information retention, but help in making well-constructed notes and brainstorm for projects and assignments, which will surely be given and will require you to apply problem-solving based methods. This was true in my case as a first semester student where the impact of lecture capture was beneficial in me learn better both inside and outside the classroom environment (Danielson et al., 2014). Fortunately, in most of the classes I had, the lecturers were proactive in recording each of our session through Cisco Webex or Google meet platforms, and thereby sharing each recording in e-learning (an UTM based student application), for future referencing by students such as me. This was also greatly beneficial for those who could not make it for a class that day, or for those with unstable internet connections, audio issues, etc. during the class. On occasions, I used the MacBook screen recording function, which had proper sound quality in all captured lecture videos, and helped me recall each topic better before tests and quizzes, compared to only reading notes.

A study on the effectiveness of lecture capture that relates to this discussion (Danielson et al., 2014), showed indeed that students learned more through recording lectures, with 93% of the 222 students who responded in the survey stating that they felt somewhat to very beneficial in learning better using lecture capture. Furthermore, a series of 75 studies on the Impact of Lecture capture, done between 2003 and 2019 and reported (Panopto, 2020), revealed that recording lectures for student's future use is correlated to higher grades, better knowledge absorption among other advantages in connection to academic performance. Figure 2 shows a pie chart of the impact of lecture capture on achievement (where blue is Improves Achievement and red is No improvement on Achievement). In further inquiry, it shows that the likelihood of negative impact of lecture capturing on student achievement was virtually insignificant.

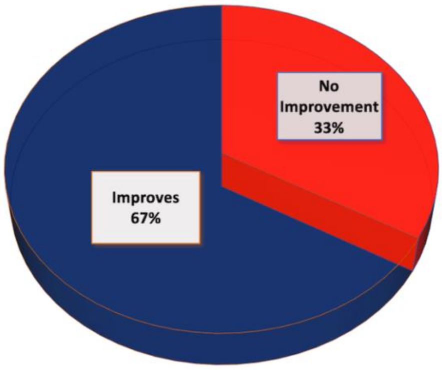

Figure 2: Impact of Lecture Capture on Student Achievement

Nevertheless, the first study on the effectiveness of lecture capture revealed in its responses that a significant number of faculty members and students felt recording and capturing lectures only (and not attending live lectures and classes) would be disadvantageous and disruptive to the overall learning manner for most students (Danielson et al., 2014). Therefore, my advice from the mistake I initially made of not paying attention in some classes and depending too much on recordings at the beginning is this: stay self-vigilant that recording lectures also means you attend every live lecture with sincerity and become involved in the actual sessions given by lecturers, as those have incredibly more value to them. Also, it is worth telling that in the first semester, do not be demotivated or make the mistake of relating peak performance in tests and quizzes to your engineering identity growth like I initially did (Gray et al., 2021). There will be so plentiful time to improve yourself, your results and grades. For that reason, stay optimistic, learn from mistakes and hone your strengths.

Reflecting on Things I Have Learnt

When I progressed through some of the introductory courses for the first semester in my Bachelor of Chemical Engineering program, I felt a deep connection to the beauty of both mechanical and digital tools that have been created over the past few decades for engineers, architects and for use in several other careers. As I began to observe every single thing I learned from day to day, and reflected upon them, I was surprised with the sophistication that withholds engineering and STEM developments of the 21st century. Mankind has truly come so far, and a look at how much we have advanced in the last 100 years inspires me to do greater things continually (Diamandis, 2017). Now is the time to start changing yourself to appreciate the learning journey from the very beginning. Through progressing in all the courses discussed below, I started noticing things in my surroundings that I was unware of prior. Soon, this journey of appreciation, alertness and a changed outlook, began guiding me resourcefully through the first semester, as it might do for you in the future.

Introduction to Computer Programming

My journey of appreciation started with the Introduction to Programming (ICP) course, where I gained the skill of basic MATLAB coding, writing longer coding structures to form loops etc., which will be tremendously valuable towards learning more advanced programs in the near future. This was improved upon with the Industrial Seminar and Profession (ISP) course, which also covered one seminar presented by an experienced individual on Programming, MATLAB in particular. To be honest, ICP had been one of the most challenging courses for me, right after Engineering Mathematics, as I felt the urge to understand the concepts of programming better as well as keeping up with my six other courses. What I mean is, to learn programming takes time, more time for some (like me) to truly understand the purpose of what one is doing, which is essential in remembering the details for future use, and in future careers, where one will have to face solving real-world problems using advanced technology and computer science.

Based on these factors, learning a programming language like MATLAB has built my logical way of thinking in other areas of life. I can now imagine and conceptualize the many careers that deal with large numbers, huge amount of data and mathematical methods, which are needed to provide a simplistic yet detailed presentation of datasets. This process is made possible using programs like MATLAB, which open doors for plotting, testing conditions and measuring a degree to which one variable may influence many others. After further thought on it, I was able to relate it to the similar complex processes occurring continuously in nature, where ecosystems are interrelated and the concentration of a certain chemical or population of a certain species has indicated to affect all other living organisms. Plus, it is where many ecologists and biologists give their whole lives to: studying the fundamental and intricate processes that make life on earth possible, most of which remains a mystery.

Moreover, keeping in mind that codes are just like nature's systems, where one line of code effects the next, and one error or fault in the code script may make the program invalid, thus unable to function until it is corrected or replaced. So, considering and thinking about the importance of interdependence in all aspects of life, including engineering, has been a key player in developing my engineering identity over the first semester. I can relate this to a beautiful learning process I came across after reading a few articles and papers: Lifelong Learning (London, 2012). Here, we were not actually given all that we needed to know to produce final ICP group project of a complex user-friendly program. Our lecturers gave us the fundamental information and basic know-how to progress into learning more about the MATLAB program independently, in order to best produce a program suited to our preferences. In this way, I was able to test different ways to make the program with my team, and it helped me gain interest, much deeper than if only a textbook would have provided. So, I learned for myself the new and hidden features that could be used for our program, to make it user-friendly; a key requirement of the group project related to Introduction to Engineering S&H 2021, a case study and project which I talk more about later. Perhaps, I have started to realize that developing a passion for a subject in this manner has loads of advantages when I transcend to an organization for work, that values responsibility and self-directed problem-solving methods (Zakaria et al., 2020). This brings me to a quote by the co-founder of Apple Inc., Steve Jobs: "It doesn't make sense to hire smart people and tell them what to do. We hire smart people so they can tell us what to do."

In regard to this, if there is one thing all students can learn before entering an engineering degree; or any other degree for that matter, it would be basic software programming and introductory computer science, as this has become central in the era we now live in and venture through.

Introduction to Engineering and Industrial Seminar & Profession

Next, the two courses which had a strong impact in my engineering identity development, as well as personal growth, was Introduction to Engineering (ITE) and Industrial Seminar and Profession (ISP). Most of the assignments and projects covered for the ITE and ISP courses were wholly new to me in both their structure and content. What was more enthralling to me were the course learning outcomes (CLO) (Zakaria et al., 2020), which I looked at as being dedicated missions to instill within us students by the end of the semester. Independent learning was predominant for all exercises done in teams and individually, to produce the best work with creativity. Later, I could correlate this process to Mezirow's Transformative Learning theory (Christie et al., 2015), where in order to produce the best work, I had to do a lot of self-examination, assessment of beliefs and the faults I had in my opinions of the world and for a particular case. This aided me to produce an overall view on a topic, think freely, consider new ideas and opinions that did not match mine, without any bias towards the variation of ideas. I was slowly growing and beginning to investigate multiple views through articles, interviews and make an adaptable choice of my own. This was necessary to create fair and accurate pieces of work, mostly concerning the use of STEM and engineering-based methods.

Following this, came the case of Cooperative Problem-based learning (CPBL), which was basically real-life case study problems using a contructive approach (Zakaria et al., 2020), and was the main idea behind our group project in ascending Stages 1, 2 and 3 for the Safety and Health 2021 campaign, a case study to showcase this CPBL. I recall that CPBL was impactful in the way it differed to traditional learning techniques (Masek et al., 2012). In CPBL, I learnt to work and research on a certain issue before we were fully taught about it. For example, when covering the topic of Hazard Identification and Risk Analysis for all possible hazards that we had to observe in our vicinity for a one-week period, we were given the problem of health and safety and why hazards need to be controlled and their risks minimized, and we were given a few methods such as HIRARC, Data collection methods, that we discussed in cluster groups in the classroom to present our own ideas. Furthermore, when forming an Engineering solution in teams, for a hazard presenting concerning risk in the local vicinity based on our data collection, we were given on methods to form and innovate engineering solutions rather than specific solution ideas. This supported my experience in filtering true information from irrelevant sources both online and offline, as I researched and learnt so much about Hazards, solutions, etc. I also noticed how to form a proper strategy to complete tasks with my teammates and stand the pressure during moments of work overload making reports, videos as well as nearing deadlines for presentations and Peer Teaching Notes (PTNs).

I felt that there was no one correct approach to this course as it considered multiple solutions to the problem at each Stage. Additionally, the problem was given to us from the very start, and we had to do the research and present findings based on what we learn ourselves or already know. The part I loved most about the whole first semester had to be this ITE group project, which I feel preserves the Cognitive Learning theory as its mainframe (Yilmaz, 2011). Here, I learned the value of research and data collection that investigators as well as engineers dedicate in contributing to, and opening doors to newer research prospects into fields such as Health and Safety within communities, the significance of Sustainability in both engineering and the global society across the three sustainability pillars (economic, social, environmental), engineering ethics and various other topics. Overall, the ITE course was truly beneficial in preparing me for new and more complex challenges and projects, both individually and in teams, in the future of my engineering studies and career.

As for ISP, it was a dedicated course to growing our imagination and dimensional way of thinking towards engineering and afar. What I gained and recall most about this course was the numerous individuals, all experienced in their fields, mostly originating from the engineering line, to become leading members, learners and leaders globally and within Malaysia. Every week was a new seminar with fresh faces of invited guests, UTM alumni, and having expertise in the topic we would cover that particular week, mostly aligning to guide us though our ITE assignment and project stages along the way. One week would be about Engineering Ethics, the next on Success and Failure Factors at University; Effective Presentation Skills Excellent and PowerPoint slides; and the following week on developing TRIZ Problem-solving skills. Yet, the most satisfying part of this course was recalling what had happened on a three-weekly basis and writing about it in Reflection Journals. I loved and almost could not wait for the next reflection journal to be written, given my passion for putting personal stories and memories onto paper, in this case in Microsoft Word. It also rocketed my attention to detail, ways to improve myself in future projects and integrated the building of other soft-skills (Zakaria et al., 2020).

From covering so many types of topics and content, I felt that I had sharpened many of my previously unknown or ignored skills, needed in the engineering world and more importantly relating to my identity development as a future engineer. Some of the abilities I felt were elevated due to this course included: judgement and decision making; critical thinking; active learning; and complex problem-solving. I was absolutely fascinated and surprised when I researched and found that the skills I mentioned were the most relevant and necessary for engineering majors for proper engineering identity development. Thus, I felt proud for understanding myself more through self-reflection, self-evaluation and further active learning, and realized that the ITE and ISP courses were beautiful partners, that conjointly allowed the maturity of my own engineering identity. Figure 3 presents a radical chart of the influence and necessity of the skills shown, for Engineering majors and the engineering field in general (Data USA, 2020).

The Cognitive Learning theory guided me and proved effective towards innovating and designing a prototype solution for my team, that eventually won two awards including the "Top Team in Breakout Room" and amongst "Top 10 Teams" for the whole competition during our online ITE, ISP and ICP combined exhibition held via Webex. This event was especially memorable for me because it was attended by a panel of judges representing several respected institutions across Malaysia including top leading universities and official bodies such as the Department of Environment (DOE), Board of Engineers Malaysia (BEM), all of whom evaluated the best and most innovative solutions, videos and presentations. Figure 4 shows the three main parts of the actual Cognitive Learning theory as a continuous process and this concluded my lessons and moments for the ITE and ISP courses (Valamis, 2021).

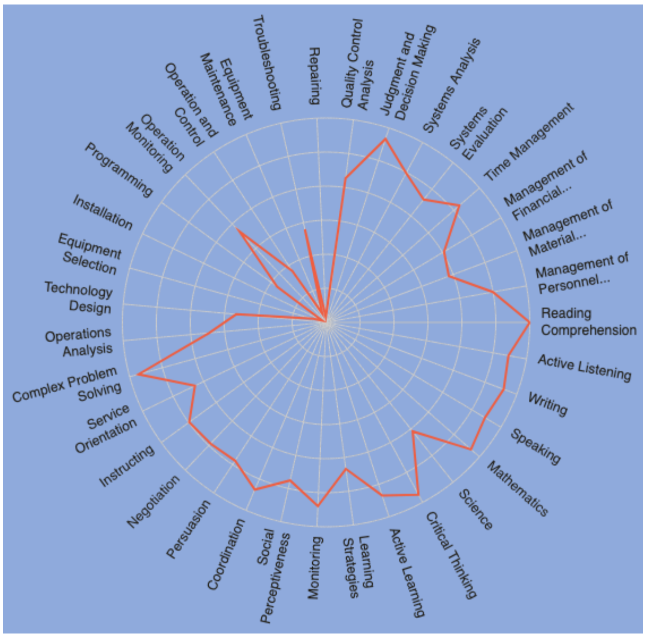

Figure 3: Radical Chart representation on necessity of skills in Engineering majors

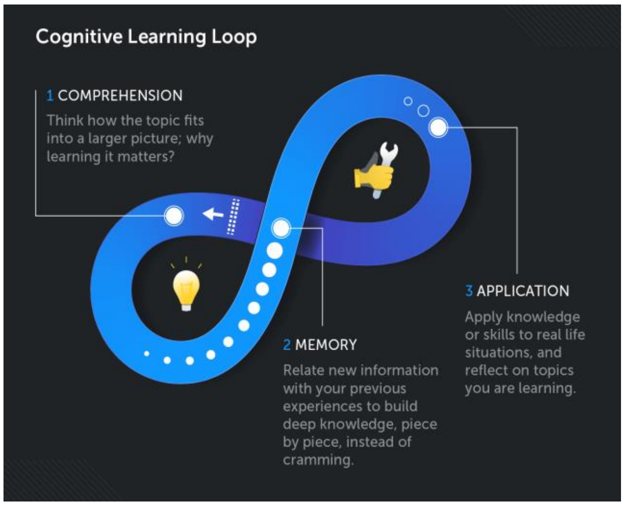

Figure 4: The Cognitive Learning Loop

Engineering Mathematics and Statics

Without a doubt, having a mathematical inclination will exponentially increase your performance and results in an Engineering program. Nevertheless, what about those facing challenges in the area of Mathematics, and their specific branches relating to necessary methods in engineering applications? When I started my first semester and began the Engineering Mathematics course, I would have never realized the value I would gain from it, despite not being strong in mathematics as a whole. The most enjoyable part of both Statics and Engineering Mathematics were the group assignments where in a 4 to 6-member group, we worked on a particular topic of matrices and applications of statics in the greater picture of engineering. For Statics, I became aware of the true applications of mechanics in rigid bodies such as bridges, everyday tools such as a clothing iron table, etc., and how engineers innovate novel designs with precision, to create the tallest and largest structures worldwide, most of which are extraordinarily beneficial to the global economy and societal development. Hence, such creativity and brilliance in the field of engineering have provided towards easier transportation and the betterment of lives. These are only some of the countless reasons why I chose engineering as my first official degree, because I have been long passionate to innovate and design something unimaginable, which can ultimately lead to mankind's progression.

As I progressed through the semester, thoroughly revising and working on examples for each chapter for the Engineering Mathematics and Statics courses, my mind was stretched to newer levels of thought, both mathematically and logically. I can strongly relate this to an engineering-based concept of Curriculum Mathematics and Mathematical Thinking (Goold et al., 2012). Curriculum Mathematics is where true knowledge, concepts and applications are learnt as a student goes through topics, to develop models, strategies and so forth. On a note, learning and becoming knowledgeable on probability and statistics in particular, will aid all engineering students like it did me, as these topics are applied to almost every aspect and type of engineering (Goold et al., 2012). Meanwhile, Mathematical Thinking is the practicability and actual mathematical way of thinking using the skills learnt and knowledge gained, to progress to use such approaches, build emotional intelligence and refine values, which may be the ultimate use of mathematics to solve real-world problems with originality and innovation.

An important study and survey also revealed that engineers consider Mathematical Thinking to be more dynamic, in the sense of long-term use, and it is "independent of the interaction between engineering discipline and engineering role" when compared to Curriculum Mathematics which is dependent on those two (Goold et al., 2012). What is meant by this is that engineers have a variety of tasks in the real workplace setting, and they may lose part of their engineering discipline and identity as they deal with increasingly more complex and broader problems, in areas outside their expertise. However, I feel that this not only applied to engineers, but many first semester engineering students, including me, where I suffered confusion of thought and understanding when the level of complexity increased before I could properly prepare myself for it. In the mathematical aspect, learning and being strong at mathematics does not always allow for solving highly complex problems directly using knowledge. Hence, to preserve the engineering identity, which is as distinctive as fingerprints, it is crucial to dedicate time towards innovation in teams, practice cognitive based learning methods and always look at the bigger picture using critical thinking. The vital reason for this being that a student needs to experience using mathematics in practical situations, which will be a big part of the true engineering working atmosphere, from the very beginning of their education in the first semester.

A first-year student also needs to experience using mathematics with increasing confidence, even if the progress is slow. Research has shown that learners will often ask themselves and others "Why am I doing mathematics?", I know I did (Harris et al., 2015). Therefore, to critically identify and actively discuss with lecturers on the mathematics course and specific topics that you are taking, is important and valuable in developing a harmonious identity and for your long-term goals. Another effective way I discovered, was to come in touch with some of my course mates for every subject, and actively interact with them from time-to-time. It surprisingly allowed for a refreshing way to absorb new information, as we gave each other brief, but effective tutorials and explanations on certain problems. I was fortunate to work in discussion groups via social media applications (this must be your own effort to network and connect with peers and make friends with confidence), as when a certain problem was not understood by someone, another student who had clarity could beautifully explain to us the details required. I can relate this to Peer Teaching in higher education (Goldschmid et al., 1976), using the dimension of consructivist learning theory of knowledge than just memorizing (Dagar et al., 2016), within and beyond the classroom. This is where students, including me, aided each other in learning and understanding challenging concepts, creating innovative ways of thinking and approach problems with coolness rather than being repelled by issues. To my amazement, I succeeded in completing almost every large assignment and project with proactiveness in teams with peers, much before the given deadlines. So, by the third month of the first semester, I started to feel really comfortable to approach as well as be approached by others for help, and I also actively contributed to their understanding for topics. Then, it increased my self-esteem, empathy (which I gained from understanding others' and sharing my own feelings) and significantly improved my academic performance across all courses.

Engineering Drawings

Drawings created an active atmosphere of learning, not only for myself, but for all others around me, while stimulating the creation of a more dynamic thinking approach to develop a sense of deep understanding of what I learnt from the art of designing and constructing. I can extend this certain thinking approach again to The Cognitive Learning Theory in classroom (Yilmaz, 2011). I was able to spend some time thinking about the actual purpose of what I was learning and concluded this both software use and engineering drawings could enhance my ability to run and handle more complex programs and boost my imagination for thinking in pictures than words. Additionally, drawing using a sophisticated and mathematical-based software also made me aware of the importance of proportions in the structures that are made by engineers, architects, rocket scientists in humanity's biggest projects throughout history. Just the idea that one single sketch by an engineering student eventually lead to the creation of a NASA satellite was dumbfounding. Next, I was able to move towards learning about how to actually make geometric, orthographic, three dimensional (3-D) and piping designed drawings of components and machinery using AutoCAD 2022. Figure 5 (a) shows one of the 3-D drawings we had to create with correct proportions, shapes and dimensions (excluded here). Next, is an attempt on an Isometric assignment (Figure 5 (b)), including blue lines for correctly constructed dimensions. This Isometric method shows a 3-D drawing; however, integrates observing from different directions and angles of the shape, to construct the drawing using 2-D type illustrations and orthographic tools, which was challenging but a great learning experience.

Finally, after forming a good base of understanding, getting familiar with AutoCAD 2022 and sharpening my professional drawing skills, I was able to apply it to a real-life and bigger situation after few days of critical thinking and reflection on the best methods.

As briefly mentioned before, I applied my drawing skills aided by the AutoCAD 2022 software to designing the ITE Engineering Solution (named CHASafeties) for my team CHAS, for the final Stage 3 of our Introduction to Engineering Safety and Health 2021 (S&H 2021) report and video exhibition. The final layered and water-resistant safety sticker (Figure 6 (a)) to prevent electric shocks from plugs, sockets, switches (relating to water contact and electrical leakage, a common issue regarding electrical hazards at home and workplaces), and 6 (b) showing the unique part of our solution, a Test bulb with non-contact voltage detection components to alert people of electrical leakage and risk of electrocution in the switch or plug ports, and ensure it can be replaced or repaired immediately, were designed. Interestingly, I got the idea to construct both using the AutoCAD 2022 drawing and drafting software for my team, so this was a perfect transfer of skills from one course to another (Engineering Drawings to ITE), which I remain pleased and proud of.

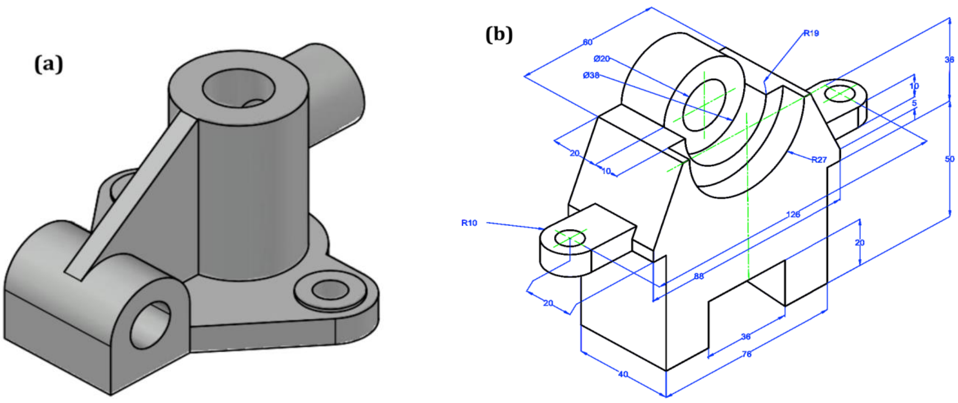

Figure 5: (a) A 3-D drawing assignment (b) Personal attempt on an Isometric drawing assignment

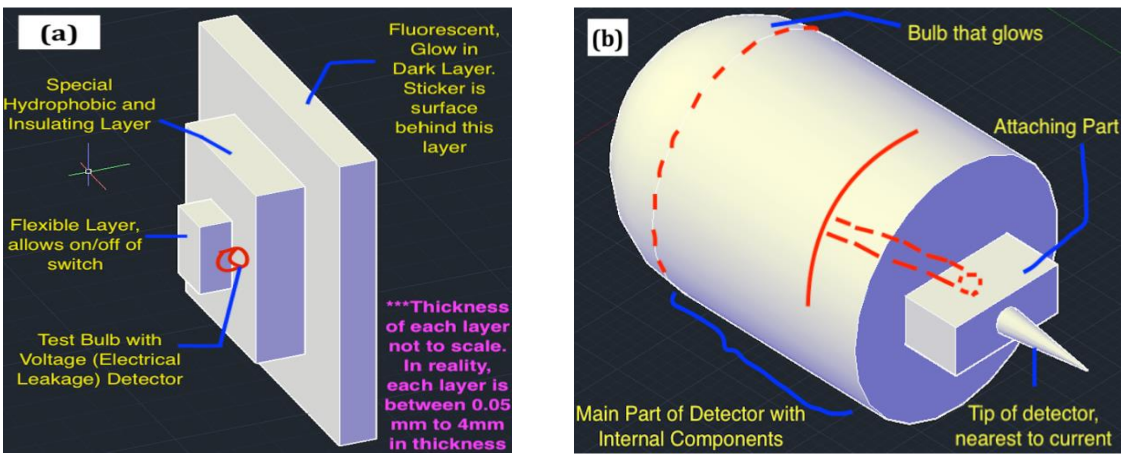

Figure 6: (a) CHASafeties layered electrical safety sticker drawing (b) Test bulb and non-contact Voltage (Electrical Leakage) detector component.

English Communication Skills

Although I have been conversing in English all my life and is almost bilingual to my native Bengali language, it was a beautiful journey to be involved in this course for the first semester. My lecturer, exceptionally jolly and approachable, was the main reason behind me loving and doing well in this particular course. The highlight was the group project on any topic we liked, creating a video and a piece of reflective writing with three of my friends for the course. I reasoned that dedicating our project to a single topic would be limiting our creativity. Hence, we all did food sharing, talked about life stories, what hobbies we had and future aspirations. As a fairly experienced English language speaker, one thing came to my mind: doing well and enjoying this course was not about the English itself, rather passionate interactions with people to develop trust, and inspiring each other though oral interactions than in only in written form, which I can relate to constructivism (Rao, 2018). Keeping this goal in mind, to simply love the conversations you have with different individuals will help boost your morale and confidence, and might just give you the humane outlook needed to build ethics; a key factor of any engineering identity. The unity that came from us talking to each other about food, what we loved to do in our spare time and our personal goals in life was memorable. Not only did conversing in English make me culturally more mature; which was an interesting match to the Cognitive Constructivist theory of learning by exploring my experience of talking to people (Rao, 2018), but also showed me that outside my mind, lies people with their own stories, passions and ambitions; quite similar to mine, yet unique.

Lifetime Lessons that are worth it

Well, I feel that all I could describe and explain to new engineering students of tomorrow have been done to the best of my abilities and limits. However, I strongly believe that no prodigious journey ever ends, or ever should. That is why, I leave a few, but deep lessons that may take a lifetime to learn, practice and spread, but will be worth it for all those who consider them. Firstly, staying out of your comfort-zone in the sense of trying new things, considering new ideas and interacting with new people. One, two or even all three of these things will give you discomfort as you progress though the first semester at university, career, and if not university, then in life. Sometimes, trying new things seem repulsive, and that it may lead to an undesirable outcome in your life. In truth, much of the time I have spent has only solidified in me that trying new things with new people gives you experiences you never thought was possible. In fact, trying new things from time to time expands the dimension and scale of thought within the human mind. It has to be nothing complex, just a simple idea can lead to great innovations. That is why considering new ideas, or those that go against your own, should be made a regular and lifetime habit as an engineering student. Next, an unimaginably beneficial lesson that can be practiced is learning how to self-analyze and self-evaluate all actions within one's life and learning progression. Examining how you learn best, and simultaneously analyzing how to effectively absorb knowledge from different sources, is invaluable to your lifetime growth and success. This aspect of self-evaluating using critical thinking can be extended to refining both teacher and student philosophies (Reber, 2011) as well as self-reflection in all fields of academics, occupational as well as social life (Iliff et al., 2019). Self-reflection was a key aspect in my growth and recalling things in a more dynamic way as to their purpose, processes and theoretical comprehension. This was applied to every topic and class I covered throughout the first semester, for all seven courses I took. A basic idea bubble of self-reflection (but not limited to) is shown in Figure 7 ('OC & CP' in the purple bubble can be left out) (Iliff et al., 2019), and can act as a guide for your own learning growth and discovery.

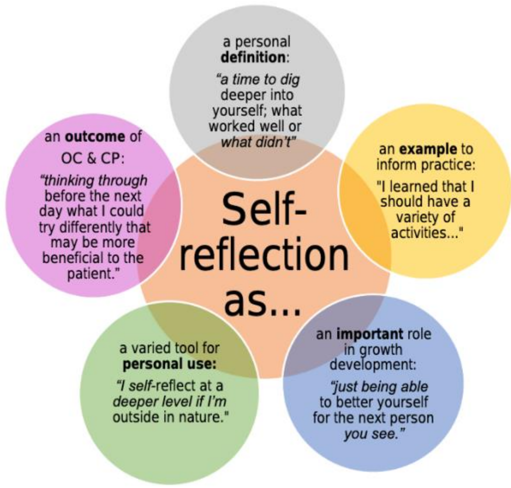

Figure 7: Self-reflection - A basic idea bubble

Finally, communicating throughout this semester, with so many creative and passionate individuals, made me more of a human engineer who understands his or her faults, than a robotic perfectionist, who cannot self-reflect and enjoy nostalgic memories of the learning journey as well as being motivated by mistakes. I feel special to have matured to a state of mindfulness and emotional intelligence, to sustain my growth over the long-term. On an end note, starting a nice conversation on anything with people creates trust and might bring peace to our future world. So, choose words with careful thought, and say them at the right time. I was fortunate to be able to do and understand this partially, given the limitations of online classes compared to live lectures due to the pandemic. However, I feel future learners will have more opportunities of working together compared to present times. Perhaps they will be fortunate to discuss larger, more complex ideas in a simpler way when learning face-to-face. There is no time to procrastinate, the beauty of learning something new is out there for your taking. All you have to do is give effort in wanting to, and extend your hand saying yes to, learning something new, every single day!

Conclusion

After a deep conversation with myself, and presenting my experience and lessons learnt in the process of developing a personal engineering identity, there are three quintessential ideas that emerge from the findings of this study. First, the learning process of a student at university, particularly in the first semester at undergraduate level, is vastly unique and much more a story of waves of successes and failures than a chronological development process. Secondly, all the lessons I have shared will hopefully aid future engineering students in doing well over the entirety of their degree and program, and perhaps create beautiful memories of being an undergraduate student, that will remain with them for a lifetime.

Lastly, considering the multiple learning theories interweaved within my journey, developing a harmonious identity while excelling academically relies on multiple factors. Growing on such factors depends on true effort from the student's side. Thus, it becomes beneficial for students to keep written accounts of all experiences and challenges faced, to form future studies and research into learning experiences and identity development, using the narrative enquiry analysis or other methods, both within engineering, engineering education and beyond. In conclusion, I advise future freshmen to keep written journals and notes, become story tellers of their journey as students, as opportunities and breakthroughs will arrive when they least expect it.

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Literature Review on the Factors Affecting Employability of Engineering Graduates

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Abstract
Graduate Employability (EM) is a major issue for Institutions of Higher Learning (IHL). In a challenging economy, the role of IHL is not only to produce graduates with specific areas of specialization, but more importantly, to develop EM skills that are most demanding in the 21st Century. This literature review aims to identify the determinant factors influencing the employability of engineering graduates. The Narrative Literature Review method was used to search for relevant articles. The literature review indicates that researchers have identified soft skills, problem solving skills, functional (knowledge) skills and academic reputation as the primary factors influencing the employability of engineering graduates.

Keywords: Employability, soft skills, functional skills, academic reputation and problem solving skills.

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Introduction

In recent years, there has been a global trend towards enhancing graduate employability (EM) through Institutions of Higher Learning (IHL) (Griffiths et al., 2017; Milburn-Shaw & Walker, 2017; Donald et al., 2018; Alemu, 2019; Sin et al., 2019; Zahavi & Friedman, 2019; Cheng et al, 2021; Mistry, 2021). Employability represents the potential to secure, maintain, and grow in a particular job at the workplace. Employability means that students and graduates can discern, acquire, adapt and continually enhance the skills, understandings and personal attributes that make them more likely to find and create meaningful paid and unpaid work that benefits themselves, the workforce, the community and the economy (Oliver, 2015). Gedye and Beaumont (2018) conceptualizes employability as the capability of obtaining work, functioning effectively within work; moving between jobs; and having the skills, knowledge and attributes that make this possible.

The Malaysian Ministry of Higher Education (MOHE) defines employment as the potential to secure a job at a workplace while employability is defined as the potential to secure, maintain, and grow in a particular job at the workplace (The National Graduate Employability Blueprint, 2012-2017). Kubler & Forbes (2004) defined Engineering as a profession directed towards the skilled application of a distinctive body of knowledge based on mathematics, science and technology, integrated with business and management, which is acquired through education and professional formation in a particular engineering discipline. Engineering is directed to developing, providing and maintaining infrastructure, goods and services for industry and the community.

The two greatest concerns of employers are finding good workers and training them. One problem in some countries is unemployment among engineering graduates. Employers complain that the graduate-level job applicants are lacking in generic skills. New engineering graduates have good basic engineering knowledge and are not actually lacking in technical competency (Kamsah, 2004). However, engineering graduates are required to possess the employability skills to help them use their technical skills and their knowledge effectively.

Globally, employers agree that graduates are lacking in generic skills and they want higher education provider to emphasis more on developing these skills to students (Lankard, 1990; Gregson, 1992; Kamsah, 2004).

The main issues in the economic development of a country are the employment and unemployment rates. A country is said to have sustained growth if unemployment is low. On the other hand, a high rate of unemployment means a waste of human resources. Unemployment continues to be one of the most important economic problems and must be addressed in the labour market. The causes of unemployment are varied and complex. One of the main factors which causes unemployment is lack of employability skills (Surya, 2012). In order to address this issue, studies need to be conducted in order to determine the specific factors of graduate employability (EM). Once graduates understand the skills and characteristics that employers seek, they can tailor the requirement of the employer.

India faces a massive skill gap problem with hundreds of engineers graduating every year but only a few possess the skills required by the employer in the industry. There were not more than 50% of fresh engineers from All India Council for Technical Education (AICTE) approved colleges who secured employment between 2017 to 2018. According to a survey by Aspiring Minds, out of more than 1.5 million engineers who graduated in India, 80% were unemployed in 2019 (Mahadevan, 2019). Vijay (2021) claims that the core problem lies in the education modules that most of India's technical universities follow, emphasising technical writing skills and memorisation abilities of the students instead of deploying innovative methods that may improve their technical competence and skills.

In Malaysia, MOHE stated that the economy is an open economy driven primarily by foreign direct investment and export growth. The future workforce has to be able to cope with the changing nature and demands of the works. Future workforce must have the employability skills required by industries. Thus, the education system must recognize the changing demand conditions in terms of the needs of multinational and large corporations. This is important to ensure a country is able to produce adequately and appropriately trained human resource and does not face a skill-shortage problem. Currently, deficiencies are seen in the areas of communication, Information and Communications Technology (ICT) knowledge, and professional and technical skills which have resulted in an insufficient supply of employable graduates. This situation is further aggravated by university students not pursuing fields of study that are relevant to industry and not acquiring the skills demanded by the employers.

In the global economy today, the world is rapidly becoming one interdependent marketplace. This economic reality and challenges require engineering graduates to equip themselves not only with paper qualifications but also with other related skills to enhance their prospects of employment. In such a challenging economy, the role of IHL is not only to produce graduates with specific areas of specialization, but more importantly, to develop graduate employability skills that are most demanding in the 21st Century (Lee & Tan, 2003). MOHE's objective on EM was to produce competent graduates to fulfill national and international manpower needs with 75% of graduates employed in their relevant fields within six months of their graduation (The National Graduate Employability Blueprint, 2012-2017). MOHE's objective shows the government's serious concern on EM and marketability. The unemployment rate of technical graduates for the period of four years (2008-2011) improved from 46% to 24% (Strategic Action Plan for Engineering Education in Malaysia, 2013-2018). However, it is a challenge now to ensure the steady rate of employment of engineering graduates. MOHE aspires to increase the EM rate to more than 80% by 2025 (MOE, 2015).

Employable graduates must possess the pertinent attributes, skills and knowledge which ensure they have the capability of being effective in the workplace to benefit themselves, their employers in the industry and society. What are the significant factors of engineering graduate's employability? This literature review aims to identify the important characteristics or skills of engineering graduates as required by employers.

Literature Review

This research was conducted using the Narrative Literature Review (NLR) method as classified by Cook et al. (1997) and Rother (2007). We had selected over 300 articles for review of what constituted significant factors to industry over the past two decades considered as a requirement to employ new engineering graduates.

A lot of terminology of graduate employability (EM) is used in researching the basic skills needed by graduates (Brochado, 2009; Hall et al., 2010; Surya, 2012). EM skills are those basic skills necessary for getting, keeping and doing well on a job. EM skills are also known as job readiness skills. EM are also defined as a set of achievements, understandings and personal attributes that makes individuals more likely to gain employment and be successful in their chosen occupations. Employability is defined as a set of attributes, skills and knowledge that all labour market participants should possess to ensure they have the capability of being effective in the workplace – to the benefit of themselves, their employer and the wider economy (Andrews & Russell, 2012). There are a number of interpretations of 'employability' in the literature, which can be reduced to three overarching constructs: (i) Employability as demonstrated by the graduate actually obtaining a job, (ii) Employability as the student being developed by their experience of higher education (i.e., it is a curricular and perhaps extracurricular process), (iii) Employability in terms of personal achievements (implicitly and potentially). Employability implies something about the capacity of the graduate to function in a job, and is not to be confused with the acquisition of a job, whether a 'graduate job' or otherwise. A review of literature suggests that employability is about the work and ability of being marketable in the industry or in other word, employability is about being adept at getting and keeping a job (MOHE, 2012).

In addition to being well-grounded in technical courses, engineers should be well-shaped in broader knowledge-base and diverse personal/interpersonal key-skills. Such attributes and skills include teamwork, communication, inter/multidisciplinary knowledge, analytical thinking, ingenuity, creativity, technological innovation, business skills, management skills, leadership, ethics, professionalism, and understanding work strategies. Employability of graduates is not just determined as the outcome of discipline specific study programme or professional studies, but also the graduate's ability to promote wider skills like communicative, problem solving, interactive skills, showing initiative and efficiency (Yusof & Jamaluddin, 2015). Employability also includes the aspect of attitude and personal attributes of loyalty, commitment, honesty, punctuality and integrity.

A common recommendation is that the pertinent attributes, skills and knowledge are all characteristics or qualities that can be learnt and therefore should be taught within the education programme. Employability skills are teachable and transferable skills. Newport and Elms (1997) stated that the employable qualities are learnable, and that therefore they are teachable within an education programme. Some `knowledge' areas were identified in their study which they concluded should be incorporated into an education programme. The categories they used were based on Carter's (1985) 'A Taxonomy of objectives for professional education'. Categorizing the distinguishing effective engineer qualities by type of learning experience reveals a large number of 'skill' qualities. If these qualities are developed among the students through academic programmes, it would surely enhance their chances of employability. Better teaching outcome should also improve the chances of EM (Sahudin et al., 2019).

Determinant Factors affecting Graduate Employability (EM)

Changes are the norms at the workplace. Globalization and development of technology demand employees to be highly skilled. Every employer is looking for a specific set of skills for job seekers that match the skills necessary to perform a particular job. The need to establish employability skills among university graduates is imperative. It is important for graduates to improve their skills through training, professional development, from someone who understand these skills.

To keep pace with global competition, fresh graduates need to adapt to the new business environment and workplace demands (Bhagwath & Pal, 2013). The key element to enable graduates to keep up with those demands seems to be the employability skills and traits that are imparted during tertiary education. It has also become a common belief in industry that IHL should equip graduates with the proper skills necessary to achieve success in the workplace. The on-going changes in the workplace, the work itself and the development of advance technology will require workforce to have advance knowledge in the areas of works, high skills and positive attitudes (Surya, 2012). The advancement of new technologies changes the way work are done and brings about a shift of workforce requirement from low skills to the workforce being well informed and highly skilled.

There are various definitions of graduate employability (EM) and a number of different terms are used. Generic skill is the term used for employability skills in most countries, but what is meant by this term varies between countries. Employability skills are the general skills which play an important role in contributing to employees' successful performance at their workplaces. The UK Commission for Employment and Skills report 'The Employability Challenge' (2009) has drawn on the most commonly used definitions of employability: "We take employability skills to be the skills almost everyone needs to do almost any job. They are the skills that must be present to enable an individual to use the more specific knowledge and technical skills that their particular workplaces will require".

Some studies suggest that a person's success is not solely determined by knowledge and technical skills which are hard skills, but also by the ability to manage oneself and others employability skills (Surya, 2012). A study by Rosenberg et al. (2012) suggest that basic graduate employability skills are transferable core proficiencies that represent essential functional and enabling knowledge skills and abilities required to succeed at all levels of employment in the 21st century workplace. Graduate employability (EM) was also categorized in the following competency areas: personal values, problem solving, decision making skills, relation with other people, communication skills, task-related skills, maturity, health and safety habits, and commitment to job. Management skills are also included under graduate employability (Rosenberg et al., 2012).

Skill is the ability to perform specific tasks (Yusoff et al., 2012). Employability skills are those basic skills necessary for getting, keeping, and doing well on a job. These are the skills, attitudes and actions that enable workers to get along with their fellow workers and supervisors and to make sound, critical decisions. Unlike occupational or technical skills, employability skills are generic in nature rather than job specific and cut across all industry types, business sizes, and job levels from the entry-level worker to the senior-most position. Employability skills, while categorized in many different ways, are generally divided into three skill sets: (i) basic academic skills, (ii) higher-order thinking skills and (iii) personal qualities. The excellent academic degrees alone are inadequate as the employers today look in fresh engineering graduates for competencies or capabilities in generic skills. Majority of studies continue to emphasize that technical content knowledge and competencies are essential for any engineer. Statistics indicating a high percentage of employed engineering graduates does not imply they are effective engineers. An engineer may be employed simply because they were considered adequate.

It has traditionally been regarded that a remarkably outstanding cumulative grade point average (CGPA) obtained by graduates through laboriousness in university has been a passport to seeking for a qualification suited, if not highly rewarded employment (National Graduate Employability in Malaysia, 2012). It has therefore prompted undergraduates to be devoted to concentrating solely on their studies for academic excellence while compromising co-curricular activity participation, through which employment related soft skills are accumulated. Consequently, hard skills learnt from and emphasized through courses of study in university are virtually not complemented by the possession of personal qualities and soft skills among undergraduates. A perfect blend of personal qualities, soft skills and hard skills will contribute to enhancing graduate employability, a term where its definition can be connoted from various angles. The next section discusses the four primary determinant factors and the relationship with graduate employability (EM).

1. Soft Skills

Recently, educational researchers and employers have placed increasing attention on the importance of soft-skills (Yusoff et al., 2012; Williams, 2015; de Villiers Scheepers et al., 2018; Teng et al., 2019; de Campos et al., 2020; Pitan & Muller, 2020; Hirudayaraj et al., 2021; Sarker et al., 2021).

While functional (knowledge) skill or discipline-specific knowledge is typically content specific, soft-skills are non-academic skills (communication and interpersonal adaptability skills) that are presumed to be useful in a range of working environments. The term soft skills, used interchangeably with nontechnical skills, is defined as the interpersonal, human, people or behavioural skills needed to apply technical skills and knowledge in the workplace. Soft skills are categorized as being related to human issues, such as communication, teamwork, leadership, conflict management, negotiation, professionalism, and ethics (Williams, 2015).

Evidence suggests that soft-skills are an important predictor of employability (Finch et al., 2012; Lievens & Sackett, 2012; Nickson et al., 2012; Williams, 2015; Abd Majid et al., 2020). Specific soft-skills that may affect employability include the following types of communication skills: written communication skills; verbal communication skills; and listening skills. Workplace communication skills encompass competent oral and writing skills, the ability to work in teams with ample team-spirit and cooperation, mingling with those from diverse backgrounds, cultures and regions, and in crisis and adversities, passing through them with courage and acumen of mind (Das, 2018). Professionalism has been identified as contributing to employability (Ashton, 2011). Soft skills such as human relations skills, communication skills, ethical behaviour skills and cognitive skills are the attributes that employers consider when reviewing job applicants (Kenayathulla et al., 2019). Lastly, scholars have identified interpersonal skills – such as the ability to work effectively in teams – as an important employability factor (Wellman, 2010). In sum, research conducted from a range of disciplines and occupations converges on the finding that soft-skills influence employability.

The ability to communicate effectively worldwide, understanding of business issues, concern about societal and ethical issues, and global sustainability have also become necessary attributes for engineers to face the challenges of globalization; in addition, graduates are expected to contribute towards the socio-economic development of the country and assist in national unity. Language proficiency, especially in narrative skills, is required for engineers to effectively convey their ideas and solutions to the community in a comprehensible and appropriate manner.

Rasul et al. (2013) investigated the importance of employability skills as perceived by 107 employers from manufacturing industries. The findings of the study revealed employers place great importance on interpersonal skills, thinking skills and personal qualities that students need to emphasize to be employed in manufacturing industries. Indicators such as work safety, integrity, customer service, creative/innovative thinking and problem solving, and exercise leadership showed the highest mean score. Overall employers from manufacturing industries placed employability skills as must be owned by all graduates to enable them to compete in the global market. Results support a growing body of research that identifies soft-skills as one of the most important competencies employers look for when hiring new graduates (Finch et al., 2012). A recent study by the Australian Employment Agency found that 85% of the desirable skills for employability are related to soft skills, while 15% are technical skills, highlighting the importance of the need to teach and highlight soft skills during the academic period (de Campos et al., 2020). MOHE (Wan Muda et al., 2021) developed seven constructs under soft-skills and Hanapi (2015) asserted that graduates should focus on the dominant soft skills to enhance their marketability. The individual employability factors that are measured most are from the category of soft-skills. This suggests that new engineering graduates who demonstrate soft-skills (e.g., effective communication and interpersonal skills) will be more competitive in the marketplace than those who do not. It is important for IHL to embed soft skills into the curriculum in order to develop graduate work readiness (Teng et al., 2019).

In summary, the literature review indicates that researchers have identified soft skills as an important factor influencing EM (Finch et al., 2012; Lievens & Sackett, 2012; Nickson et al., 2012; Yusoff et al., 2012; de Villiers Scheepers et al., 2018; Teng et al., 2019; de Campos et al., 2020; Hirudayaraj et al., 2021; Sarker et al., 2021; Wan Muda et al., 2021).

2. Problem Solving Skills

Researchers have identified that problem-solving skills are core to employability (Reid & Anderson, 2012; Yusoff et al., 2012; Asonitou, 2015; Ito & Kawazoe, 2015; Azmi et al., 2018; de Villiers Scheepers et al., 2018; Scott et al., 2019; de Campos et al., 2020; Fajaryati et al., 2020; Liew et al., 2020; Saleh & Lamsali, 2020; Zapalska et al., 2020; Idkhan et al., 2021). Similar to soft-skills, problem-solving skills are important across disciplines (e.g., engineering, marketing) and employer type (Wellman, 2010). Problem solving skills term have been explicitly mentioned in a wide variety of literature. Problem-solving skills are higher-order cognitive skills that are complex, requiring "judgment, analysis, and synthesis; and are not applied in a rote or mechanical manner". Problem solving is a competency closely related to intelligence or general mental ability (Scherbaum et al., 2012), which is the best predictor of job performance across a variety of occupations. Problem solving incorporates a range of competencies including critical thinking skills (Reid & Anderson, 2012; Zapalska et al., 2020), creativity, leadership skills (Conrad & Newberry, 2012), and adaptability (Jabr, 2011).

Problem solving skills also include the creativity of manpower. It refers to applying creative thinking to develop appropriate solutions; ability to come up with new ideas, solutions and envision of original ideas and concepts, inventing new products and solutions, and apply 'lateral thinking. Analytical ability is also an important dimension of problem solving skills. Analytical ability means strong analytical skills. Engineers should be critical thinkers so that they can be able to apply a systematic and critical assessment of complex problems and issues (Hounsell, 2011). Critical thinkers use critical, conceptual, reflective, and rational thinking in drawing and evidence-based assessing systematic conclusions and finding underlying relationships for solutions. They should also be innovative in nature in designing new products and business polices also giving innovative solutions to existing problems (Rabl & Hillmer, 2012). Innovative employees add values through introducing novel ideas, methods, directions, opportunities, and solutions that meet new requirements, through more effective products, processes, services, and technologies that are readily available to stakeholders.

Consistent with past research (Reid & Anderson, 2012; MOHE, 2015) employers identify problem-solving skills (critical thinking skills) as an important factor when assessing new graduates' employability. Second only to soft-skills, problem solving was considered a key skill employers assess when hiring new graduates. A number of research findings provide additional support for the notion that problem-solving skills are important across disciplines (Wellman, 2010), due to their strong predictive validity when it comes to job performance. Organizations seek candidates that can perform at consistently high levels, be trained to perform new tasks and possess the skill sets required to solve fundamental and complex problems (Bhatnagar, 2021).

In summary, the literature review indicates that researchers have identified problem solving skills as an important factor influencing EM (Reid & Anderson, 2012; Yusoff et al., 2012; Asonitou, 2015; Ito & Kawazoe, 2015; Azmi et al., 2018; de Villiers Scheepers et al., 2018; Scott et al., 2019; de Campos et al., 2020; Fajaryati et al., 2020; Liew et al., 2020; Saleh & Lamsali, 2020; Zapalska et al., 2020; Idkhan et al., 2021).

3. Functional (Knowledge) Skills

Functional engineering knowledge skills are unique core specialized competencies that are required for each engineering discipline's respective work settings. Functional engineering skills encompass communication, information management, organization management, investigation, research, design, planning and technical skills unique to each engineering discipline (Lithgow, 2010). Job-specific Functional Skills or Industry skills are Job-specific functional skills, including job-specific competencies, job-specific technical skills (Rosenberg et al., 2012; Low et al., 2016; Uddin, 2021), and knowledge of software are essential when considering an individual's employability (Smith, 2008; Laker & Powell, 2011). Engineering graduate competencies of IHL accredited by organizations that are members of the International Engineering Alliance (IEA) are listed in the IEA Graduate Attributes & Professional Competencies (IEA, 2021).

Generally speaking, these skills send a signal to employers that a new graduate has mastered the specific proficiencies needed to perform highly on a particular job (Bhaerman & Spill, 1988). Job-specific functional skills are more context specific than soft-skills and problem-solving skills. For instance, the technical skills required by a software engineer will differ from those required by a business analyst.

For the time being, job-specific functional skills have become an important employability factor. Within this category, three individual factors were identified: job-specific competencies, job-specific technical skills, and knowledge of software. To be a successful job applicant as a new graduate, technical skills are important but ranked intermediate to the other categories (Smith, 2008; Laker & Powell, 2011). Employers who have technical requirements understand that they may have unique software and/or technical processes that graduates may not have been exposed to in their studies. However, by selecting graduates with strong problem-solving skills, employers can ensure that it will be easy for their employees to learn these job-specific functional skills through training or on-the-job experience. This functional skill requires graduates to apply knowledge and skills, essential for effective professional practices, into real-world settings (Gowsalya & Kumar, 2017).

In summary, the literature review indicates that researchers have identified functional (knowledge) skills as an important factor influencing EM (Laker & Powell, 2011; Low et al., 2016; Gowsalya & Kumar, 2017; Fajaryati et al., 2020; Idkhan et al., 2021; Uddin, 2021).

4. Academic Reputation

Reputation is a social construct that is defined as the generalized level of esteem for an organization held by a stakeholder (Fombrun & Shanley, 1990; Dalton & Croft, 2003; Deephouse & Carter, 2005). Academic reputation has a significant impact on a variety of outcomes of interest to employers (Mihut, 2015), policy makers, and academics alike. Reputation is an intangible asset that has been recognized as an essential part of an organization's management, which provides great strategic value for creating long-term competitive advantages (Taeuscher, 2019; Miotto et al., 2020). Reputation synthesizes information about the organization, its product, its relationship with customers, competitors and suppliers, as well as providing information on the reliability and credibility of the organization, determining the public's favorable response towards it (Lappeman et al., 2018). Reputation is built over time, is nonnegotiable, and is one of the most important determinants of the prevalence of any organization (Martín-Miguel et al., 2020).

For instance, researchers have examined how student retention and perceptions are affected by: institutional image; institutional branding; institutional ranking; and programme structure (Bano & Vasantha, 2019). Comparatively, few studies have explored the relationship between academic reputation and employability. The academic reputation of a specific school (e.g., Harvard) or a category of schools (e.g., Ivy League) may enhance EM from IHL (Nogales et al., 2020; Shanmugam & Bano, 2020).

Evidence suggests that academic reputation and its relationship to employability should be considered at three levels. The first level considers institutional-level reputation. Institutions and the ranking systems that have emerged in the past two decades (e.g., Maclean's University Rankings, Forbes Top Universities List) influence the employability of new graduates (Maclean, 2017; Strauss, 2017). Second, scholars have identified that programme-level reputation also can influence the perception of employability skills. For example, the Financial Times (2018) releases an annual ranking of MBA programmes which may influence the employability of graduates from these programmes. Lastly, individual academic performance (grade-point average) contributes to the employability of a new graduate and is frequently used in selection systems for entry-level positions.

Finch et al. (2012) conducted a study where they tried to relate academic reputation with employability. The results illustrate that, compared to other categories; employers place the least importance on academic reputation when hiring new graduates. The academic reputation issues were ranked above the mid-point on the scale, suggesting that employers do place some importance on them. These findings contribute to the relatively small body of literature on the relationship between academic reputation and employability. Interestingly, it appears that there may be a disconnect between the importance students place on academic reputation when choosing their post-secondary institution and the relative lack of importance employers place on academic reputation when hiring graduates.

In summary, the literature review indicates that researchers have identified academic reputation as an important factor influencing EM (Mihut, 2015; Maclean, 2017; Strauss, 2017; Bano & Vasantha, 2019; Nogales et al., 2020; Shanmugam & Bano, 2020; Aviso et al., 2021).

As an overall summary, the literature review indicates that researchers have identified soft skills (Finch et al., 2012; Lievens & Sackett, 2012; Nickson et al., 2012; Yusoff et al., 2012; de Villiers Scheepers et al., 2018; Teng et al., 2019; de Campos et al., 2020; Hirudayaraj et al., 2021; Sarker et al., 2021), problem solving skills (Reid & Anderson, 2012; Yusoff et al., 2012; Asonitou, 2015; Ito & Kawazoe, 2015; Azmi et al., 2018; ; de Villiers Scheepers et al., 2018; Scott et al., 2019; de Campos et al., 2020; Fajaryati et al., 2020; Liew et al., 2020; Saleh & Lamsali, 2020; Zapalska et al., 2020; Idkhan et al., 2021), functional (knowledge) skills (Laker & Powell, 2011; Gowsalya & Kumar, 2017; Fajaryati et al., 2020; Idkhan et al., 2021; Uddin, 2021) and academic reputation (Mihut, 2015; Maclean, 2017; Strauss, 2017; Bano & Vasantha, 2019; Nogales et al., 2020; Shanmugam & Bano, 2020; Aviso et al., 2021) as factors influencing EM.

Discussion and Conclusion

Research on graduate employability (EM) has gained much attention as employers are now more concerned about finding good workers who not only have basic academic skills but also higher order thinking skills like learning, reasoning, thinking creatively, decision making and problem solving. Quality engineering education leads to quality engineering graduates that the employer will be satisfied with. IHL should design courses and curriculum in a way so that students can achieve the required skills necessary for the competitive job market (Rowe & Zegwaard, 2017; Sahudin et al., 2021). Quality education should also guarantee the employability of the graduates (Abiodun-Oyebanji & Omojola, 2018; Sahudin et al., 2019). Research opportunities include conducting Systematic Literature Review (SLR) applying quantitative synthesis using statistical methods as classified by Cook et al. (1997) and Rother (2007). Future studies could also be recommended to determine which among the identified factors are the most pertinent factors influencing graduate employability (EM).

The literature review indicates that soft-skills are an important predictor of employability. Employers give importance on some specific soft skills like the communication skills including written communication skills, verbal communication skills and listening skills; similarly, professionalism and interpersonal skills – such as the ability to work effectively in teams as contributing to employability. Therefore, graduates should not only focus on the academic issues or job specific skills; rather they should also develop good communication skills, professionalism and interpersonal skills to survive in the competitive job market. Future studies could be recommended to survey employers to determine EM relationship with Program Learning Outcome (PLO) related to soft-skills.

The literature review indicate problem solving skills as an important predictor of graduate employability. Problem solving is a competency closely related to intelligence, which is the best predictor of job performance across a variety of occupations. Among the different types of skills explored through the literature review, problem solving skills was found to have a significant predictor of EM from the employers' point of view. Employers want engineering graduates to have problem solving skills as it includes the creativity of manpower. It refers to applying creative thinking to develop appropriate solutions; ability to come up with new ideas, solutions and envision original ideas and concepts, inventing new products and solutions, and apply lateral thinking. Analytical ability is also an important dimension of problem solving skills. Therefore, engineering graduates should develop these skills to secure a job position in the competitive job market. Future studies could be recommended to determine whether engineering education should focus on students solving more engineering problems or solving complex engineering problems.

The literature review indicates functional (knowledge) skills as an important factor of graduate employability. To be a successful job applicant as a new graduate, technical skills are important. Employers who have technical requirements understand that they may have unique software and/or technical processes that graduates may not have been exposed to in their studies. However, by selecting graduates with strong problem-solving skills, employers can ensure that it will be easy for their employees to learn these job-specific functional (knowledge) skills through training or on-the-job experience. This functional (knowledge) skills require graduates to apply engineering knowledge and skills, essential for effective professional practices, into real-world settings. Future studies could be recommended to determine how engineering education can improve student's learning knowledge skills.

Finally, the literature review indicates that academic reputation of graduates is related to graduate employability. The academic reputation of a specific institution may enhance employability of graduates from these institutions. Though few studies concluded that academic reputation has a significant influence on a variety of outcomes of interest to employers and policy makers, the literature review indicates that it is correlated to graduate employability. Employers give importance to the institutional image or academic results of the candidates. Future studies could be recommended to survey employers in the relevant industry to examine EM relationship to academic reputation.

In summary, the literature review indicated that researchers have identified soft skills, problem solving skills, functional (knowledge) skills and academic reputation as factors influencing engineering graduate's employability.

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Sustainable Assessment: The Inevitable Future of Engineering Curriculum

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Abstract

The programme outcomes, also known as graduate attributes in the International Engineering Alliance, serve as a benchmark of standards for engineering education to higher learning institutions in Malaysia and other signatory countries under the educational accords. Various studies conducted around the world have revealed that evaluating programme outcomes is perhaps the most important criterion for Outcomes-Based Education (OBE) which focuses on improving graduates' intellectual skills and capabilities. Several Higher Learning Institutions (HLIs) in Malaysia have struggled with assessing programme outcomes since the Engineering Accreditation Council Malaysia (EAC) introduced OBE in 2005. Despite the fact that the programme has been in place for over a decade, issues with assessing programme outcomes persist. Unsustainable effort and meaningless outcome assessment among academic staff are exacerbated by a lack of a specific programme outcome model, improper use of assessment tools, and the collection of massive amounts of unnecessary data. The challenges of assessing programme outcomes experienced by HLIs and academic staff are elaborated on in this article. The concept of sustainable development is introduced, which is believed to be capable of alleviating the problems associated with programme outcome assessment. The background of the adoption of OBE in Malaysia, as well as the assessment requirements of the Washington Accord, are presented in order to emphasise sustainable assessment as the inevitable future of engineering curriculum. The sustainable assessment in engineering curriculum advocated in this article aims to produce sustainable engineering graduates while also reducing the burden of programme outcomes assessment on academic staff.

Keywords: Programme outcome; Engineering accreditation; Outcomes-based education; Sustainable assessment.

1. The Washington Accord and Outcomes-Based Education (OBE)

The Washington Accord is an agreement between the accreditation bodies responsible for accreditation or recognition of undergraduate engineering degree programmes in its signatory countries. The accord is a multi-lateral agreement between bodies responsible for accreditation or recognition of tertiary-level engineering qualifications within their jurisdictions that have decided to work collectively to assist the mobility of professional engineers (IEA, 2022). The Accord has grown from its six founding signatories in 1989 to a well-sought-after organisation with 21 signatories as of 2022 with Costa Rica being the most recent addition (IEA, 2022). After serving as a provisional member since 2003, the Board of Engineers Malaysia (BEM) was admitted as a full signatory of the Washington Accord for Malaysia in June 2009. It was the 13th signatory of the accord. The agreement recognises the substantial equivalency of programmes accredited by those bodies and recommends that graduates of accredited programmes in any of the signatory countries be recognised as having met the academic requirements for entry into the practise of engineering by the other signatory countries (Liew et al., 2014; IEA, 2011). Malaysia's entry into the Accord was a significant milestone in the country's engineering education whereby its graduates are recognised and met the academic standards for engineering practice in other signatory countries. The engineering degree programmes in Malaysia are accredited by the EAC, a body delegated by BEM.

Although every signatory countries may have a distinct set of assessment criteria in their accreditation programme standards, one of the goals of the Washington Accord is to place a greater emphasis on the programme outcomes assessment (IEA, 2011). The list of programme outcomes was agreed upon by all signatory countries for the purpose of benchmarking engineering education standards and serves as an example of the outcomes expected of graduates from a Washington Accord signatory country's accredited programme (IEA, 2021). In 2012, the EAC adopted the same set of programme outcomes for the accreditation of engineering programmes in Malaysia. According to EAC (2020), engineering programmes must establish a process of measuring, assessing, and evaluating the degree to which students achieve programme outcomes, and the results of this assessment process must be used for continuous improvement. The EAC does not prescribe the details on the assessment process. HLIs must instead demonstrate that they have a robust assessment process in place that allows for continual improvement.

The Accreditation Board for Engineering and Technology, Inc. (ABET) of the United States which was founded in 1932 and has accredited over 2,999 programmes as of October 2021 (ABET, 2020) is highly benchmarked by the Washington Accord signatory countries. It defined assessment with regards to student outcomes as follows:

> "Assessment is one or more processes that identify, collect, and prepare data to evaluate the attainment of student outcomes. Effective assessment uses relevant direct, indirect, quantitative and qualitative measures as appropriate to the outcome being measured. Appropriate sampling methods may be used as part of an assessment process."
>
> (ABET, 2018)

This definition of assessment by ABET (2018) highlights that the effectiveness of the assessment is determined by the appropriate use of relevant direct, indirect, quantitative, and qualitative measures.

The International Engineering Alliance (IEA) introduced outcome-based accreditation criteria in 2005 through a set of individually assessable outcomes to assist signatories and provisional members establish their accreditation systems (IEA, 2013). The graduation attributes are exemplars of the characteristics required of a graduate from a signatory country's accredited programme, and are equivalent to the twelve programme outcomes outlined in the 2020 EAC programme accreditation standard. According to Spady (1994), Outcomes-Based Education (OBE) is as "an educational system that focuses and organises what is essential for all students to be able to do well at the end of their learning experiences. This means starting with a clear picture of what students should be able to do, then organising curriculum, instruction, and assessment to ensure that this learning happens." Butler (2004) went on to explain that one of the most important aspects of OBE is the learners' commitment to lifelong learning and professional growth. In this context, OBE aims to produce sustainable graduates capable of functioning in a complex society and solving future problems (Liew et al., 2020).

OBE can be seen of as an educational theory or philosophy based on a certain set of beliefs and assumptions about learning, teaching, and the systemic structures within which activities take place (Killen, 2000). Many of these OBE approaches have been documented in the EAC accreditation programme standards, for example, under the criteria of contents and teaching approach, where the mandatory accreditation requirement of an integrated design project in the engineering curriculum encourages students to work in a team to apply classroom knowledge to a real-world situation (EAC, 2020). In essence, OBE requires change within the educational system to facilitate learning for learners to reach the desired outcomes. The focus of education has shifted from the educator to learner with the role of an educator being to enable and support all learners to achieve the desired outcomes. In the meantime, the learners are expected to actively participate and contribute to the learning process, as well as to be devoted to professional development and lifelong learning (Liew, 2019).

2. The Engineering Accreditation Council Malaysia's Programme Outcomes

The programme outcomes, also known as graduate attributes stipulated in the IEA graduate attributes and professional competencies serve as a benchmark of standards for engineering education to HLIs in Malaysia as well as other signatory countries of the Washington Accord (IEA, 2013; EAC, 2020). These programme outcomes are intended to prepare engineering graduates for future technological and societal developments, and help them acquire new knowledge that may be applied to 21st-century problems (IEA, 2013). Understanding these programme outcomes is generally a common challenge among the academic staff, and a lack of understanding has frequently resulted in poor constructive alignment and unsustainable assessment (Liew, 2019). The EAC's programme outcomes are widely available and can be referred from its accreditation programme standard (EAC, 2020). According to Hanrahan (2012), the programme outcomes can be classified into four groups, namely knowledge-oriented, problem-solving skill, skill-oriented, and attitude-oriented. The relationship between competency, programme outcome, and knowledge, skills, and attitude is illustrated in Figure 1.

The Washington Accord's first five programme outcomes (engineering knowledge, problem analysis, design or development of solutions, investigation, and modern tool usage) are seen as the enablers and joint enablers of engineering applications (Liew et al., 2020). Engineering applications are examples of problem-solving that are embodied in the above-mentioned outcomes (Hanrahan, 2012). According to Hu Hanrahan (2009), the programme outcomes on problem analysis and design or development of solutions are related to the analysis of engineering problems and the synthesis and design of solutions, whereas the programme outcome on investigation is related to the investigation of problems and is thus a type of problem-solving as well. He further added that the use of engineering knowledge and the store of methods or tools are both joint enablers of engineering applications. Therefore, the programme outcomes in this category can be categorised as the ability to

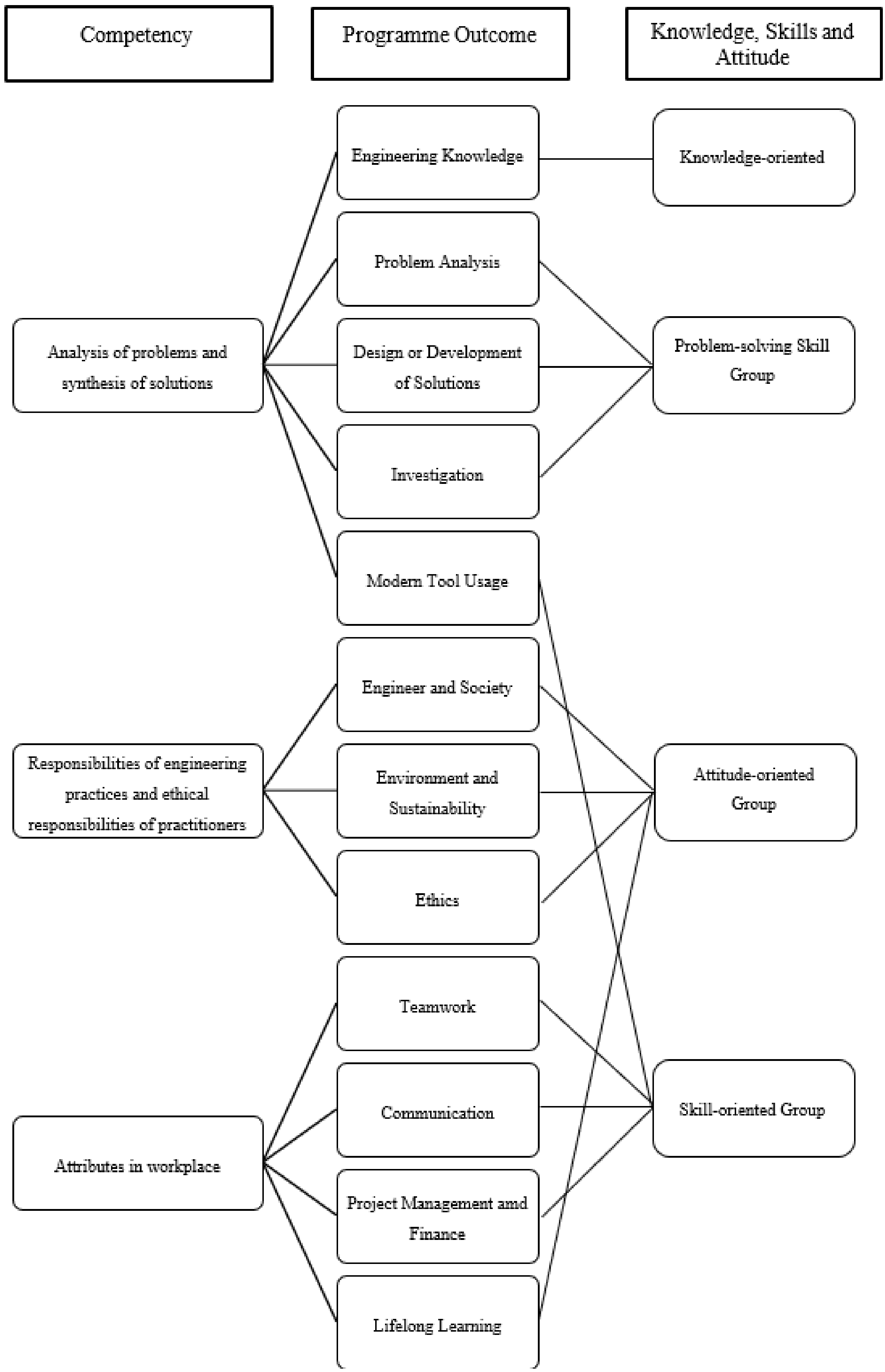

Figure 1. The relationship between competency, programme outcome, and knowledge, skills and attitude (Hanrahan, 2009; Hanrahan 2012; Liew, 2019)

analyse problems and synthesis solutions using engineering knowledge supported by engineering tools and methods.

Graduate engineers have a larger range of responsibilities beyond their technical roles (Hanrahan, 2009). These responsibilities are spelt out in the programme outcomes on engineers and society, environment and sustainability, and ethics. Engineer and Society is concerned with the need of graduate engineers to understand the issues arising from engineering activities, such as social and cultural, health and safety, economic, legal, regulatory, environmental, and sustainability, whereas Environment and Sustainability is concerned with the need for graduate engineers to predict and detect the impact of engineering activity on the environment, as well as to incorporate sustainability considerations into their work. Meanwhile, Ethics is concerned with the need for graduate engineers to understand and to act ethically. In summary, the programme outcomes in this category can be summarised as engineering practise responsibilities in terms of social, economic, cultural, health, safety, regulatory, environmental, and sustainability challenges, as well as engineering practitioners' ethical responsibilities (Hanrahan, 2012). In summary, this category encompasses engineering practise responsibilities in terms of social, economic, cultural, health, safety, regulatory, environmental, and sustainability challenges, as well as engineering practitioners' ethical responsibilities (Hanrahan, 2012).

The final four programme outcomes: teamwork, communication, project management and finance, and life-long learning are individual attributes that are essential in the engineering workplace. Engineering graduates may progress to the management of projects, control of finances and dealing with risk, and supervision of people. They must adapt to the constant change of knowledge, technology, applications, and environment. Graduate engineers must be able to communicate effectively, collaborate with people in other disciplines, continue learning, and deal with the impacts of engineering activity (Hanrahan, 2009).

3. Characteristics of an Effective Programme Assessment Model

Programme outcomes assessment model is the approach taken to determine the attainments of programme outcomes by students. It was recognised that an effective programme outcomes assessment model should use a good combination of direct and indirect assessment tools to assess, analyse and evaluate students' outcomes; the appropriate use of direct, indirect, quantitative, and qualitative measures to the outcome being measured; the model should also practise systematic data collection and able to provide evidence to demonstrate attainment of outcomes with a well-documented process; and finally, it should demonstrate that a continual improvement process is in place (Gurocak, 2009; ABET, 2018).

In the Malaysian context, the EAC programme accreditation standards (EAC, 2020) states that engineering programmes seeking accreditation must design their curriculum around the programme outcomes specified in the programme standards. The programme standards outlined three requirements: the curriculum, teaching-learning activities, and assessment tools must all support the achievement of programme outcomes; programme outcomes must also be assessed and used for continuous quality improvement (CQI); and engineering programmes must demonstrate a high level of stakeholder involvement in the process (Liew, 2021a). Given that, Liew (2021a, 2021b) suggested that the characteristics of an effective programme assessment model shall:

a) Utilise a good combination of direct and indirect assessment tools to assess, analyse and evaluate students' attainment of outcomes;
b) Provide evidence that demonstrates students' attainment of outcomes with a well-documented process;
c) Demonstrate that a continual improvement process is in place;
d) Support the attainment of outcomes with well-aligned curriculum teaching-learning activities and assessment tools;
e) Show a high degree of stakeholders' involvement.

4. Assessment Tools for Programme Outcomes Assessment

In the assessment of programme outcomes, HLIs in Malaysia adopt both direct and indirect assessment tools as illustrated in Figure 2. The appropriateness of these tools for outcome assessment will be discussed in this section.

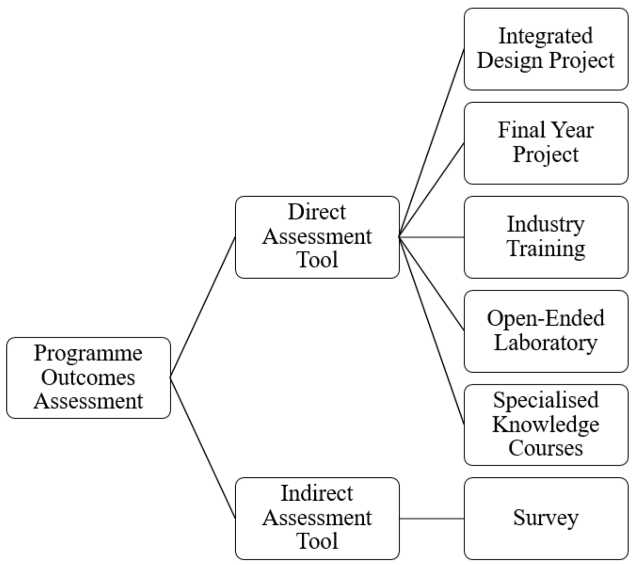

Figure 2. Assessment tools for programme outcomes assessment (Liew, 2019)

Integrated design projects use the principles, concepts, and techniques learned in earlier engineering courses to solve complex engineering problems and design systems, components, or processes. In addition to addressing the project's stated requirements, the impact of the solutions to public health and safety, as well as cultural, societal, economic, and environmental must be considered (EAC, 2020; ABET, 2018). An integrated design course is one of the indicators of outcomes and an ideal milestone for assessing the qualities of the undergraduate engineering experience (Davis et al., 2002; Shaeiwitz, 2002; Daniel et al., 2006; Gnanapragasam, 2007; Liew et al., 2020; EAC, 2020). The design course can assess numerous aspects by measuring technical and communication competencies. In addition, students' ability to solve design problems with realistic constraints can be assessed (EAC, 2020). Typical performance assessment tools include project progress by the course instructor or facilitator, peer review of team member participation, project reports by course instructor or facilitator, and presentation assessment by the public (Scales et al., 1998; Yousafzai et al., 2015; Zytner et al., 2015).

Furthermore, according to IEA (2014), integrated design projects can be used to address some of the characteristics of complex engineering activities. During their undergraduate studies, students are expected to experience some of these characteristics that will help them transition to professional life. These characteristics are common in the industry, incorporating them into the undergraduate engineering curriculum will facilitate students' transition from student communities of practise to professional communities of practise (Lave, 1988; Dym et al., 2005; Johri & Olds, 2011; Hotaling et al., 2012). Johri and Olds (2011) further elaborated that industry-based integrated design projects allow students to apply their skills and knowledge toward developing a robust understanding of what it means to be an engineer.

Final year project, on the other hand, is defined by Jawitz et al. (2002) and Fraile et al. (2010) as an activity carried out by students at the end of an engineering programme. It is regarded as an individual task that a student must do under the supervision of one or more tutors; and it must be sufficiently complex to necessitate the integration of student's knowledge and training acquired throughout his or her studies (Jawitz et al., 2002). It is one of the most effective ways of introducing an investigative research-oriented approach to engineering studies and sourcing of knowledge externally from the real-world (IPENZ, 2017; EAC, 2020). According to Liew et al. (2020), final year project involves the review of open research literature which challenges students to interpret new information, perform critical analysis, generate own ideas and judgments, and learn independently.

EAC (2020) defined industrial training as a key component of learning in an integrated engineering academic curriculum. Industrial training equips students with knowledge base and skills necessary to integrate isolated and abstract concepts into practical applications (Noyes et al., 2011). Furthermore, it allows students to participate in ongoing job experiences, learn from them, and reflect on them (Raelin et al., 2014). It helps students' transition into full-time employment and assists them in overcoming the challenges associated with first-job experiences. However, in Malaysia, the primary goal of industrial training is to gain an understanding of engineering practise rather than to acquire craft skills (Liew et al., 2020). Similar to the integrated design project, industry training can address some of the attributes of complex engineering activities (IEA, 2014). Students are expected to develop some of these attributes during their undergraduate studies that will them transition to professional life.

In addition, an open-ended laboratory is another direct assessment tool in assessing programme outcomes. Open-ended assessment is considered as a strength of curriculum in engineering education, owing to its ability to challenge students at the required depth involving high-level critical thinking (EAC, 2015). This approach is appropriate for engineering education because it produces self-directed, reflective engineering graduates who can integrate knowledge, think critically, practise life-long learning and collaborative with others (McKinnon, 1999). In the open-ended approach, the problem may have multiple solutions, and there is no obvious solution. The main goal of an open-ended laboratory is to encourage students to design their experiments related to the topics of study. This encourages students to do self-reflection and, as a result, develop their experimental approaches. Students are expected to plan out their approaches to laboratory activities.

Engineering specialist knowledge courses are those that can demonstrate the attainment of programme outcomes (Yamayee & Albright, 2008). According to Hordern (2014), engineering specialist knowledge is built upon engineering fundamentals which are built on natural sciences, with mathematics serving as an essential facilitator for these layers of knowledge. With this definition, natural science courses, mathematics courses, and some engineering fundamental courses are not ideal for demonstrating programme outcomes, although they are important in the formation process of an engineering graduate's knowledge profile. By definition, the demonstration of programme outcomes is typically shown at the end of the programme (ABET, 2018; EAC, 2020), therefore, engineering specialist knowledge courses are well-suited for this purpose.

Surveys are commonly used as indirect assessment techniques to obtain data that cannot be observed (Soundarajan, 2002; Olds et al., 2005). Some possible survey assessment tools at the programme level include graduating exit survey, alumni survey, and employer survey (Felder and Brent, 2003). Graduating exit surveys are mostly used for triangulation with direct assessment, whereas alumni surveys are primarily utilised to evaluate programme objectives. Despite the fact that surveys are the most widely utilised assessment tool, they must be used with caution due to possible flaws in their design (Soundarajan, 2002). Because they are self-report instruments, the accuracy of the information acquired is determined by the extent to which participants choose to respond honestly and the researchers' ability to report accurately (Olds et al., 2005). Hence surveys are subjective, and over-reliance on them may be misleading (Barbero et al., 2004). Liew (2019) suggested that they should be used in tandem to triangulate the data collected from direct assessment tools.

5. The Challenges of Assessing Programme Outcomes

Despite the growing number of signatory countries and widespread of accreditation of engineering programmes, with regard to assessing the programme outcomes in the Washington Accord, most accreditation bodies do not specify any specific model to encourage innovation and creativity in the assessment (ABEEK, 2015; ABET, 2018; CEAB, 2019; ECSA, 2019; EAC, 2020). It is the sole responsibility of the HLIs to develop and establish suitable and appropriate outcome measures for their programmes. However, the extent of guidelines in assessing programme outcomes provided by the accreditation bodies may differ from country to country, for examples, the CEAB provides guidance in the form of performance indicators for each programme outcome (CEAB, 2014) while the Engineering Council South Africa (ECSA) provides description on each programme outcome (ECSA, 2019).

A number of amendments were made to the EAC's accreditation programme standards as Malaysia moved closer to being a full member of the Washington Accord. In 2008 and 2010, the Malaysian Council of Engineering Deans and the EAC held multiple meetings to discuss issues relating to accreditation (EAC, 2010). The engineering deans were concerned that the accreditation programme standards presented unclear requirements for engineering programmes accreditation. They also emphasised the burdensome responsibilities and massive amount of data preparation and collection that accreditation necessitates, according to Liew et al. (2021a). Apart from that, he highlighted that the HLIs' OBE or programme outcomes assessment models were unable to reflect the true outcomes of their students during the engineering programme accreditation exercises in Malaysia. The models have underlying issues such as poor constructive alignment, improper use of assessment tools for different types of outcomes, and failure to use assessment data to improve the programmes.

A comparison with the global scenario was performed in order to identify the gravity of the issue. Literature indicated that the challenges of assessing programme outcomes at the institutional level have been reported as early as the 1990s. Although ABET places a strong emphasis on programme objectives and programme outcomes, many HLIs in the United States misinterpreted the assessment and evaluation requirements due to a lack of understanding of the requirements of accrediting engineering programmes (Prados et al., 2005). As a result, a massive amount and unnecessary data was always collected and presented to the accreditation panel reviewers. In addition, the HLIs often failed to perform a meaningful analysis of the results and presented ambiguous plans on the utilisation of data for CQI on their programmes. The lack of understanding on the requirements of accrediting engineering programmes has caused increased workload to the academic staff (Williams, 2002; Howell et al., 2003; Shuman et al., 2005; Gurocak, 2009) due to the evidence needed in order to fulfil the requirements of accreditation (Rogers, 2000). Briedis (2013) further indicated that the use of inappropriate assessment tools employed by the HLIs, and unsustainable efforts, and resistance from the academic staff are among the challenges faced by the HLIs in preparing for accreditation.

6. Sustainable Assessment

The concept of "sustainable development" was originated in the Brundtland report issued by the World Commission on Environment and Development of the United Nations (Brundtland, 1987). Boud (2000) and Boud and Falchikov (2006) then established the concept of sustainable assessment based on a reframed definition of sustainable development that focus on learning. They defined sustainable assessment as 'assessment that meets the needs of the present and [also] prepares students to meet their own future learning needs' which is commensurate with the programme outcomes defined by the IEA and EAC that require engineering graduates to solve complex problems and function in a complex society (IEA, 2013; EAC, 2015). In another word, this concept emphasises on the importance of assessment practices to equip students for the challenges of learning and practice that they will face in the workplaces once their current episode of learning at the HLIs is completed (Boud & Soler, 2016).

According to Beck et al. (2011), educational sustainability can be defined as a feature of educational systems that involves not only the physical environment but also the sustainability of educational practices (Beck et al., 2011). In addition to the sustainable assessment of educational practices stated earlier, the sustainability of academic staff's efforts must be addressed when establishing a framework for assessing programme outcomes. According to Fullan (2007), academic staff and students sustain each other's learning processes in sustainable education. He emphasised that the key to sustainable educational systems is to put academic staff and students at the forefront of driving force. What has been learned continuously stimulates one's own and others' new learning, as well as the desire to continue learning. As a result, institutions transform into learning communities that eagerly exploit the huge potential of social interaction to keep the energy flowing (Van den Branden, 2012). In this approach, learning energy is converted into renewable energy.

Sustainable assessment theory is an emerging approach to assessment that complements the existing summative and formative assessment methods in the context of programme outcomes assessment (Boud 2000; Boud & Falchikov, 2006). The objective is to integrate assessment with teaching and learning so that graduates can evaluate their learning abilities in a variety of non-academic, relatively complex settings after graduation (Beck et al., 2011). As a result, Beck et al. (2011) concluded that long-term assessment is part of the 'constructive alignment' advocated by Biggs between teaching and learning and assessment tasks (Biggs, 2003). The missing link in Biggs' constructive alignment model is that present assessment practices in higher education do not adequately prepare students for a lifetime of learning and the assessment challenges they would face in the future (Boud & Falchikov, 2006). According to Boud (2000) and Boud and Falchikov (2006), sustainable assessment theory encompasses four principles: (1) a focus on long-term learning outcomes that are applicable not only to course activities but also to the workplace; (2) explicit criteria defining student outcomes; (3) co-participation by students and academic staff in making judgements in assessment activities; and (4) the development of devices for self-monitoring and judging progress toward goals.

The complex engineering problems defined by the IEA are identical to the nature of the problems that arose in the industry (Liew et al., 2020). From that standpoint, EAC's programme outcomes embrace the nature of the problems which engineering students must be trained to adapt to the industrial sector's problems and solutions. Hence this is very much commensurate with the first principle of sustainable assessment, "focus on long-term learning outcomes that apply not only to course activities but also to the workplace".

The second principle is very much concerned with the performance criteria in assessing EAC's programme outcomes. The challenge with the absence of performance criteria for assessing programme outcomes in the assessment models will not only lead to unsustainable assessment but also create associated issues on sustainability in terms of the academic staff's efforts. For example, heavy workload and unreasonable expectations in assessment experienced by the academic staff as reported by Brumm et al. (2006), Shay et al., (2008), and Yamayee and Albright (2008). Mohammad and Zaharim (2012) added that the absence of performance criteria has resulted in the use of incorrect assessment tools which in turn led to the failure of HLIs to demonstrate effective CQI for improving students' outcomes. Other reported issues are poor constructive alignment (Felder & Brent, 2003; Hamzah & Liew, 2018), resistance from academic staff (Gurocak, 2009), and lack of a culture of assessment among academic staff (Anagnos et al., 2008; Briedis, 2013). These issues can be summarised under Biggs' (1995) three main factors that hinder the change in assessment among the academic staff and are closely related to the sustainability of academic staff's efforts highlighted by Fullan (2007) and Van den Branden (2012).

According to Boud and Falchikov (2006), the third principle is about preparing the students for lifelong learning with the co-participation between students and academic staff. It involves preparing the students to make judgements about their work and that of others and to make decisions under uncertain and unpredictable circumstances in which they will find themselves in the future workplace.

Finally, the fourth principle is about developing strategies and devices for the students to judge whether progress is being made towards outcomes. According to Boud (2000), this involves the development of a range of strategies and devices deployed in the process of learning from setting intermediate goals and checking progress at regular intervals, keeping learning journals, or to more sophisticated meta-cognitive devices. It is not only necessary to know what are the appropriate standards and criteria defined in the first three principles, however, it is also essential to measure and determine the extent to which students' work meets the standards and criteria (Boud, 2000).

To summarise, the concept of sustainable assessment necessitates the alignment of all assessment practices with teaching and learning in order to allow learners to actively participate and contribute to the learning process, as well as to prepare them for the challenges of learning and practice that they will face in the workplace once their current episode of learning at the HLIs is completed (Boud, 2000; Boud & Falchikov, 2006). The concept of sustainable education described by Fullan (2007) and Van den Branden (2012) is also adopted to achieve sustainability in terms of academic staff efforts, reducing the feeling of burden due to assessment. The relationship between sustainable assessment and the major elements of engineering curriculum is illustrated in Figure 3.

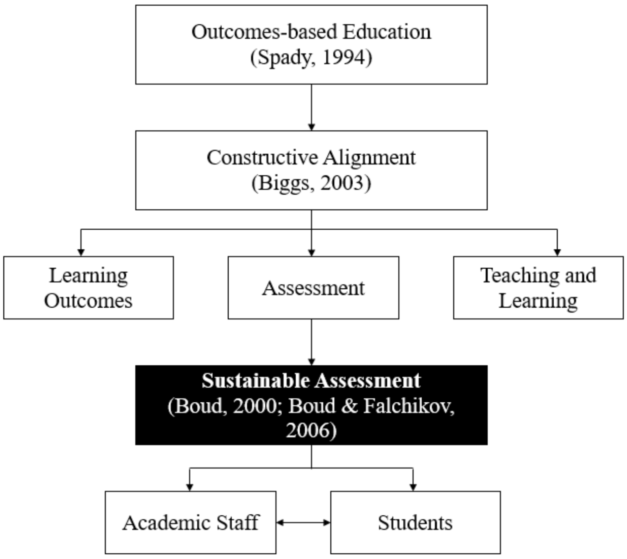

Figure 3. Sustainable assessment to complement the constructive alignment advocated by Biggs (2003) in engineering curriculum

The first two principles of sustainable assessment are concerned with the establishment of assessment standards and criteria at the faculty and institutional levels, which should be capable of alleviating academic staff's problems with programme outcome assessment. The following two principles address student-academic staff collaboration and students' self-monitoring of their own progress toward stated goals, both of which are not widely practiced in Malaysia or other Washington Accord signatories. This is regarded as a practice gap (Figure 4) that HLIs must address in order to ensure that engineering programmes produce sustainable engineering graduates who are prepared for future technological and societal changes, and that the assessment model and practices used are sustainable in terms of effort, thereby reducing the burden of programme outcome assessment on academic staff.

7. Conclusion

Most HLIs conduct programme outcomes assessments to gain accreditation for their programmes, not to improve the quality of their graduates. Most HLIs' programme outcomes assessment is currently done on an ad hoc basis, which is done whenever accreditation is required. As a result, the challenge is to move from a system designed for accreditation to one that produces sustainable engineering graduates. Courses should be constructively aligned to the assessment, teaching and learning, and course outcomes, and the intended programme outcomes. An effective assessment model should encourage the use of performance criteria for programme outcomes, which will result in sustainable effort from academic staff. The first two principles of sustainable assessment could address issues with programme outcome assessment, whereas the following two principles, which are not widely practiced, address student-academic staff collaboration and students' self-monitoring of their own progress toward stated goals. This is an area worth investigating in the future because the success of an engineering curriculum necessitates a sustainable programme outcomes assessment that not only aims to produce sustainable engineering graduates who are prepared for future technological and societal changes and who can acquire new knowledge and apply it to new problems, but also to be sustainable in terms of effort, reducing the burden of programme outcomes assessment on academic staff.

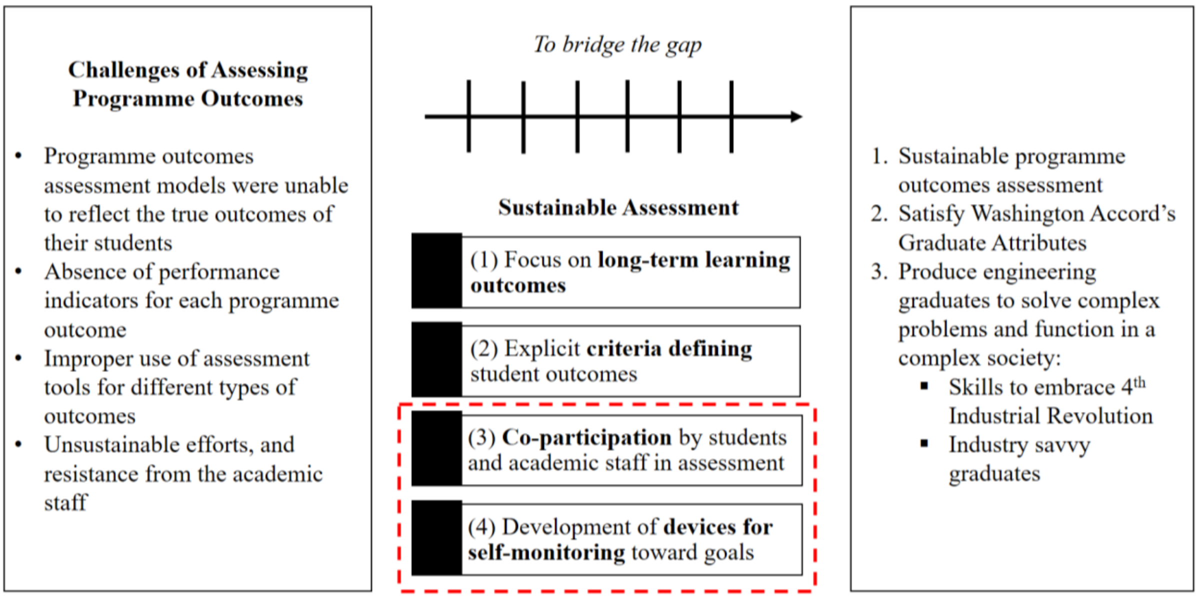

Figure 4. Illustration of incorporating the concept of sustainable assessment to address the current challenges of assessing programme outcomes (principles that are not commonly practiced are indicated in red box)

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Evaluation on Academic Performance of Students in Teaching and Learning in Engineering Course

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Abstract
Teaching and learning session all over the world—refraining teachers and students from primary, secondary and tertiary education levels from attending physical classes in the traditional way has disrupted due to pandemic. The uncertainty situation in teaching and learning have brought concern in academic performance of the students to educators, students, institutional higher education as well as parents. However with emergency circumstance with proper planning and action in delivering their subject matter, impacts evaluation on academic performance to educators and students can be assessed. This study evaluates the course and program outcomes on academic performance of students for specific course at a department of university A in engineering course using open and distance learning approach. Case study method was used to evaluate the students' academic performance by having quantitative data which were analyzed using descriptive statistics. The findings show the students are able to perform well in the course assessments despite the pandemic. The future trend in T&L will be flexible learning and open distance learning as well student-centered learning.

Keywords: Course outcomes, programme outcomes, academic performance, open and distance learning

1. Introduction

Outcome based education (OBE) may include a range of knowledge (cognitive domain), skills (psychomotor domain) and emotional (affective domain) aspects. In Malaysia, OBE is under the responsibility of Malaysia Quality Agency (MQA) (established in 2007) to ensure the quality of all levels of education starting from primary, secondary and tertiary levels in public and private sectors. The implementation of OBE was firstly introduced for engineering education and essential requirement by the year to become a fully signatory member of a multinational agreement for the mutual recognition of engineering degrees, i.e. The Washington Accord (WA) (Noor Al-Huda Abdul Karim and Khoo Yin Yin, 2013). The Board of Engineers Malaysia (BEM) is responsible to ensure that the quality of engineering programme obtained by its registered engineers fulfil the minimum standard comparable to global practice (Engineering Programme Accreditation Manual, 2017) according to the WA. Engineering Accreditation Council (EAC) is the body delegated by BEM for accreditation of engineering degree programmes where all bachelor in engineering degrees are required to implement OBE in line with industrial globalization (Wan Abdullah Zawawi et al., 2013) needs and demands. There are three learning domains in the OBE system namely cognitive, psychomotor and affective domains as required by the MQA with eight learning outcomes: knowledge; practical skills; social skills and responsibilities; values, attitudes and professionalism; communication, leadership and team skills; problem solving and scientific skills; information management and lifelong learning skills; and managerial and entrepreneurial skills (Noor Al-Huda Abdul Karim and Khoo Yin Yin, 2013). Meanwhile, the EAC outlined twelve programme outcomes (PO) to describe what students are expected to know, be able to perform or attain through the programme by the time they graduate (Engineering Programme Accreditation Manual, 2017). The PO are engineering knowledge (PO1), problem analysis (PO2), design/development of solution (PO3), investigation (PO4), modern tool usage (PO5), the engineer and society (PO6), environment and sustainability (PO7), ethics (PO8), individual and team work (PO9), communication (PO10), project management and finance (PO11) and lifelong learning (PO12). According to Liew et al.(2021), based on the Engineering Programme Accreditation Manual, (2017), there are three requirements for outcomes-based assessment; 1) curriculum-T&L activities-assessment, 2) POs attainment are evaluated for continuous quality improvement (CQI) at the course and programmes level, and 3) high degree of stakeholders' involvement.

In order to ensure the quality of education through OBE system, constructive alignment is an important design in T&L. Constructive alignment is what we want, how we teach and how we assess academic performance of students as well as the course offered. Malmqvist (2011) and Borrego & Cutler (2010) studied the importance of constructive alignment to ensure the quality of programme offered by Institutional Higher Learning (IHL) which its intended learning outcomes as well as teaching and assessment activities can be identified, aligned and improved in future. Iqbal et al., (2020) illustrated a smart learning management system framework which imposed the importance of students feedback/response and strategies for continuous quality improvement by utilizing smart educational tools and learning management systems in T&L. They also highlighted additional prerequisite goals for students, namely; 1) organizational attributes, 2) technological tools, 3) conceptual framework, 4) interconnected and communication and 5) ethical attributes.

The OBE implementation could not be taken for granted in any way of T&L especially during the pandemic situation such as Covid-19 (C-19). The open and distance learning (ODL) has changed the T&L landscape during the C-19. The ODL is as a flexible learning pathway where the contents must be made available in such a way that students can access it anytime and anywhere. Müller et al. (2018), Kormaz et al. (2021), and Yaseen et al. (2021) stated with flexible learning trough ODL, students gain access and flexibility with regard to at least one of the following dimensions: time, place, pace, learning style, content, assessment or learning path which can be assessed online and offline (recorded lectures).

The objective of this study is to evaluate students' academic performance in engineering course. The study will compare academic performance between male and female students according to course and programme outcomes.

Course Programme Outcomes

Outcome based education was first implemented in year 2007 at school of department in university A and the program educational objectives, program outcomes, curriculum and syllabus with outcome based education approach were reviewed periodically and accredited by Engineering Accreditation Council to ensure the quality of the program delivered and graduates sufficiently fulfil the standard requirement of Board of Engineers Malaysia to be in line with the vision and mission of university A. The school has developed and implemented a Geotechnics course for its students in Year Two Semester 4. The three-unit credit civil engineering course introduces the course outcomes (CO) as the roles of geotechnical engineer in analysing various geotechnical engineering parameters and design methods (CO1) and conceptualizing and resolving problems related to geotechnical engineering (CO2). Table 1 lists programme outcomes (PO) of Geotechnics course which are Problem Analysis (PO2) and Design/Development of Solutions (PO3).

Table 1. Geotechnics programme outcomes

Programme Outcome (PO)	**Description**
PO2: Problem Analysis	Ability to identify, formulate, research literature and analyse complex civil engineering problems in reaching substantiated conclusions using principles of mathematics, sciences and engineering knowledge
PO3: Design/ Development of Solutions	Ability to design systems, components or processes for solving complex civil engineering problems that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations

The school has decided in the OBE system, cognitive domain and level of difficulty for Year Two students are designed with 20-30% for Knowledge (C1) and Comprehension (C2), 60-80% for Application (C3) and Analysis (C4) and remaining cognitive domain (Evaluation (C5) and Create (C6)) are 0-10%. In the Geotechnics course, the school decided that during the C-19 pandemic, the level of difficulty in the evaluation of assessments for Test, Quiz and Final Examination (Assignment 1 & 2) were 27% (C1-C2), 69% (C3-C4) and 4% (C5-C6).

Several online platforms used by the educators and students for offline/online T&L include Microsoft 365, Telegram and WhatsApp. Mohmmed et al. (2020) stated those online tools and platforms for offline/online T&L experienced by educators and students in Oman was very excellent and efficient but has small technical issues such as poor internet connection in the remote area. Similar difficulties found by a study (Md Nujid and Tholibon, 2021) for remote area is having a good internet connection. In order to avoid any issue in accessing the course, the course was delivered via two hours online lecture (synchronous) and one-hour offline lecture (asynchronous) in which recorded lecture video was uploaded to YouTube to allow flexible time accessed by registered students. The course assessments were conducted asynchronous (offline) within specified period in allowing students to answer the questions at their convenience time. The learning activities were given mostly in asynchronous mode for students' to perform self-learning, conduct revision session, overview the topic content and do exercise on the topic given. Via this method, student-centered learning was employed through T&L using lecture and problem-based learning which were evaluated from test, quiz and assignments.

2. Methodology

A total number of fifty students/respondents who registered for Geotechnics course in Semester 4 of session March 2020 to July 2020 was selected for the study. This study adopted focus group method which divides the respondents into small groups. An online demographic survey was distributed to the respondents via WhatsApp group. The study intended to evaluate academic performance of students' during C-19 pandemic. The Geotechnics course was introduced for the Bachelor of Engineering (Hons.) Civil (Infrastructure) program at the school of department in university A to help engineering students learn about geotechnical engineering and its applications. The course was first offered to the engineering majors' under-graduate course in 2007 and has been taught every semester since then.

The course is offered as a major for engineering junior students in Semester 4 Year 2 of degree programme, with an average class size of 30 students. The course was outlined based on PO set by EAC, BEM with CO set by the school. The three-unit credit course deals with the roles of geotechnical engineers in analysing geotechnical engineering parameters based on various fields and laboratory tests. The course consists of four learning topics namely Geotechnical Investigation (GI); Foundation and Settlement (FS); Slope Stability (SS) and Earth Retaining Structure (ERS) and teaching is conducted via three hours per week lecture and problem-based learning methods.

The course evaluations comprised of summative and formative assessments where continuous assessment namely test, and quiz contribute to 30% and 10% respectively of the course grade. Meanwhile, final examination which contributes to 60% of the course grade focuses on the design and analysis of geotechnical problems in the context of developed/developing world. Table 2 shows marks distribution based on assessment types, course outcomes and program outcomes.

However, during the pandemic, the final examination was changed to final assignments and maximum of four assessments were allowed to be evaluated to decrease students' burden in facing the pandemic. The same goes to continuous assessment where only selected topics was asked in each assessment. For example, questions from topic's one (GI) and two (FS) were included in the test which contributed to 30% marks, while topics three (SS) and four (ERS) were asked in quiz for 10% marks. For final assessment which contributed to 60% of course grade, two set of assignments were provided where topic's one (GI) and three (SS) were included in Assignment 1 (24%) and topics two (FS) and four (ERS) were assessed in Assignment 2 (36%). All assessments were conducted through online platforms such as Microsoft Teams (MT) and university A learning management system known.

Table 2. Assessment types measured by topics according to course and programme outcomes

Assessments	Topics	Course Outcomes (CO)	Programme Outcomes (PO)
e-Test	Topic 1 (GI)	12 (CO1)	12 (PO2)
	Topic 2 (FS)	18 (CO2)	18 (PO3)
e-Quiz	Topic 3 (SS)	5 (CO1)	5 (PO2)
	Topic 4 (ERS)	5 (CO2)	5 (PO3)
e-Assignment 1	Topic 1 (GI)	8 (CO1)	8 (PO2)
	Topic 3 (SS)	16 (CO1)	16 (PO2)
e-Assignment 2	Topic 2 (FS)	12 (CO2)	12 (PO3)
	Topic 4 (ERS)	24 (CO2)	24 (PO3)

In the beginning of every semester, the educators described the course in detail in terms of its learning outcomes, module topics, teaching methodologies, references list and evaluation methods. The Geotechnics course was selected for this study because of its unique challenges: (a) it conceptualizes the geotechnical engineering theories and parameters based on field and laboratory data, (b) it applies geotechnical engineering parameters in design and analysis of complex problems, (c) it is composed of students from diverse demographic background, and (d) its structure consists of problem-based earning modules.

A quantitative study was conducted to obtain respondents' demographic information background. Results from test, quiz and assignments provided were evaluated to measure students' achievement for CO1PO2 and CO2PO3. Each two course and programme outcomes CO1PO2 and CO2PO3 were evaluated and addressed using course assessments (test, quiz and final examination) and the course learning outcomes were to: a) acquire various geotechnical engineering parameters and design methods, and b) conceptualize and resolve problems related to geotechnical engineering using direct approach (El Maaddawy et al., 2017).

Meanwhile indirect measures used include student self-assessment survey on course outcomes (Diagnostic Test (DT)) and online student course evaluation survey (for instance Entry Survey (ES) conducted at the beginning of the semester to evaluate their knowledge before taking the course). Exit Survey (ES) and Student's Feedback Online (SUFO) were answered by students' after completing the course to evaluate knowledge gained. However, as shown in Figure 1, data for DT and ES, evaluations of learning outcomes and output data such as Student's Feedback

Online (SUFO) and Exit Survey (ES) were out of scope of the present study and were not analysed.

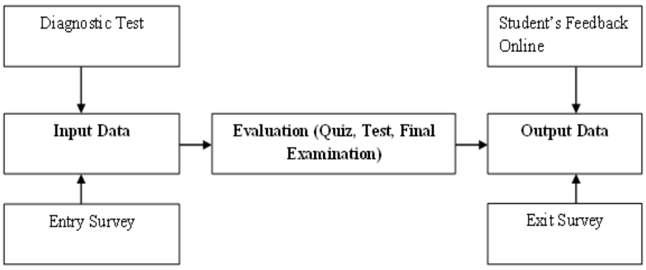


Figure 1. Data collection for study

All the responses were analysed, tabulated, and converted to percentages. Data and variables involved in the study were analysed using open-source software, JASP 0.14.1.0.

3. Results and Discussions

The results and discussions are presented based on the evaluation on students' academic performance based on programme and course outcomes (PO-CO), evaluation course from various assessment types and overall grading score earned by the students for Geotechnic course.

Demographics

A total of 50 (n=50) participants from Semester Four Year Two students registered for the Geotechnic course participated in the study. For the purpose of this study, the participants were divided into five small groups. At the beginning of the semester, each group was allocated a maximum of 30 students.

As shown in Figure 2a, PEC2214J1 group has the largest percentage of total respondents while the smallest percentage is recorded by PEC221J2 group. Majority of the participants are male (66%), and about one third of them are female (34%) as depicts in Figure 2b. In contrast to the current finding, Shahzad et al. (2020) stated that the number of female students enrolled in Malaysian universities is higher compared to their male counterparts. This issue may be because the participants involved in this study consist only half of the total batch of engineering students in the university. Figure 2b shows the percentage of students in each group and percentage of male versus female students for all groups indicating imbalanced gender segregation for each group where male respondents constitute a large portion of the survey. The course group registration was done by students individually to choose their group followed to their own's time table arrangement for the particular semester with considering class from other courses registered in the semester from avoiding clash while attending the online course.

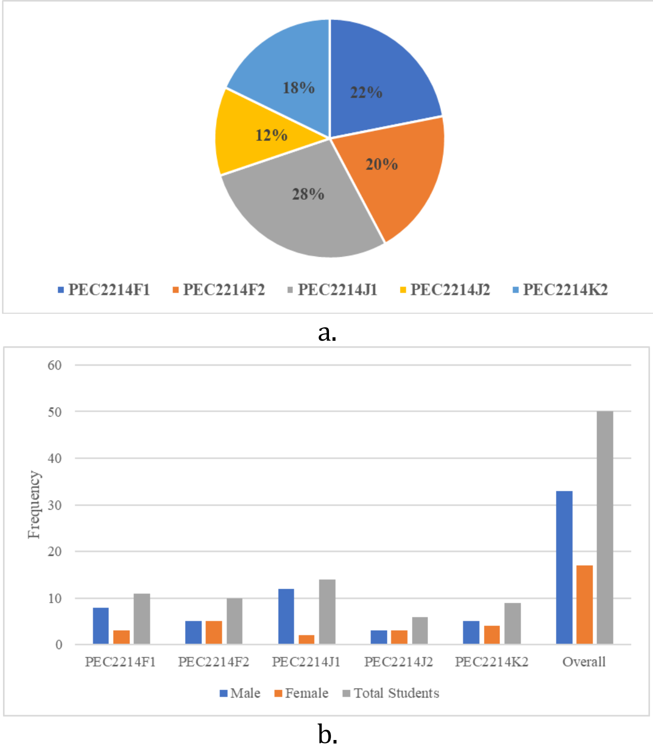
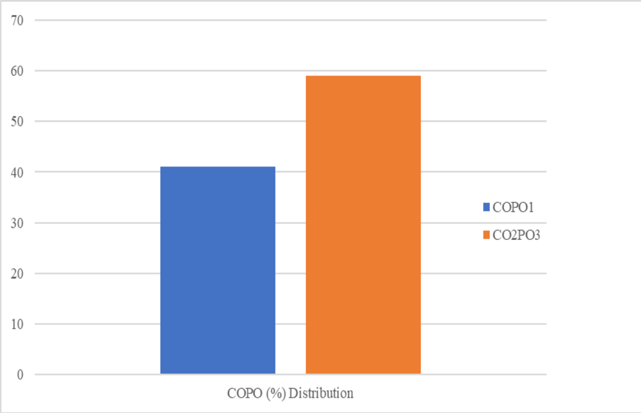


Figure 2. Percentage of students in each group and gender

Evaluation on students' academic performance (assessment marks) by programme and course outcomes

Programme and course outcomes are evaluated based on designated by school members and in this study only PO2 and PO3 for CO1 and CO2 respectively are evaluated. These POs and COs are evaluated from quiz, test and final examination. Figure 3(a) and (b) below show the COPO (%) distribution and average attainments of CO1PO2 and CO2PO3 for undergraduate Geotechnics course for Semester 4 of March 2020 session. The CO1PO2 and CO2PO3 distribution percentage are 41 and 59 respectively.

The average COPOs percentage are 67 (CO1PO2) and 81 (CO2PO3). Evaluation shows that the average percentage of each PO and CO are at below satisfactory level (more than 60%). The study from (Arshad, Razali and Mohamed, 2012) indicated the satisfactory level on program outcomes achievement is above 60%. This result demonstrates achievement of PO2 and PO3 for respective CO1 and C02 with assessment on the ability to design analysis and propose solution to geotechnical problems by adopting engineering parameters. The T&L delivery in the course are suitable in gaining the outcomes. Students' performance on COPO achievement may be enhanced by improving learning engagement and assessment between educators and students (El Maaddawy et al., 2017). It is also important to be transparent on the evaluation methods utilized and quality of the learning environment.



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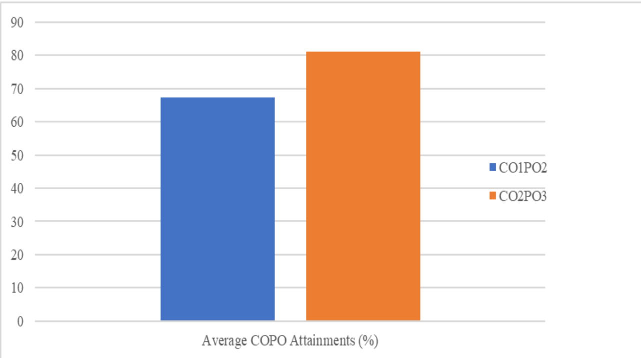


b.

Figure 3(a,b). COPO (%) mark distribution and average COPO attainments (%)

Evaluation on students' academic performance (assessment marks) by course topics

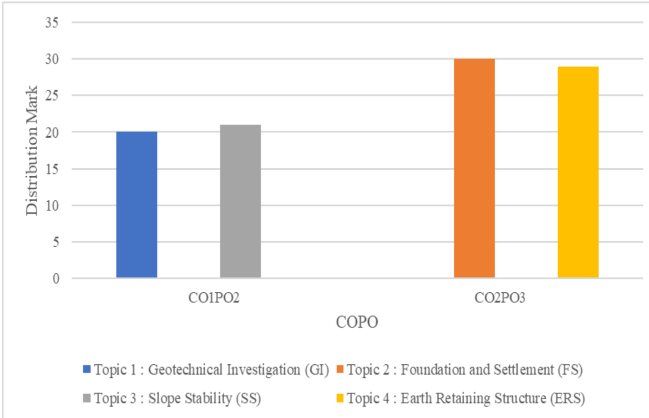
Table 3 and Figure 4 show the distribution marks according to topics, course and programme outcomes. The CO2PO3 outcomes evaluated in topics two and four contributed higher marks because it evaluates students' ability to design, develop, conceptualize and resolve problems related to geotechnical engineering. Students are assessed using CO1PO2 outcomes from topics one and three to be able to understand various geotechnical engineering parameters and design methods. As can be seen from Figure 3, the mark distribution for CO1PO2 is 41 out of 100 total marks for all assessments evaluated in the course.

Table 3. Distribution marks according to topics, course and programme outcomes

COPO	Topics	Marks
CO1PO2	Topic 1 : Geotechnical Investigation (GI)	20
CO2PO3	Topic 2 : Foundation and Settlement (FS)	30
CO1PO2	Topic 3 : Slope Stability (SS)	21
CO2PO3	Topic 4 : Earth Retaining Structure (ERS)	29
Marks		**100**

T&L delivery for Geotechnics assessments are through lecture and problem-based learning were performed on formative assignment and summative assignment (online class). Meanwhile the learning activities were assigned weekly to students in non face to face (offline class).

The purpose of giving the learning activities to students in which they can achieve basic knowledge and comprehension by identifying geotechnical engineering parameters and design methods as well as familiarize design concept and to resolve geotechnical engineering problems. It is a best pedagogies practice to achieve sustainability learning outcomes in Civil and Environmental Engineering students in United State as reported by Bielefeldt (2013).



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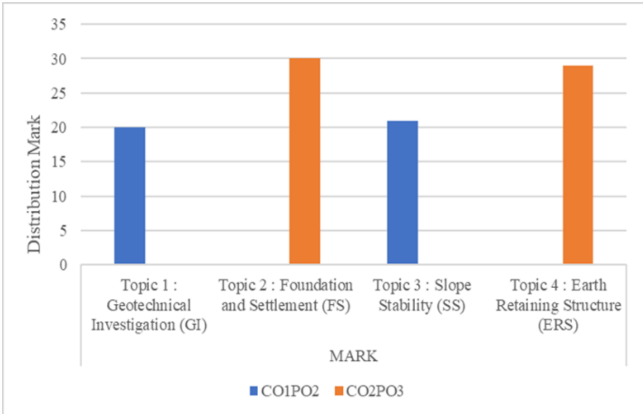


b.

Figure 4(a,b). COPO distribution mark by topics with respective COPO and distribution marks

Meanwhile Figure 5 shows assessment types for course evaluation where CO1PO2 and CO2PO3 obtained the highest percentage from quiz and test which were assessed via final examination (assignments) and test. The course started off with face-to-face physical class in the early semester before ODL commenced in mid-March 2020, after three weeks the semester started. CO1PO2 and CO2PO3 are able to effectively deliver the lecture and problem based learning that were supposedly delivered through physical class. Students' performance for ODL cannot be assumed similar to the previous face-to-face classes due to various factors (Lapitan et al., 2021).

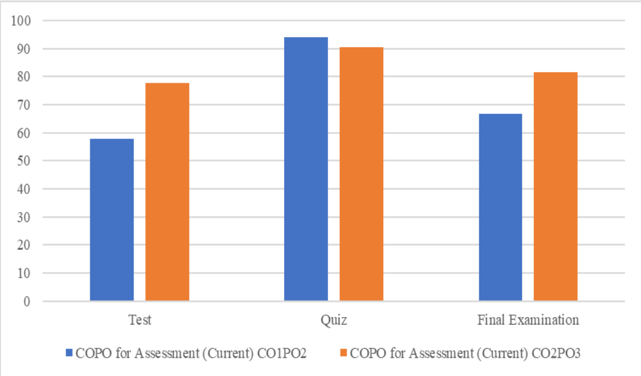
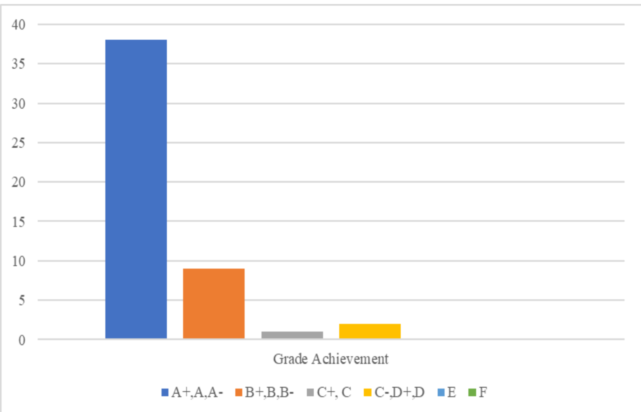


Figure 5. Assessment types for course evaluation

Grading Score

Figure 6a shows that overall, 96% students passed the course and only 4% students failed with grading score D+/D the subject. Meanwhile, Figure 6b provides scoring grade by gender where male students performed better than female students, scoring more A and A- grades than their counterparts. Academic performance of students' taking online class improved although there is no physical class data available to be compared to. There are factors contribute to students' academic performances such as total number of assessments given to students throughout semester, methodology approaches in T&L, methods of examination conduct and student learning time allocation for face to face and non face to face approaches.

Santiago et al., (2021) reported students achieved better results under emergency remote teaching which is insignificantly affected by class size, choice of synchronous and asynchronous delivery and choice of virtual communication tools.



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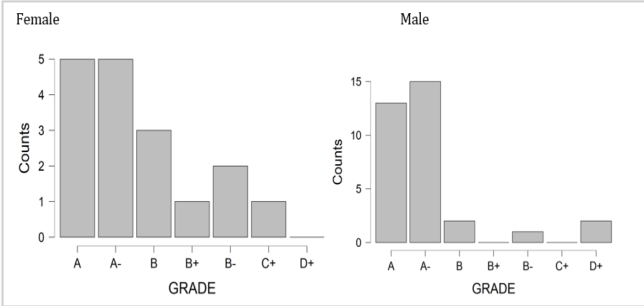

b.

Figure 6. Grade achievement for the course

Conclusion

This study evaluates students' academic performance for Geotechnics course at the school department of university A via ODL as a flexible method for T&L. The findings show the students are able to perform well in the course assessments in which CO1PO2 and CO2PO3 obtained the highest percentage from quiz and test which were assessed via final examination (assignments) and test despite the pandemic. The future trend in T&L is to promote flexible learning and open distance learning as well student-centered learning to educators and students.

Acknowledgement

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Using Phenomenological Approach to Identify Mathematical Competency in Engineering Workplace

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Abstract: Engineers are responsible for solving highly complex problems and, hence, some training to solve such problems, particularly real-life issues, are necessary. The Engineering Accreditation Council (EAC), Board of Engineering of Malaysia (BEM), emphasizes the important of engineering competencies in engineering Program Learning Outcome (PLO), such as the ability to identify, formulate, analyze, and apply mathematical knowledge to engineering problems. However, it was reported that students in university face more challenges in understanding engineering mathematics as they are not taught by instructors who specialize in the respective field. Thus, this study was conducted using a phenomenological approach to identify the mathematical competencies (MC) among practicing engineers at manufacturing workplaces in PDCA (Plan-Do-Check-Action) process workflow. Three respondent engineers were chosen as respondents for this study, but only one respondent reported in this study. Data was gathered through intensive interview sessions at the workplace. Data analysis technique of phenomenological reduction was primarily utilized in this study were Epoche, identify significant statement, Meaning Units, Textural Description of the Experience, Structural Descriptions of the Experience, and Textural-Structural Synthesis phenomenology. The method provides logical, systematic, and coherent design elements that lead to an essential description of the experience. The findings revealed that the MC elements frequently used at each stage of the PDCA process are thinking mathematically, problem handling, and mathematical communication. This study will inform instructors to develop mathematical competencies related to real-life problem-solving during teaching and learning in engineering activities and academic programs at their institutions.

Keywords: mathematics at workplace, mathematics in industry, PDCA, phenomenological method, mathematical competency

Introduction

In embracing industrial Revolution 4.0, engineers solve highly complex problems requiring practical training to solve real-life problems. Meanwhile, the engineering accreditation council board of engineering of Malaysia (EAC-BEM, 2015) emphasizes engineering competencies, such as having the ability to identify, formulate, analyze, and apply mathematical knowledge engineering problems in the undergraduate engineering curriculum.

However, it was reported that university students face more challenges in understanding engineering mathematics as they are not taught by instructors who specialize in the respective fields (ASCE, 2008). Although there are contradictory findings regarding the methods and approaches to how engineering mathematics should be taught, most researchers agreed that the teaching approaches between engineering and mathematics undergraduates must differ (ASCE, 2008).

Hence, engineering mathematics' teaching and learning approach may degrade students' understanding as they cannot relate the mathematical principles with real-life applications (Irish *Academy* of Engineering, 2004). Thus, there is a need to enhance the understanding of mathematics related to engineering tasks in this real environment. Therefore, it is rational to bring the practice's mathematical context from the engineering workplace and embed it constructively and systematically into the mathematics curriculum in engineering programs. Therefore, this study will consolidate mathematical competency for engineering program where practicing engineers' experiences are considered.

Phenomenology Approach

The phenomenology approach has been translated into a qualitative research method and is currently expounded by Moustakas (1994). This phenomenology approach was based on principles that Husserl introduced in 1931. Moustakas (1994) highlighted that in phenomenology, the researcher is more focused on describing participants' experiences than the researcher's interpretations.

This approach is helpful in "describing the common meaning for several individuals of their lived experiences of a concept or phenomenon (Creswell and Poth, 2018).

To capture engineers' experiences, this phenomenology approach has been selected as the appropriate research design for this study. According to Creswell and Poth (2018), phenomenological approach allows the researcher to capture detailed descriptions of the participants' experiences. A detailed description of participants' experiences is very useful for describing the phenomenon that has been experienced by participants' (Cordes, 2014). Husserl's concepts of epoche (or bracketing) have been used in this research to capture a good description of experiences from practicing engineers by "setting aside own experiences as much as possible to take a fresh viewpoint toward the phenomenon under investigation of this study" (Creswell and Poth, 2018).

Mathematical Competency (MC)

21st-century educational attributes for engineering graduates in higher education includes problem-solving ability to think mathematically. It is a valuable and powerful way of thinking about things in the world (W.A et al., 2002 and K.J et al., 2002). Moreover, mathematics is an important tool as it equips students with the ability to use mathematics in a single or multiple disciplines environments (K. Stacey, 2007).

Abstractly, teaching engineering mathematics may not help students understand as they cannot relate the mathematical principles with real-life applications, and students' anxiety about mathematics has been reported. Anxiety creates strong negative emotions and can hinder a person's cognitive, learning, and academic performance (Linde, 2001; Nor et al., 2016; Rahman et al., 2012; Zeynivandnezhad et al., 2016). Thus, there is a need to enhance their understanding of engineering practice at the workplace to narrow the gap between what is being taught in institutions and what engineers really do at the workplace. With this knowledge, instructors of engineering undergraduates can identify what matters to be focused on in teaching and learning activities to prepare engineering assessment program. According to Niss (2003), mathematical competency is the ability to understand, judge, do, and use mathematics in various intra- and extra-mathematical contexts and situations in which mathematics plays or could play a role. Niss listed eight mathematical competencies as below: -

1. Thinking mathematically
2. Reasoning mathematically
3. Posing and solving mathematical problems
4. Modeling mathematically
5. Representing mathematical entities
6. Handling mathematical symbols and formalism
7. Communicating in, with, and about mathematics
8. Making use of aids and tools

Engineers and PDCA

An engineer is a person whose job is to design or build machines, engines, or electrical equipment, or things such as roads, railways, or bridges, using scientific principles (Oxford English Dictionary, 2019). Meanwhile, engineering is defined as an application of science and mathematical application to tackle technical problems economically. Engineers' work depicts a relationship between scientific discoveries and commercial applications, which aim to serve the demand made by society and consumers (U.S. Department of Labor website., 2010).

Engineers' working fields do not range from only designing, developing, testing, and maintaining, but also extensively utilize computers to; i) produce and analyze designs; ii) simulate and test the operation of a machine, structure, or system; iii) generate specifications for parts; iv) monitor products' quality; and v) control the efficiency of processes (U.S. Department of Labor, 2010-11). Meanwhile, Wulf and Fisher (2002) mentioned that engineers are designing under constraint as their creativity is constrained by numerous elements, including nature, cost, safety concerns, environmental impact, ergonomics, reliability, manufacturability, maintainability, and others.

In 1996, the automotive vehicle company TOYOTA introduced the "LEAN Manufacturing" technique. the purpose of "LEAN Manufacturing" is to "determine value accurately according to a particular product, identify the value flow for each product, create an uninterrupted flow of value, let customers draw value from the manufacturer, and pursue perfection. '"In LEAN, there are 25 analysis methods, and One of the methods is Plan-Do-Check-Act (PDCA) cycle. The PDCA cycle is also known as the Deming or Shewhart Cycle (Strotmann, 2017).

In view of that, this study explored the PDCA management cycle in the manufacturing workplace to investigate how mathematics is applied during engineering tasks. The PDCA cycle is repeatedly implemented to improve performance so that the ultimate task goal is gradually achieved continuously, as described in Table 1.

Table 1: The PDCA cycle

Process/ Step	Description
PLAN	Establishing the objectives and processes necessary to produce the expected output
DO	Implementation of the plan
CHECK	Studying and analyzing the actual implementation results and comparing them with the expected ones,
ACTION	Corrective actions (including adjustments) to solve differences between actual and expected results or closing the loop.

Methodology

Figure 1 shows the overall flow chart details for this study's phenomenological methodology and analysis. Figure 1 also shows four steps to complete this study: background study, data collection, data analysis, and result. This study aims to identify the mathematical competency most commonly demonstrated in PDCA engineering tasks from the perspective of practicing engineers using phenomenological approach. A phenomenological approach to qualitative research was the focus of this study. The study focuses on detailed, textural descriptions, structural descriptions, and the study's essence (Creswell, 2013; Moustakas, 1994). Phenomenology helps describe the phenomenon using the participants' experiences, perceptions, and voices. According to Creswell (2013) and Moustakas (1994), the phenomenological reduction data analysis method was used to achieve a textural-structural synthesis and essence of the experience.

Selection engineer at the workplace

Purposive sampling strategy was applied to achieve representativeness and cover all practicing engineers regardless of their gender, level of achievement, and cultural background (Teddlie and Yu, 2007). Teddlie and Yu (2007) explained that this technique is used when the researcher wants to select a purposive sample representing a broader group of cases as closely as possible. The practicing engineers in this research were selected purposively utilizing a homogeneous sampling scheme (Patton, 2002; Teddlie and Yu, 2007; Creswell, 2012). Homogeneous sampling is individuals with similar traits or characteristics (Creswell, 2012, Onwuegbuzie and Collins, 2007). Patton (2002) states that homogeneous sampling aims to describe a subgroup in depth.

The initial stage was searching for a company registered with Federation of Malaysia Manufacturing (FFM) that manufacture certain product(s). An electronic manufacturing company located at Pasir Gudang, Johor, was selected for this investigation. This study has been done in the manufacturing department of the company where problem solving is critically performed by an experienced engineer in that field, who was selected as the sample for this investigation. The nature of work at the engineering department was consistent with the requirements of the intended study, which examine mathematical competencies among engineers at the workplace.

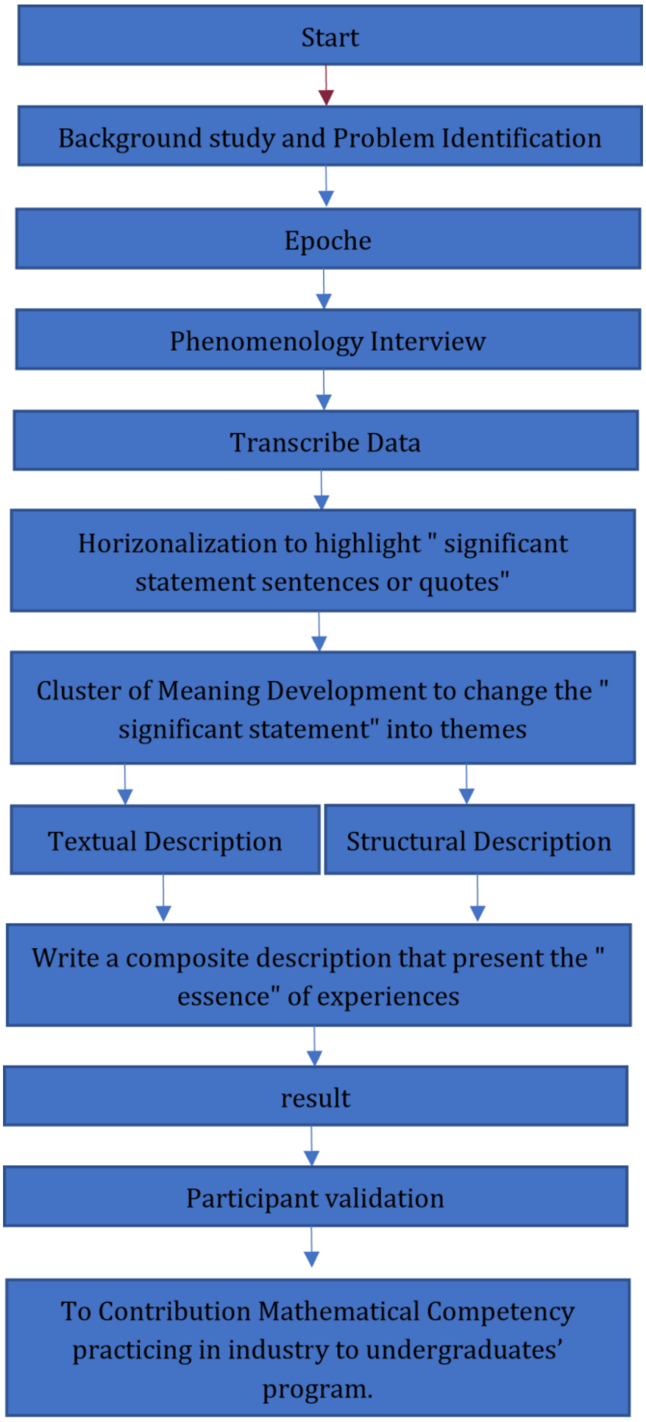

Figure 1. The Flow Chart for Phenomenological Methodology and Analysis

There are four main departments that involves engineers' expertise in the company (Table 2).

Table 2: Type of Engineers

No.	Department	Type of Engineers
1	Factory Engineering	Electrical R&D Engineer, Mechanical Engineers
2	Quality Control	Quality Control Engineers, Supplier Quality Engineer
3	SMT Production	SMT Production Engineer
4	Production Engineering	Production Engineer

The Factory Engineering Department includes Electrical R&D Engineer and Mechanical Engineers. Electrical R&D Engineers are responsible for planning, assembling, troubleshooting, repairing, and modifying prototype devices and fixtures with minimal supervision from engineers. They are also responsible in electronic prototypes assemblies, printed circuit board assemblies, electrical wiring, and cable assemblies. Mechanical engineers are responsible for designing, developing, building, and testing mechanical and thermal sensors and devices.

The Quality Department has two types of engineers. The first is Quality Control Engineer, and the second is Supplier Quality Engineer. Quality Control engineers are responsible for testing new products and determining whether they meet the business's reliability, durability, and functionality standards. A supplier quality engineer ensures all suppliers and the materials they provide comply with engineering and manufacturing specifications and company and government standards.

The production department has one type of engineer, which is the SMT Production Engineer. The SMT Production Engineer is responsible for the hands-on SMT manufacturing lines, including process development, scheduling, quality, and other SMT process logistics. The SMT Production Engineer will also work with the SMT Process Engineer to troubleshoot problems with production and implement corrective actions as required.

The Production Engineering department has Production Engineers. Production Engineers are responsible for supervising and improving production at plants and factories. They support engineering teams, draw up safety protocols, report issues to the manager, and develop strategies to improve efficiency and profit.

Table 3: Background of practicing engineers

Informants	Designation	Department	Experience in Engineering (Years)	Duration of interview (Minutes)
Engineer 1 (E1)	Senior Engineer	Production Engineering	15	82
Engineer 2 (E2)	Engineer	Quality Control	16	82
Engineer 3 (E3)	Senior Engineer	SMT Production	12	155

Table 3 shows the background of three practicing engineers as the samples of this study. The following is background and data for respondent (E1) to show how the data is analyzed. The first respondent (E1) is an SMT Process Engineer from the Surface Mount Technology (SMT) Production Department. SMT is affixed to the surface-mount components, soldered into the printed circuit board (PCB) provides the location on the circuit assembly technology's surface, used in the circuit board with responsibility unprincipled drilling. In particular, it is the first in the circuit PCB solder paste coating on the disk, and then surface mount components accurately coated with solder paste on the pad and the printed circuit board by heating until the solder paste melted.

Engineer E1 has been working as a company engineer for 15 years. The responsibility of the SMT Process Engineer is to manage and perform the necessary operations while running smoothly and orderly. The respondent also analyzes each problem, new process, equipment, and technology for suitability, application, and implementation. As an experienced engineer, he also needs to improve efficiency, maintenance, and performance in the SMT department by providing training and guidance to SMT partners and developing technologies in electronics and sub-installations.

Besides, the respondent has been applying LEAN for the analytical method to improve as imposed by the company using selected materials (solder paste, PCB/ stencil cleaning solution), and process optimization skills (time, quality, cost) based on specific data and formulas. Data programs were produced by the SMT engineers. The program is to move or direct SMT equipment (Paste Printer, select and Place, SPI, AOI), thermal profile, and calibration equipment. For all the performance-enhancing efforts to go smoothly, the respondent needs technical specifications from the R&D SMT Department and the Production Line for evaluation of electronic design, optional components, stencil order. Also, respondents need to manage engineering changes for significant electronic boards, such as spare parts/consumables for the equipment used.

Finally, the main task as an of SMT engineer is to prepare professional practical and systematic report, for record and further actions.

Methods of Data Collection

The researcher needs to identify the required types or methods for data collection to address all the research questions. The researcher has decided to use interviews to collect data in this study. This was due to the focus of the Phenomenology research study, typically on a single person, gathering data through the individual reporting experiences and discussing the meaning of those experiences. The following sections explain how these data collection methods were employed in this study are discussed.

Phenomenology Interview

This study used interviews for data generation, which involved the researchers directly accessing the data source. The selection of informants is intentional and focused on narrowing the theoretical sampling to allow the researcher to examine only informants that can contribute to the generation (Creswell, 2013).

The first round consisted of a phenomenology interview. The researcher's interventions were to be kept to a minimum not to affect the respondent's memories and speaking style (Lee, 2006).

In the second round, a semi-structured interview explored the practicing engineer's experiences in further detail. According to Cousin (2009), a semi-structured interview allows researchers to develop in-depth accounts of experiences and perceptions with individuals. A semi-structured interview facilitates the researcher to inquire more about manufacturing-related engineering tasks.

Before beginning the interview sessions, the researcher made an effort to get to know each of the participants by conversing with them during their free time, emailing them to see if they had any additional questions or concerns, and calling them to arrange an appointment before scheduling the interview sessions to ensure that the interview sessions did not interfere with their busy schedules. This strategy worked well because it enabled the researcher to develop a friendly, accessible, and flexible relationship with the study participants (Creswell and Guetterman, 2019).

Each of the two series of interviews had its own set of interview protocols. Each interview lasted around 60 and 120 minutes and included several questions. The lengths of the interviews differed greatly depending on the topics discussed. The researcher would move on to another subject if the participant had nothing to say. When gaps in the participants' data are discovered, the researcher will later contact them by email or phone to gain additional information to fill the gap. The time spent filling in the gaps was not included in the initial interview times. By filling in the gaps, the researcher could get a more in-depth look at the phenomenon (Moustakas, 1994).

Phenomenology was chosen as the appropriate methodology for this study as a researcher searched for an understanding of the meaning of these participants' experiences. Additionally, Moustakas's systemic procedures and detailed data analysis steps are suitable to assist less experienced researchers. the phenomenology approach using systemic procedures is consistent with our philosophical view of balancing both the objective and subjective approaches to knowledge and detailed, rigorous data analysis steps

Further, the researchers validated the storyline's flexibility and transferability among the informants and validated the credibility of the storyline and emergent substantive theory via expert.

Because the study focused on understanding the mathematical competency usage in the engineering manufacturing process in manufacturing engineering practice, the researcher was positioned as a social being whose experiences, ideas, and assumptions can contribute to understanding and interpreting the social processes studied. The finding was developed to understand better the main concerns encountered in its substantive area from the researchers' perspective. nevertheless, the substantive finding is considered transferable to contexts of other engineering processes that are comparable to the context

Data Analysis

Data Transcription (Phenomenology interviews)

In adopting Moustakas' (1994) phenomenological model using phenomenological reduction, the following step identifies significant statements, meaning units, textural description of the experience, structural descriptions of the experience, and textural-structural synthesis. The purpose is to identify a significant statement.

Horizonalization (Significant Statements Identification)

As shown in Table 4, Column 2, the researcher identified individual verbatim statements shared by the respondent (E1) depending on each PDCA step for purposely showing only for step *Plan* to show how to analyze at this step. These statements represent non-repetitive, non-overlapping significant statements. These statements reflected entire sentences and were a subjective extrapolation from the transcripts. No attempt was made to group these statements or order them in any way. In this analysis phase, the researcher wanted to learn how individuals viewed the term. Reading their statements provides details about how individuals experience reinvestment in others. These significant statements are gleaned from the transcripts and provided in Table 4 so that researcher can identify the range of perspectives about the phenomenon (Moustakas, 1994).

Table 4. Selected Significant Statements for PLAN Step

No.	Verbatim statements	Researcher interpretation
	PLAN	
1	I accept PCB quality issue out of spec above 2.6mm. We take ten pcs to sample before reflowing and found four pcs reject from ten pcs over 1.56, meaning 40% reject and after oven getting worse, at point a, b, c, d warpage making a lot. We have to check the size of all 10 points in the original state and after the oven process, besides whether the process causes component defects. Similarly, the SMT process is problematic or not; for example, solder printing is impractical; the PCB surface will crack when the PCB is pressed while testing is running and assembled within the cabinet, thus making components break,	Engineer Recognition of mathematical concepts Engineer investigating various problems (identifying, posing, and specifying) Engineer following and assessing chains of arguments put forward by others
2	As always, as practice, we will receive problems/problems from production or QC and solve problems. That is a fixed strategy.	Engineer investigating various problems (identifying, posing, and specifying)
3	When I get an email from QC, I will understand the real problem by understanding the symptoms of the reported issue. For example, there is information such as quantity reject, percentage reject, and a scene of rejection. That information will help me understand more and make initial guesses and hypotheses about the problem and why it is. It also helps me to explain to others the pain.	Engineer expressing oneself about mathematical contents Engineer investigating various problems (identifying, posing, and specifying) Engineer utilizing and understanding different representations of entities (decoding, interpreting, distinguishing between) Engineer understanding relations between different representations
4	It started with a data collection that would send an email to call several departments such as QC, Production, Warehouse, and Engineering.	Engineer Expressing oneself about mathematical contents
5	The purpose is to find the correct issue information and the rights situation, in which case we will also discuss some issues on the issue, such as how much quantity? How often? If interrupting efficiency/efficiency, for example, one hour too often, can result in lost time, we have to study. Is there a mechanical problem or RAW part problem? Identifies normal or abnormal. It involves several parties like in charger machines, storing the raw problem claims to PCB maker in charge. We will tell the inspector PCB maker and defective part and advise the issue that the warpage part cannot be high.	Engineer investigating various problems (identifying, posing, and specifying) Engineer utilizing and understanding different representations of entities (decoding, interpreting, distinguishing between) Engineer recognition of mathematical concepts Engineer expressing oneself about mathematical contents
6	The data involved is an email stating the problem, reject what? How many Quantities? What is the ratio?	Engineer recognition of mathematical concepts Engineer understands the scope/limitations of a given concept
7	YES. There are departments like QC, Production, warehouse, and Engineering department.	Engineer expressing oneself about mathematical contents

Table 5. The Cluster of Meaning Development for PLAN Step

Plan	Themes/ Meaning Units	Evidence in Engineer statement
	Thinking mathematically	I accept PCB quality issues out of spec above 2.6mm. We take ten pcs to sample before reflowing; he found four pcs rejected from 10PCs over 1.56, meaning 40% reject. After the oven gets worse, at points a, b, c, d, warpage making a lot
	Problem handling	Besides whether the process causes component defects. Similarly, the SMT process is problematic or not. For example, solder printing is impractical. The PCB surface will crack when the PCB is pressed while testing is running and assembled with the cabinet, thus making the component crack
	Communicating mathematically	Well, once I get an email from QC, I will pick the exact problem with the different problem syntax used,
		The purpose is to find the correct issue information and the rights situation, in which case we will also discuss some issues on the issue, such as how much Quantity? How often

Development of meaning units

The next step is meaning Units or Themes, as every significant statement is initially treated as possessing equal value, as in Table 5. This next step deletes those statements irrelevant to the topic and, for this study, what is always mathematical competency frequently used. The remaining statements are the horizons or textural meanings. The researcher carefully examines the identified significant statements and clusters them into themes or meaning units (Moustakas, 1994). But this paper will show only for step *Plan* to show how to analyze at this step. Constructing themes will be performed based on deductive methods. Deductive ways are the knowledge, theory, or framework that has since become a code/theme (Boyatzis, 1998).

Textual Description and Structural Description Formation

In textural descript, the researcher then describes "what" was experienced in the textural description from the thematic analysis. Next, textural descriptions are considered, and additional meanings are sought from different perspectives, roles, and functions (Moustakas, 1994), and the *structural stage*; the researcher then describes "How" was experienced in textural descriptions.

In the following section, examples of respondent textural and structural descriptions are presented. Samples from this individual were selected to illustrate common horizons that emerged among the participants' interviews regarding their experience during task or workplace work. The analysis of individual textural and structural descriptions precedes the final step of the phenomenological analysis, textural–structural synthesis. The experiences of E1 below reveal both similarities and differences in their experience conducting tasks or working at the workplace. The respondents' analyses were intentionally selected to highlight the structures that were part of the absolute essence of their experience conducting tasks or working at the workplace. The search for similarities and reliance in E1 description, experience during conduct task or work at the workplace. In line with the phenomenological approach's goal, the final results that follow the textural and structural descriptions refer to the essence of the shared experience while conducting tasks or working at the workplace. The similarities in their experiences are elaborated upon in this Results section, in which we describe the structures that underlie the essence of the phenomenon under study.

In E1 individual textural description, he describes thinking mathematically about how to understand when he received the problem or task during work.

"Well, by the time I get the email from QC, I will take the problem with the problem of the relevant problem symptom, that are if there is information such as quantity of reject, percentage of reject, scene of occurrence of push. Received a PCB quality issue out of spec above 2.6mm, where a ten pcs sample found 4 pcs reject from 10PCs over 1.56, meaning 40% reject—after the oven getting worse, at point a, b, c, d, warpage making a lot. So we have to check the size of all 10 points in the original state and after the oven process, besides whether the process causes component defects. Similarly, the SMT process is problematic or not. For example, solder printing is impractical. The PCB surface will crack when the PCB is pressed while testing's running and assemble with the cabinet, thus making component crack."

The researcher can express the E1 individual structural description as follows:

"He received information on the quality problem regarding the PCB via email. He tries to understand and think about the problem by taking the information in the email, such as quantity of rejects, percentage of rejects, percentage of rejects, where it happened, and so upon, knowing the information involved. He thinks whether the information or data received is enough to help continue the calculation and solve the problem. Therefore, he need to think of initial expectations that need to be taken, such as taking the example of PCB and checking to carry additional data to strengthen all the problems involved. Meanwhile, it is also trying to determine the probable cause of this problem. For example, he stated the possible SMT process might be problematic. He also thinks about what issues will occur in other processes due to these problems, such as cracked components."

Results

The last step is the essence and finding and result. The concept of "saturation" was used to determine the number of samples involved in this phenomenology study. Typically, a qualitative researcher will collect data until they reach data saturation (Simon, 2011; Fusch and Ness, 2015; Nascimento et al., 2018). *The last step is the essence of engineer mathematical competency used for each PDCA process while working in the workplace*. After that, all finding and transcribe will ask a respondent to see and verify and validate them.

Mathematical competencies in PDCA Step.

To extract the essence of engineer mathematical competency in how to perform or solve the problem or task during work, the composite textural and structural descriptions developed for each engineer were integrated and synthesized. The essence underlying the experiences of engineer mathematical competency in performing or solving the problem or task during work is that the engineer describes mathematical Competency used for each PDCA process while working in the workplace.

Three composite structural descriptions of the experiences of engineer mathematical competency in how to perform or solve the problem or task during work by following PDCA,

(1) Thinking Mathematically
(2) Problem handling
(3) Communication mathematically

Plan step:

Engineers use mathematical competency to solve or do work tasks during the performance or solving the problem or task during work.

Thinking Mathematically

In this step, the engineer uses mathematical thinking by extracting and understanding the raw data or raw information received. Besides, with the help of engineers posing questions characteristic of mathematics to understand the problem they received, for example, "how many presents rejects? How often does it happen?

"I get an email from QC.; I will understand the real problem by understanding the symptoms of the reported problem if there is information such as quantity reject, percentage reject, and scene of reject. That information, t will help me understand more and be able to make initial guesses and hypotheses of what the problem is and why. it also helps me to explain to others about the problem." (E2)

Problem handling

Also, engineers use problem handling during this stage; engineers try to understand the problem and what is related to the main problem. Then, in an implicit sense, the engineer tries to plan how to conduct an investigation and find additional information.

"Besides whether the process causes component defects. Similarly, the SMT process is problematic or not. For example, solder printing is impractical. The PCB surface will crack when the PCB is pressed while testing is running and assembled with the cabinet, thus making the component crack …. it started with a data collection that would send out an email to call the meeting several departments as Q.C., Production, warehouse, and Engineering. "(E3)

Communication mathematically.

Engineers use mathematical communication at the planning stage. Engineer understands other mathematical texts when received information problem. Also, engineers communicate to explain the real situation regarding data and information obtained from other parties.

"Well, once I get an email from Quality Control, I will pick the exact problem with the different problem syntax used. The purpose is to find the correct issue information and the right situation, in which case we will also discuss some issues on the issue, such as how much quantity? How often. "(E2)

Do step:

Thinking Mathematically

In this step, the engineer uses mathematical thinking by understanding and handling a given concept's scope and limitations.

"After that, would measure the curvature using flat mirrors and micrometer gauges, and t proved problematic because the dimensions made were 1.70mm, and the 190mm good section size was 0.2and 0.3mm." (E1)

Problem handling,

In this step, the engineer uses mathematical thinking by problem handling. Besides, engineers use problem handling during this stage; engineers try to solve various problems related to the main problem. Then, in an implicit sense, the engineer tries to plan how to use the remaining or new data to calculate and get the solution.

"The data will be used during analysis and analysis decisions. After taking a sample/sample of the problematic part of 10pcs, and ten pcs…I will record it in one table to facilitate curved or warpage areas. "(E2)

Communication mathematically.

Besides, engineers use communication mathematically at the do level. For example, engineers communicated to obtain additional data and information during meetings with other parties and tried to give their views to understand the problems.

"For the QC Department, at the beginning of the meeting, I will open the meeting by explaining the issues you want to discuss. During the discussion, I will ask the relevant department, for example, the QC department. They will answer the same data (above). that data is meant and intended. Total reject 50pcs means knowing how many parts are at risk, which means different types of problems and sizes we can analyze. A lot of different data can help you find the right root cause. So does the reject ratio. This data is very important to know the real situation in production. Whether production can work or not." (E3)

Check step:

Thinking Mathematically

At this stage, engineers use mathematical thinking by finding continuous quality improvement by asking questions or anticipating what will happen.

> *"Discussions with all departments regarding the action we take during the analysis study and how we implement it. What data are you using? action enhancement." (E3)*

Problem handling,

In this step, the engineer uses mathematical Competency with Problem Handling. The engineer tries to prepare any possibility when the solution's result is a mistake by asking for feedback from the other party. If there is an error or needs improvement, the engineer plans what data is needed again.

> *"Then, preparing the report and meeting with the relevant department will receive feedback from the meeting. According to the meeting analysis report, there is no question arising from the study analysis in this case. All can understand and agree. We will only wait for feedback from the supplier." (E1)*

Communication mathematically.

Besides, engineers use communication mathematically at the check level. Engineers communicate to obtain additional data and information during meetings with other parties and try to give their views on improvement

> *"Discussions with all departments regarding the action we take during the analysis study and how we implement it. What data are you using? Action enhancement." (E2)*

Action step:

Thinking Mathematically

In this step, the engineer uses mathematical thinking by understanding and handling the scope and limitations of a given concept; for example, the engineer will monitor the data or part after the improvement action if all data is inside the specification. The part considers good.

> *"Let us see, based on that decision. Based on that data. All the parts are in the specifications we know. mean, this part is OK." (E3)*

Problem handling

In this step, the engineer uses mathematical competency with problem handling; engineers try to plan to monitor the part after the action is taken. For example, engineers take measurements or data for some sample parts that are in the production line. Based on that data, the engineer will make the next decision.

> *"In this case, we will observe the part that has been upgraded. Or the newly arrived part. We will do the same measurements as before. Is the same problem still happening? Or repaired." (E2)*

Communication mathematically.

Besides, engineers use communication mathematically at the check level. Engineers communicate to obtain additional data and information during meetings with other parties and try to give their views for improvement

> *"The discussion is about analysis for continuous improvement. And solve the problems." (E1)*

Discussion

Phenomenological Approach

Phenomenology is a fundamental field of research in engineering whose central aim is to describe people's experiences (Norlyk et al., 2010 and Streubert et al., 2011). As a research method, phenomenology is primarily concerned with elucidating the first-person experience of phenomena (Wertz et al., 2011) by verbalizing particular experiences. In choosing this method, prospective researchers are expected to understand its basic assumptions and tenets as a philosophy and method of inquiry. The two questions of 'what' and 'how' is experienced provide a concrete framework for asking questions and recording responses, enabling them to make important decisions such as whether to focus research on 'individual' or 'general' aspects of an experience. This deeper understanding of phenomenological philosophy and method encourages engineering researchers to articulate the study design, including the rationale for their choice and preferred data collection methods and analysis. It also enables researchers to present their findings narratively, using language infused with 'facts' and 'emotions' to lead to a deeper understanding of the phenomena under study. In summary, the fact that this approach relies on participants' experiences means that the stories being told are told from the participants' voices rather than those of the researcher or individuals reporting on studies on the literature, which is consistent with human science research. Previous studies evidence this, and Phenomenology is a great and helpful research strategy that is well suited to explore challenging problems (Neubauer et al., 2019; Picton et al., 2017; Stolz, 2020; Khan, 2014).

Thinking mathematically

Engineers view an issue and a task as more than the ability to perform simple arithmetic or solve an algebra problem. It's a way of looking at things, reducing them to their essential components, whether numerical, structural, or logical, and then evaluating the fundamental patterns. Mathematically, they emphasize how to manage to solve problems by adding data or the size of a problem to each item involved. Based on most of the previous research, thinking mathematically will ease problem-solving (Henderson et al., 2002; Mason, Burton & Stacey, 2010; Blitzer, 2003). The addition of information or published data can help engineers to provide several ways of mathematical solutions.

Problem Handling

Problem handling is involved in most engineering task, and engineers must examine actual problem to get a clear perspective. They need to ensure and modify the mathematical content of the data if necessary. They emphasize how to design to solve the problem by adding data or problem size to each item involved (Grootenboer & Jorgensen, 2009). Ensuring the actual state of the published information or data can help engineers provide mathematical solutions.

Communication mathematically

"Communication is an essential part of mathematics and mathematics education "(National Council of Teachers of Mathematics [NCTM], 2000, p. 60). Writing and discussion are integral to communication, promoting a deeper understanding of concepts (Cramer & Karnowski, 1995; NCTM, 2000). The ability of engineers to organize and connect their mathematical thinking through communication and convey their logical and clear mathematical thinking to their colleagues, superior, and others; engineer also analyzes and evaluates the mathematical thoughts and strategies used by others; and use mathematical language to express mathematical ideas correctly

Conclusion

The results show that MC is suitable for applying problem-solving in the workplace. Therefore, it is suggested that the focus of mathematics teaching for prospective engineers should consider mathematical competencies, and these competencies should be included as important learning outcomes. In view of that, the National Academy of Engineers ;(2005) states that the future engineering curriculum should be built around developing skills such as analytical and problem-solving skills rather than teaching content knowledge. Furthermore, emphasis should be laid on teaching students about methods to derive solutions rather than giving the solutions (the National Academy of Engineers, 2005).

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Civil Engineering Student Performance Observation During COVID-19 Pandemic Period

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Abstract
The coronavirus disease 2019 (COVID-19) pandemic shifted the learning method from conventional face-to-face to online. Such abrupt changes provide insufficient time for students to adapt and hence affect their academic performance. Situation seems to be critical towards engineering education, as it at most applicable to blended learning mode, with limited application of fully online mode. The objectives of this study are to compare students' academic performance with different delivery methods and identify potential learning-related issues in civil engineering material subject during the COVID-19 pandemic period. Three batches of students in the academic year of 2019, 2020 and 2021, are the targeted population, with the delivery modes of conventional face-to-face mode, mixed mode and fully online mode respectively. All three batches of students were undergoing similar assessments of a fundamental subject, Civil Engineering Materials, in Curtin University Malaysia. The findings revealed that students with fully online mode were not performing well in their assessments, notably final examination. There seems to have a lack of peer assistance and non-adaptability in the online mode. Recommendations such as effective online model and collaborative activities have been included to cope for studies during the pandemic. As it is unpredictable for the evolvement of COVID-19 pandemic, this study suggests future research to look into ways of strengthening online teaching tools in engineering degree programmes.

Keywords: student behaviour, performance, civil engineering, COVID-19, online learning.

Introduction

The conventional course delivery of world higher education changed from conventional face-to-face to online learning during the COVID-19 pandemic in order to keep education system running without delay. This forces current university students to adapt online learning without considering the readiness of students and technologies. Engineering education has been designed as content-centred, design-oriented and hands-on to develop students' critical thinking and problem solving (Bourne et al., 2005). Previous learning methods have been proven effective in engineering education, such as active learning (Lima et al., 2017), project-based learning (Mills and Treagust, 2003), blended learning (Kashefi et al., 2012), flipped classroom (Bishop and Verleger, 2013), and etc.

During COVID-19 pandemic, online learning was positively impacting the tertiary education, such as medical and dental courses in Pakistan (Mukhtar et al., 2020) and engineering course in United State of America (Asgari et al., 2021). The adaptability to the limitations of online learning seems to imply that online learning could benefit those students who performed well in face-to-face mode but disadvantage the low-achievers, with higher dropout rate in the fundamental subjects (García-Alberti et al., 2021). Some guidelines have been proposed for quality teaching and online engineering course evaluation (Khan and Abid, 2021).

There were some identified negative issues of online engineering education learning during the pandemic, such as cyber security problems, low level of students' focus, connectivity issues, lack of hands-on training, and etc (Asgari et al., 2021). In response to the emergent change of delivery mode in higher education and its impact on engineering degree programmes, researchers explored on the new and existing methods to improve engineering degree programmes. Examples include: Luburić et al. (2021) explored the success of full online teaching implementation in three software engineering subjects; Sweidan et al. (2021) tested the applicability of Student Interactive Assistant Android Application with Chatbot (SIAAA-C) in various disciplines including engineering discipline; Singhal et al. (2020) proposed a digital-based iterative and evidence-based active learning in two subjects of computer science and engineering programmes. However, to the best of researchers' knowledge, existing studies on civil engineering degree programme during the pandemic period has not captured much attention. This study specifically observes civil engineering student performance on a fundamental subject during the pandemic period. The recorded results from the assessments are compared among three consecutive years (i.e. 2019, 2020 and 2021) which represent different students' learning experience (i.e. conventional face-to-face, mixed, and fully online).

Theoretical background

Online education theories

Based on the concept of presences: teaching, cognitive and social, Garrison, Anderson and Archer (2000) developed a "community of inquiry" model for online learning, particularly emphasizing students-instructor interaction in an active learning environment. Changing from traditional individual learning to crowd activities with internet technology, connectivism learning model is developed (Siemens, 2004). Derive from social constructivism, online collaborative learning describes the collaborative learning and knowledge building with the use of internet (Harasim, 2012).

Integrated model

Bosch (2016) developed model of blending with pedagogical purpose where the approaches are driven by pedagogical objectives and activities. The learning module contains six basic pedagogical goals: content, social/emotional, dialectic/questioning, evaluation, collaboration and reflection. This forms an integrated community of learning with active interaction.

Subject and student descriptions

Subject details

The observation was conducted for the subject of Civil Engineering Materials (CEM), which is one the core subjects in Civil Engineering curriculum. There are four learning outcomes on successful completion of this subject: able to identify the material qualities to obtain adequate performance over structures life, understand the internal response of construction materials towards external applied loads, able to evaluate material performance with the calculated internal stresses, and able to design (specify, modify or protect) with the civil engineering materials to gain better performance. This subject is delivered with two hours of lecture and tutorial respectively per week over 12 weeks period and contained three assessments, namely, laboratory reports, calculation assignment and final examination. Students need to obtain an overall of 50% and at least 45% in the final examination for passing this subject.

Targeted students

Three batches of students in year 2019, 2020 and 2021 are included in this observation. Table 1 provides a summary of these students. All of the students were in their second year of study to explore the core subjects of civil engineering degree, after completing the first-year engineering common subjects. These students experienced different learning and teaching methods, which changed mostly due to the Covid-19 pandemic. Students for year 2019 experienced face-to-face physical classes, while students for year 2020 and 2021 experienced online classes. The 2020 and 2021 batches students were differed in their first year of learning curve, as 2020 batch students experienced face-to-face and batch of 2021 experienced fully online. Therefore, 2019 batch described as fully face-to-face, 2021 batch as fully online and 2020 batch as the transition from face-to-face to online, during their two-year university life.

Table 1. Targeted students in this study

	2019	2020	2021
Total enrolled students	59	64	31
New students	56	53	25
Repeat students	3	11	6

Delivery method

The outbreak of Covid-19 caused lockdown to many countries for curbing the spread of virus in community. In response to the instruction from the government, higher education institutions are forced to close. Such closure affects the teaching delivery mode in many countries. In Malaysia, the Ministry of Higher Education Malaysia instructed all universities to opt for online teaching and learning for accommodating continuous learning.

The students in 2019 cohort experienced both first year (2018) and second year (2019) with conventional face-to-face delivery method. As CEM is the second year subject, the 2019 students represented the conventional physical class delivery method, with two hours of weekly lecture and tutorial respectively. The learning materials were obtained from learning management tool, and students could refer to the recorded lecture class from main campus in Australia, which are the similar contents for other campuses.

The 2020 cohort experienced face-to-face physical classes in 2019 (first year) and first three weeks in 2020 (second year) before lockdown occurred in Malaysia. They were in the transition period of shifting from conventional physical classes to online delivery. Some consideration steps have been applied to help these students, such as longer final examination time with 24-hour window for students to enter the final examination, and consideration for assessment extension.

The 2021 cohort experienced similar course content delivery in 2020 for their first year of study. The students met in virtual classes with their course lecturers and did all assessments through learning management tool. Overall, as shown in Tables 2 and 3, the attendance rate of live classes was not high if compared to physical classes, as students could refer to the recorded videos.

Resources access

There were several resources for the learning materials, through learning management system or cloud storage. The 2019 cohort attended physical lecture and tutorial classes with all resources provided in the learning management tool. For 2020 and 2021 cohorts, cloud storage link was provided to students for live classes recordings with additional examples. The view counted for watching these videos were recorded in Tables 2 and 3 for cohort 2020 and 2021 respectively.

Table 2. Attendance and view counted for recorded video for 2020 cohort

Date	Live attendance for tutorials, %	View counted for recorded version
Week 1	Face to face (F2F)	Not applicable
Week 2	Face to face (F2F)	Not applicable
Week 3	Face to face (F2F)	Not applicable
Week 4	29.69	0
Week 5		
Week 6a		
Week 6b		
Week 7a	26.56	2
Week 7b		
Week 8		
Week 9		
Week 10	31.25	0
Week 11		
Revision		

Table 3. Attendance and view counted for recorded video for 2021 cohort

Date	Live attendance, % Lectures + tutorials	View counted for recorded version	View counted for lecture note
Week 1	90.32	173	Not applicable
Week 2	74.19	192	
Week 3	70.96	188	
Week 4	80.65	134	
Week 5	74.19	139	8
Week 6a	45.16	102	25
Week 6b	67.74	110	
Week 7a	35.48	66	32
Week 7b	48.39	49	
Week 8	64.52	112	35
Week 9	51.61	8	19
Week 10	41.94	6	40
Week 11	41.94	8	40
Revision	45.16	8	116

Assessments

This subject contained three assessments: laboratory report (30%), assignment (20%) and final examination (50%). The assignment consisted of seven questions, where Q1, 2 and 3 with 6 marks, Q4 and 5 with 4 marks, Q6 with 7 marks, and Q7 with 3 marks (refer to Table 4). All of the marks were then converted into 20% as the final assessment marks. Five laboratory sessions were divided into six submissions, which contributing to 30% of the final assessment marks (refer to Table 5). Both laboratory report and assignment were assessed through learning management tool, and final examination was assessed through learning management tool for 2020 and 2021 cohorts, while face-to-face for 2019 cohort. All marks are shown in Tables 4, 5 and 6.

Table 4. Marks division and scores for assignment

	Q1,2,3 (6 marks)	Q4,5 (4 marks)	Q6 (7 marks)	Q7 (3 marks)	Overall*, 20 marks
2019	-	-	-	-	11.01
2020	3.538	2.497	4.469	2.120	1.262
2021	3.281	2.229	2.946	1.620	1.008
This assignment is divided into 4 sections with (total marks) each					
*Mark contribution of this assignment is 20%					

Table 5. Marks division and scores for laboratory reports

	1	2A	2B&C	2	3	4&5	Overall*, 30 marks
2019	32.18	67.45	42.97	59.83	45.48	28.92	20.23
2020	28.63	77.60	51.84	71.24	40.33	31.61	21.45
2021	31.06	79.06	48.49	68.26	45.94	36.23	22.24

This laboratory report assessment is divided into 6 sections
*Mark contribution of this assignment is 30%

Table 6. Marks division and scores for final examination

	Stresses				Materials	Overall*	Average time spent, min	Time limitation
	Q1	Q2	Q3	Q4				
2019	9.22	8.33	9.80	10.24	10.07	43.03	120	2 hours + 10 min reading time
2020	14.83	7.34	12.07	6.85	9.90	51.00	222	2.5 hours + 1.5 hours SU time
2021	8.44	3.16	10.23	3.94	10.65	36.42	143	2 hours + 30 min SU time

SU – scan and upload
This final examination is divided into 2 sections (stresses and materials)
*Mark contribution of this assignment is 50%

Methods

Student behaviour observation

The observation included delivery, resources access and assessments. The student performances were compared with assessment records observation for three cohorts of students with different background of learning experiences (conventional face-to-face, mixed and fully online). The governing factors were analyzed and discussed.

Qualitative data collection

Student behaviour was discussed among instructors during the Board of Examination with other campuses. The comments and feedback from instructors were recorded for continuous quality improvement plan. The feedback consisted of effectiveness of content delivery, assessment, content framework and reliability of online assessment.

Analysis and discussion

After the observation, the student behaviour throughout the semester were discussed and finalized during the Board of Examination meeting. The discussion was mainly focusing on student behaviour, as others were identified as non-critical or constant throughout the study. The constant parameters are assessment type, content framework and study period.

Delivery method and student behaviour

According to the six basic pedagogical goals of integrated online model (Bosch, 2016), there is a lack of collaborative goal in the implementation of CEM online course. Due to the sudden lockdown, instructors were lack of training with regards to the online delivery. This reduced the effectiveness of the content delivery through online platform.

Students were found not interested and not constructive in learning the contents. Constructivism concentrates on the experienced dynamic structure in a learning process (Mahoney and Granvold, 2005) and online learning students did not possessed this characteristic throughout the observation. Students also seem lack of self-determination (Chen and Jang, 2010).

Assessment and content framework

In order to maintain the quality and consistency of the course, CEM has the same assessments and content framework throughout these three cohorts. The marks division, types of assessments, and topics covered remained the same. Although the assessment of laboratory was through online platform, there is a difference for students in between online/mixed delivery and face-to-face delivery. Students of online and mixed delivery methods were given pre-recorded demonstration videos and pre-determined data, and completed the online assessment through learning management tool. Students who experienced face-to-face delivery conducted the laboratory tests before attempting the online assessment.

Reliability of online assessment

By benchmarking with cohort 2019, higher passing rate was found in cohort 2020. Due to the transition period, more time was allocated for final examination and students were allowed to attempt examination in

24-hour time frame. Students may start their attempt anytime in the stated 24-hour window. Once started, students needed to complete the examination within four hours, where it has been recorded the average time spent in completing the examination was 222 minutes, which is almost four hours. It is assumed that the students were fully utilizing the time allocated for scanning and uploading to attempt exam questions, thus cohort 2020 student seems to have more time in completing the exam.

In order to solve the arising issues such as academic misconduct and prolonged scanning and uploading time, the final examination in 2021 has been modified to online invigilated exam with shorter time allocated for scanning and uploading, as well as eliminate 24-hour activation window. Therefore, all of the students must attempt the questions at the same time. However, this examination has recorded lower passing rate compared to benchmark. As the 2021 cohorts only spent the first three weeks of their university life in campus, group study or peer assistance seems not non-accessible to the students, but could only through instructors' consultation for problem solving.

Information seeking is one of the major focuses in engineering first year study (Lamont, 2020). The online learning mode since in the first year of study has hauled the students from pedagogical to andragogical or even heutagogical learning, from high school to tertiary education. Despite the additional examples which not being provided to other cohorts who experienced face-to-face delivery, the students experienced online delivery scored unsatisfactory results in the final examination.

Critical discussion

Student performance in CEM was compared for three cohorts which representing students who experienced conventional fully face-to-face mode (year 2019), mixed mode (year 2020) and fully online mode (year 2021). The highest passing rate was reflected in cohort 2020 and the lowest in cohort 2021, as shown in Table 7. Majority of the students fall under the range of 50%-60%, skewed towards the right for normalized graph. As CEM is one of the core subjects in civil engineering curriculum, the students might find it more difficult as compared to the first year subjects. From the assessments, students performed almost equally balance for both assignment and laboratory report. Therefore, the analysis is concentrated on the final examination, as it is the passing requirement for this subject.

Subjects in first year engineering study with general mathematical principles are easily caught up with reference books. However, it might become challenging when stepping into core subjects of civil engineering curriculum in the second year of study. The stress analysis in this subject may require deeper understanding of internal responses of a structural members and material behavior. The information seeking behavior should be developed in the first year of engineering study (Lamont, 2020). The passive learning style of students shall be transformed for better performance. Throughout this transformation, educators play an essential role in enhancing students' learning interests. With both learners and educators efforts, better performance can be achieved to produce more competitive engineers in the future.

Table 7. Overall marks distribution with passing rate

	Passing rate, %	Marks					
		90-100	80-90	70-80	60-70	50-60	Fail
2019	71.19	0	0	7	9	26	17
2020	81.25	2	4	9	17	20	12
2021	38.71	0	2	3	4	3	19

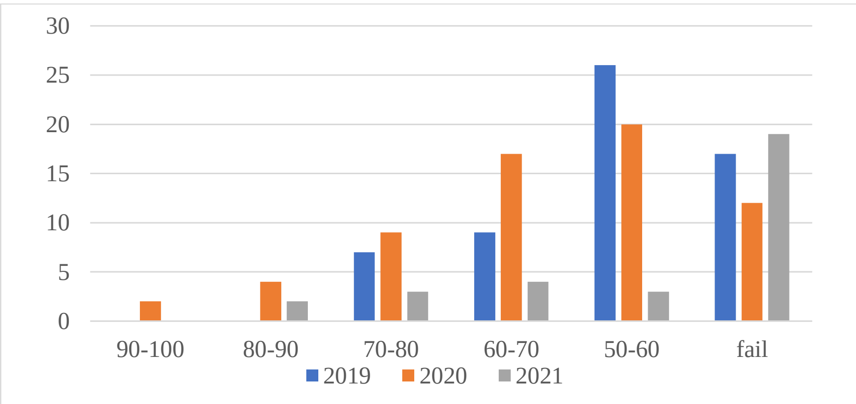

Figure 1: Mark ranges for cohorts 2019, 2020 and 2021

Effective online model should be setup in accordance to the integrated model (Bosch, 2016), as it identified the lack of collaborative element in online delivery. Learners need to develop their interests to make the process towards constructivism with high self-determination. Moreover, according Ko and Rossen (2017), an extra course should be delivered by the institution in preparing students for online courses. Online course framework is suggested by Reeves et al. (2018) to consist of components related to course overview, communication, activities for collaboration and interaction, content presentation, and assessment.

According to How People Learn (HPL) theory, the interaction between learners, knowledge, assessment and community should be considered in the learning process (Kuchi et al., 2003). In order to develop the effective online course, HPL should be incorporated into course's framework, which seems to be lack of consideration in the pandemic period.

Conclusions

The COVID-19 proposed social distancing which prompted fully online as the sole teaching and learning mode for education system. However, the fully online mode is challenging for engineering education due to the limitations of course design. In this study, observation was conducted for three batches of civil engineering students, by comparing their assessments' results. Several conclusions were drawn.

i. Lower average mark was obtained for fully online mode students when benchmarking against conventional face-to-face mode students.
ii. Relatively higher mark was obtained for mixed mode students (i.e. mixed classes of online and face-to-face) as longer time was allowed for final examination.
iii. The low scoring marks in assessments for students experiencing fully online mode, could be affected by students' incorrect information seeking behavior, and limited peer assistance due to a lack of involvement in campus life.
iv. Educators should assist students' learning interests with collaborative activities for overcoming students' passive learning.

This study urges the educators in civil engineering field to improve the existing learning and teaching methods in the fully online learning and teaching virtual environment. This is crucial in maintaining and strengthening the employability of civil engineering graduates during and after the COVID-19 pandemic.

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Design of an Innovative Assessment Instrument Integrating Service-Learning Malaysia University for Society Approach for Engineers in Society Course during Covid19 Pandemic

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Abstract
Service-Learning Malaysia-University for Society (SULAM) has served as a learning experience in Malaysia for the past few years, merging theories and practices to expose students to real-world community problems. SULAM was developed as a cutting-edge teaching and learning technique in Malaysia's higher education institutions (HEIs). Alternative assessment is one of the instruments for evaluating students' work in a real-world environment. It can also help students develop their higher-order thinking skills (HOTs), particularly at engineering HEIs. However, there is a dearth of research on SULAM in engineering programmes, particularly in terms of the assessment instruments utilised in achieving the essential skill sets for societal well-being. This study improves on the ordinary way of assessment by creating a unique alternative assessment instrument for the Engineers in Society (EIS) course integrated with SULAM (EIS-SULAM) to analyse the expected outcomes and evaluate its success. The EIS-SULAM course and its curricula were assessed in this study through document analysis and the creation of an assessment instrument by subject matter experts. The assessment instrument was used by 415 respondents utilising a purposive sampling of civil engineering students taking the EIS-SULAM course during the February–July 2020 semester (starting of Covid19 Pandemic) to determine its usefulness in measuring students' skill sets. The students submitted 90 projects using the Google Classroom platform and were assessed by three (3) lecturers using a syndicated marking method to assure fairness and uniformity in the report's marking. The results show that the student's grades are distributed normally, with around 20% of the 415 students receiving A+, A, and A- grades, 70% receiving B+, B, and B- grades, and 10% receiving C+ and C grades. Overall, all students met the 50% cut-off mark for the EIS-SULAM course, which satisfies the EAC Standard 2020 criterion. It is envisaged that the findings of this study will be used to improve engineering assessment instruments to increase societal well-being.

Keywords: *Engineers in Society, Innovative Alternative Assessment, Complex Engineering Problems, Outcome Attainment, SULAM*

Background of Study

One of the Engineering Accreditation Council (EAC) standards' requirements is to ensure that graduates of accredited engineering programmes meet the minimum academic standards for registration as graduate engineers with the Board of Engineers Malaysia (BEM) (EAC, 2020). To achieve these objectives, the EAC established several evaluation criteria, including Program Educational Objectives (PEOs), Program Outcomes (POs), and Academic Curriculum for Malaysian Higher Education Institutions (HEIs). Students must demonstrate the achievement of the 12 EAC's POs. As a result, it is critical to ensure that the programme outcomes are also not simply a list of course outcomes, but rather broad statements about basic transferrable skills that prepare students to be well-prepared (Mutalib et al., 2012).

The fundamental component of learning is assessment, which aids students in learning and determines their degree of comprehension of course material. Alternative assessments, such as problem-based and project-based assessments, could be linked to performance exams or authentic assessments to verify a student's ability to solve the specific work that is given. Furthermore, an alternative assessment focuses on applied proficiency rather than knowledge in a subject. In today's higher education, alternative assessment can be used to critically evaluate the student's performance and the development of reflective thinking, both of which can aid in deep learning (Woyessa, 2009; Kiew et.al., 2020). Othman et al., (2015) investigated the implementation of an integrated project (IP) course, in which aspects from many areas were creatively combined to help students better comprehend how the topics linked to one another.

Since engineering education is the process of transferring knowledge and concepts to engineers who work in the field, the authors advocated using an alternative assessment in the Engineers in Society course to measure students' ability to apply their knowledge and abilities in a real-world setting. The Department of Higher Education, Ministry of Education Malaysia (Ministry of Higher Education (MoHE, 2019) launched Service-Learning Malaysia, also known as SULAM (Service-Learning Malaysia-University for

Society). The creation of this curriculum contributes significantly to the Ministry of Education Malaysia's goal of preparing university students to become public intellectuals accountable for solving society's problems and assisting people in improving their lives in every way. As a result, HEIs should promote and implement SULAM approach inaugurated on April 13th, 2019. This curriculum exposes students to a learning environment that includes both theory and practical problem-solving in the community. SULAM was viewed by Truong et al., (2020) as a teaching technique to examine students' reflections on structured activities to satisfy the demands of their target community as well as get real-world experience for their professional development and other benefits.

SULAM is currently being integrated into the Engineers in Society (EIS) in a civil engineering undergraduate programme at the School of Civil Engineering, Universiti Teknologi MARA (UiTM), Shah Alam. The project-based learning (PrbL) course is offered in the final year of the curriculum. The project is carried out as a structured service activity, which is a civil engineering community project that addresses identified community needs through complex engineering problem-solving. Students must also understand the role of engineering ethics and the engineer's professional duty to safeguard public safety, as well as the economic, social, cultural, environmental, and sustainability consequences of engineering activity (Kiew et al., 2020). Furthermore, today's engineering profession is continually confronted with uncertainty and competing (sometimes conflicting) requirements or needs from clients, governments, environmental agencies, and the public which demands both interpersonal and technical abilities (Liew et al., 2020).

Engineers must deal with constant technical and organizational change in the workplace while seeking to incorporate more human qualities into their knowledge base and professional practices. They must also deal with the reality of modern industrial practices, as well as the legal implications of every professional decision they make. Students can use service-learning to produce a real-world result for society while also deepening their understanding of themselves and the community. As a result, students will be able to understand how to deal with complex issues in real-life application, such as societal needs.

Mamat et al. (2019) used a qualitative approach to investigate the practice and implementation of service-learning in four (4) public universities in Malaysia, using interview sessions to ask questions about practice, implementation methods, evaluation, documentation, and the impact of positive teaching-learning using the most recent service-learning method, while Yusof et al. (2020) focused on the perspectives of lecturers and students on the challenges they have faced. With the use of scoring rubrics, McGowan (2017) discovered that there are quantitative (i.e., work hours, pre and post experience survey results, and ratings of learning experience) and qualitative (i.e., portfolio, diary, and content analysis) assessment methods for evaluating learning outcomes effectiveness. The importance of a top-down approach in the assessment of experiential learning outcomes is emphasized by Krieger and Martinez (2012). Chan (2012) cited a scarcity in research on outcomes-based assessment methods in community service experiential learning.

Based on the identified problems, research questions to address the study's objective are: (1) Why was the new alternative assessment required during the pandemic? (2) How was the alternative assessment instrument developed? (3) What are the performance criteria used to effectively assess the intended learning outcomes set for the course, and finally (4) How effective were the assessment tools used in this exercise. Thus, this study was conducted to design and develop an effective alternative assessment instrument for the Engineers in Society course that incorporates the SULAM concept and addresses the EAC standard 2020 requirements for complex engineering problem characteristics.

Methodology

The design and development of the new innovative assessment tool for the EIS course was carried out after the faculty received the directive from the university to replace final examination with continuous assessment during the COVID-19 pandemic, starting March 2020. In addition, it is also regarded as a pilot SULAM project as mandated by Universiti Teknologi MARA (UiTM) that aligns to the Ministry of Education Malaysia requirements. Thus, the EIS-SULAM project was specifically developed to fulfil a continuous assessment for ODL as a replacement for the final examination.

The design and development of the assessment was carried out by five (5) internal experts, namely the Resource Person, Course Coordinator and three (3) lecturers teaching the course. The design and development processes are: (1) Document review on the syllabus, course contents, lesson plan and the assessment tools relevant to the Engineer in Society course, EAC Standard 2020 requirements to address complex problems (WPs) and knowledge profile (WKs); (2) Development of project brief and problem statement and assessment tools; (3) Development of the learning outcomes, detailed task breakdown with mark distribution(see Table 2) complemented by the performance criteria matrix or assessment rubrics for project report (see Table 3).

First, based on the document review, the course's prior evaluation mechanisms included a final examination (40%), a common test (20%), and a group assignment (40%). The new assessment tools for the course are EIS-SULAM project constitutes of 60% weightage while, the balance of 40% weightage is allocated for Test 1 and Test 2. This paper presents the new and innovative tool that has been developed as a main component of the continuous evaluation, with an overall percentage of 60% assessed as a group (30%) and individually (30%).

As stated in Table 1, the project addresses three (3) course outcomes (COs) that are mapped to two (2) programme outcomes (POs), as well as complex engineering problems (WPs) with the required knowledge profiles (WKs) specified by the EAC Standard 2020. Students apply engineering fundamental (WK3) and specialist knowledge (WK4) for engineering problem identification and solving problems in the project through research literature (WK8) such as valid sources, resources and past knowledge and experiences, in addition to understanding of issues and approaches (WK7) of professional conduct and the roles of civil engineers in broad contexts. Students working in an engineering team with knowledge in engineering procedures (WK5) emphasize stakeholders' conflicts, analyses, and make judgements based on societal demands.

Table 1. Mapping of CO-PO with WP and WK in EIS-SULAM Project

Course Outcome (CO)	Programme Outcome (PO)	Complex Engineering Problems Characteristics (WP) and Knowledge Profiles (WK)
CO2: Ability to explain the roles of engineering professional bodies. CO4: Ability to understand the local and federal authorities' Regulations.	PO6: Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues, and the consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems (WK7);	WP1: Depth of Knowledge Required (WK3, WK4, WK6 & WK8) & WK7 WP2: Conflicting requirements WP3: Depth of Analysis – Non-obvious solutions WP4: Familiarity of issues or infrequently encountered issues WP5: Extent of applicable codes
CO3: Ability to describe the Code of Ethics and Professional Conduct for engineers	PO8: Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice (WK7).	WK7: Comprehension on issues and approaches in engineering practices

Next, the EIS-SULAM project brief and problem statement was developed for a group of 4 to 5 students and comprised of open-ended problems related to the COVID19 pandemic. During the February to July 2020 semester at the Faculty of Civil Engineering, UiTM, Shah Alam, Selangor, 415 students took this course, which was facilitated by three (3) lecturers. A clear problem statement with an effective assessment method in terms of project report together with a detail assessment rubric have been established to measure the COs and POs for this course to ensure a fair and consistent assessment for the students. The problem statement initially lays out the students' overall scenario for the COVID-19 pandemic's effects on society, health, safety, legal, economic, social, cultural, environmental, and sustainability around the world. It then stimulates students' thinking by relating the pandemic's implications to the construction industry, which they will soon be working in. The full problem statement is given to the students as follows:

"The novel coronavirus disease that emerged at the end of 2019 began threatening the health and lives of millions of people. Highly contagious with the possibility of causing severe respiratory disease, it has quickly impacted governments and public health systems. This situation has been responded to by declaring a public health emergency of national and international concern and adopting extraordinary measures to prevent the contagion and limit the outbreak. As a result, millions of lives have been significantly altered, and a global, multi-level, and demanding stress-coping-adjustment process is ongoing. The COVID-19 disease has now achieved pandemic status. The World Health Organization has issued guidelines for managing the problem from both biomedical and psychological points of view. During the past few years, this unprecedented pandemic has changed the world in many ways regarding society, health, safety, legal, economic, social, cultural, environmental, and sustainability. COVID-19 has not only changed how we live by bringing us closer together as a society, but it has also disrupted financial markets, including professional engineering practices. One of the examples is the construction sector. Even though the sector contracted more challenges during the 1985 and 1998 recessions, this time around involved no construction work. This situation has a different dynamic, and we are currently in uncharted territory."

In addition, a poem dedicated by one of the lecturers teaching the course on how the COVID-19 pandemic affected civil engineering practices as shown in Figure 1 was also shared with the students.

Finally, the learning outcomes with seven (7) main tasks together with the performance criteria matrix was developed with the problem statement to measure the learning outcomes directly and explicitly in relation to the PO attainments. The rubric components expressed as tasks explicitly inform the students about the activities' requirements and were created to assess three learning outcomes (LOs) that were closely related to the COs and POs.

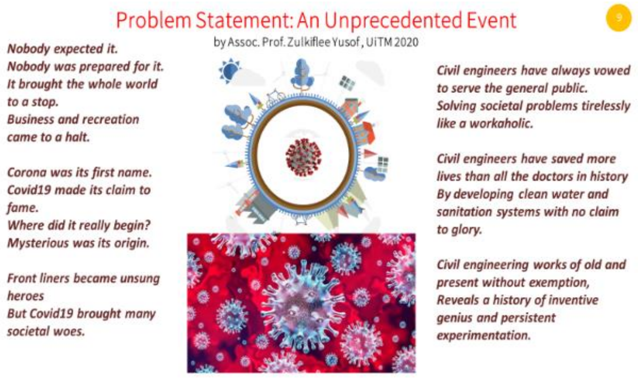

Figure 1. A Poem on role of civil engineers in an unprecedented event

Student learning activities should be centred on the role and contributions of civil engineers through professional conduct in society. The first targeted learning outcome (LO1) emphasises the student's capacity to identify current engineering problems that society is facing, as well as the responsibilities that come with them in civil engineering practises. Task 1: Identification and evaluation of infrequently encountered civil engineer-related issues in the new normal; Task 2: Identification and justification of conflicts between these issues; and Task 3: Proposal of engineering solutions and identification of new issues related to the proposal are the three rubric components associated with LO1.

The student's understanding of professional ethics and obligations was designated as the second targeted learning outcome (LO2). Task 4: Discussion of potential ethical issues and professional misconduct; and Task 5: Proposal of a remedy to overcome the potential ethical and misconduct issues are two rubric components of LO2. The students' ability to develop solutions to difficulties faced by professional engineering bodies discussing and addressing stakeholder conflicts is the third intended learning outcome. Task 6: Identification of challenges in executing offered solutions; and Task 7: Proposal of solutions to stakeholders' involvement and conflicts are two rubric components that can be used to assess LO3.

The rubrics were also created with the examination of advanced engineering problem-solving abilities in mind to address the three learning objectives (LOs) that students should achieve at the end of the project submission. Table 2 shows an overview of the tasks' breakdown, including mark distribution and mapping of COs, POs, LOs, and WPs. Table 3 shows the detailed performance criterion matrix which complements the expected learning outcomes intended for the EIS-SULAM project.

The is based on the following five-point scale: Scale 1 indicates "does not meet expectations," Scale 2 indicates "developing," Scale 3 indicates "meets expectations," Scale 4 indicates "proficient," and Scale 5 indicates "distinguished." "Distinguished" signifies student performance that exceeds "meets expectations" in terms of knowledge of the intended LOs and complex engineering problem-solving skills. The student was given the project specifics, including the rubrics, during the first week of the semester. In Week 14 of the semester, each group of students must present a report addressing all the responsibilities by chapter based on the tasks. Both students and lecturers benefit from the design rubrics to help them comprehend the "must-include" crucial features of each segment.

Results and Discussion of Findings

The EIS-SULAM project was specifically developed as a continuous assessment tool to replace the final examination during the COVID-19 pandemic starting March 2020. This new and innovative instrument has been developed as a main component of the continuous evaluation, with an overall percentage of 60% comprised of group (30%) and individual (30%) assessments.

Figure 2 depicts the submission of 90 projects by 415 students from 15 groups facilitated by three lecturers via the Google Classroom platform at the end of week 14. All lecturers participated in a moderation process that included syndicated marking: Lecturer A marked Task 1, Task 2, and Task 3; Lecturer B marked Task 4 and Task 5; and Lecturer C marked Task 6 and Task 7 using the designed performance criterion matrix (see Table 3).

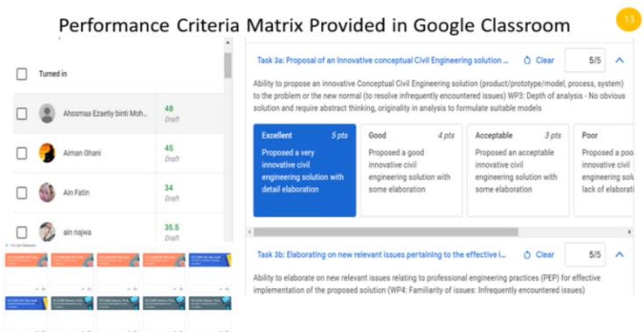

Figure 2. Google classroom used as an assessment platform

Each group of students proposed unique solution, although there is only one problem statement given to them in the project. Since the communities that the students engaged are different among groups, each group of students have diverse learning experiences particularly during the observations and identifications of specific problems faced by the community. Some of the submitted conceptual, innovative civil engineering solutions are shown in Figure 3.

Table 2. Learning outcomes and detailed task breakdown with mark distribution

Performance Criteria and Learning Outcomes with WKs and WPs		CO-PO	Marks
LO1: Identify, assess, and justify a current problem faced by society within economic, social, cultural, environmental and sustainability contexts and the consequent responsibilities relevant to professional civil engineering practices.			
Task 1 Performance criteria: a. Knowledge Profiles b. Evaluation of the identified problems **(WP1: Depth of Knowledge Required & WP4: Familiarity of issues or infrequently encountered issues)**	a. Identify a specific problem or a New Normal that have arisen during or due to the Movement Control Order (MCO) that have consequent responsibilities relevant to professional civil engineering practice	CO2-PO6	2%
	b. Evaluate the infrequently encountered issue/problem under various circumstances related to economic, social, cultural, health, safety, legal, environmental and sustainability aspects towards providing effective solutions.		3%
Task 2 Performance criteria a. Standards and codes of practice relevant to the problem or new normal b. Nature of conflict between the standards and codes of practice relevant to the problem or new normal. **(WP2: conflicting requirements & WP5: Extent of applicable codes)**	a. Identify with justification the technical, engineering, and other issues (due to the rules and regulations of authorities, code of professional practices, health and safety regulations, etc.) (WK7) relevant to the problem or the new normal arising from the pandemic, supported by relevant and validated information (reports, press statement, online news etc.) (WK8)	CO2-PO6	2%
	b. Highlight and explain the nature of conflict between the technical, engineering, and other issues (due to the rules and regulations of authorities, code of professional practices, health, and safety regulations, etc.) relevant to the problem or new normal.		3%
Task 3 Performance criteria a. Proposal of an Innovative conceptual Civil Engineering solution b. New relevant issues pertaining to the effective implementation of the proposed solution **(WP3: Depth of analysis & WP4: Familiarity of issues)**	a. Propose an innovative Conceptual civil engineering solution to the problem or the new normal	CO2-PO6	5%
	b. Elaborate on new relevant issues relating to professional engineering practices (PEP) for effective implementation of the proposed solution		5%
LO2: Propose solutions to potential ethical issues and misconduct among the engineers carrying out the above responsibilities.			
Task 4 Performance criteria Potential ethical issues and professional misconducts **(C5)**	Discuss in detail, potential ethical issues, and professional misconduct (based on the code of conduct by professional bodies) among engineers when implementing your proposed solution. (i) Provides at least 5 ethical issues and professional misconducts	CO3-PO8	5%
	(ii) Detail and excellent elaboration on at least 5 ethical issues and professional misconducts		5%
Task 5 Performance criteria Individual proposal to solve the problem and justify **(C6)**	Each student is required to propose an individual solution on how to overcome the potential ethical and misconduct challenges identified Task 4**.** (i) Excellent and innovative individual proposal	CO3-PO8	5%
	(ii) Excellent and very clear justification		5%
LO3: Identify with justifications, the challenges from the relevant local and federal authorities' regulations to the professional engineering practice and propose solutions to overcome them.			
Task 6 Performance criteria Challenges that could be faced by the engineering professional bodies in implementing the proposed solution **(WP5: Extent of Applicable Codes)**	Each student is required to identify the challenges that could be faced by the engineering professional bodies in implementing the proposed solutions (Task 3) due to the rules and regulations imposed by the local and federal authorities. (i) Identified more than 4 challenges	CO4-PO6	5%
	(ii) Excellent elaboration on the standards imposed by authorities		5%
Task 7 Performance criteria Development of solution to overcome the challenges **(WP6: Extent of Stakeholders)**	Each student is required to propose how to overcome the challenges posed by the rules and regulations imposed by the authorities. (i) Discussion addresses more than 3 stakeholders addressed	CO4-PO6	5%
	(ii) Detail explanation of conflicting requirements between stakeholders		5%
		Overall Marks	**60%**

Table 3. Performance Criteria Matrix for EIS-SULAM Project Assessment using Report

<table>
<tr><th>Performance Criteria</th><th>Complex Engineering Problem Characteristics/ Taxonomy Level</th><th colspan="5">Description of Performance Criteria</th></tr>
<tr><td rowspan="3">Task 1a:
a. Identification of specific problem using relevant Knowledge Profiles
(CO2-PO6)</td><td rowspan="3">WP1: Depth of Knowledge Required = in-depth engineering knowledge at the level of one or more of WK3, WK4, WK5, WK6 or WK8 (WK's) fundamental, first principles analytical approach</td><td colspan="5">Ability to identify a specific problem or a New Normal (WP4: Infrequently encountered issues) that have arisen during or due to the Movement Control Order (MCO) that have consequent responsibilities relevant to professional civil engineering practice (WK4-specialitst knowledge, WK6 -Engineering Practices; WK7-comprehension and WK8 – literature research)</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>Demonstrate only two (2) or less specified of WKs</td><td>Demonstrates only three (3) specified WKs</td><td>Acceptable demonstration of all four (4) specified WKs</td><td>Good demonstration of all four (4) specified WKs</td><td>Excellent demonstration of all four (4) specified WKs</td></tr>
<tr><td rowspan="3">Task 1b. Evaluation of the identified problems
(CO2-PO6)</td><td rowspan="3">WP4: Familiarity of issues: Infrequently encountered issues</td><td colspan="5">Ability to evaluate the infrequently encountered issue/problem under various circumstances related to economic, social, cultural, health, safety, legal, environmental and sustainability aspects towards providing effective solutions.</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>No evaluation of any circumstance</td><td>Evaluate 1 circumstances with acceptable justification</td><td>Evaluate 2 circumstances with acceptable justification</td><td>Evaluate 3 circumstances with acceptable justification</td><td>Evaluate more than 3 circumstances with acceptable justification</td></tr>
<tr><td rowspan="3">Task 2a:
Identifying and justifying standards and codes of practice relevant to the problem or new normal.
(CO2-PO6)</td><td rowspan="3">WP5: Extent of applicable codes: outside problems encompassed by standards and codes of practice</td><td colspan="5">Ability to identify with justification the technical, engineering and other issues (due to the rules and regulations of authorities, code of professional practices, health and safety regulations, etc.) (WK7) relevant to the problem or the new normal arising from the pandemic, supported by relevant and validated information (reports, press statement, online news etc.) (WK8)</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>Lack of supporting sources (not valid and not relevant)</td><td>Supported by 2 sources literature search but not relevant and validated</td><td>Supported by 2 sources of literature search</td><td>Supported by 3 sources of literature search</td><td>Supported by more than 3 sources of literature search</td></tr>
<tr><td rowspan="3">Task 2b:
Highlighting and explaining the nature of conflict between the standards and codes of practice relevant to the problem or new normal.
(CO2-PO6)</td><td rowspan="3">WP2: Conflicting requirement Wide-ranging or conflicting technical, engineering, and other issues</td><td colspan="5">Ability to highlight and explain the nature of conflict between the technical, engineering and other issues (due to the rules and regulations of authorities, code of professional practices, health and safety regulations, etc.) relevant to the problem or new normal.</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>Provide technical, engineering and other issues with poor explanation on the nature of conflict.</td><td>Provide technical, engineering and other issues with quite acceptable explanation on the nature of conflict between at least 2.</td><td>Provide technical, engineering and other issues with acceptable explanation on the nature of conflict between 2.</td><td>Provide technical, engineering and other issues with quite acceptable explanation on the nature of conflict between 3</td><td>Provide technical, engineering and other issues with quite acceptable explanation on the nature of conflict between more than 3.</td></tr>
<tr><td rowspan="3">Task 3a:
Proposal of an Innovative conceptual Civil Engineering solution
(CO2-PO6)</td><td rowspan="3">WP3: Depth of analysis
No obvious solution and require abstract thinking, originality in analysis to formulate suitable models</td><td colspan="5">Ability to propose an innovative Conceptual Civil Engineering solution (product/prototype/model, process, system) to the problem or the new normal (to resolve infrequently encountered issues)</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>Proposed a non-civil engineering solution</td><td>Proposed a poor civil engineering solution with poor elaboration</td><td>Proposed an acceptable innovative civil engineering solution</td><td>Proposed a good innovative civil engineering solution with some elaboration</td><td>Proposed a very innovative civil engineering solution with detail elaboration</td></tr>
<tr><td>Task 3b:</td><td>WP4: Familiarity of issues: Infrequently encountered issues</td><td colspan="5">Ability to elaborate on new relevant issues relating to professional engineering practices (PEP) for effective implementation of the proposed solution</td></tr>
</table>

Elaborating on new relevant issues pertaining to the effective implementation of the proposed solution **(CO2-PO6)**		**1**	**2**	**3**	**4**	**5**
		Provide new issues but not relevant to PEP	Provide at least 1 new issue relevant to PEP with brief elaboration,	Provide 2 new issues relevant to PEP with elaboration,	Provide 3 new issues relevant to PEP with elaboration	Provide more than 3 new issues relevant to PEP with elaboration
Task 4: Elaboration of potential ethical issues and professional misconducts **(CO3-PO8)**	**C5 - Evaluation**	Ability to elaborate in detail on potential ethical issues and professional misconduct (based on the code of conduct by professional bodies) among engineers when implementing your proposed solution				
		1	**2**	**3**	**4**	**5**
		Elaborate 1 ethical issue and professional misconduct	Elaborate 2 ethical issues and professional misconducts	Elaborate 3 ethical issues and professional misconducts	Elaborate 4 ethical issues and professional misconducts	Elaborate in detail more than 4 ethical issues and professional misconducts
Task 5: Individual proposal to solve the problem and justify **(CO3-PO8)**	**C6 - Creation**	Ability to propose an individual solution on how to overcome the potential ethical and misconduct challenges identified in Task 4				
		1	**2**	**3**	**4**	**5**
		Poor proposal with no justification	Acceptable proposal with poor justification	Acceptable proposal with justification	Good proposal with justification	Excellent proposal with clear justification
Task 6: Identification of the challenges that could be faced by the engineering professional bodies in implementing the proposed solution **(CO4-PO6)**	**WP5: Extent of applicable codes**: outside problems encompassed by standards and codes of practice	Ability to identify the challenges that could be faced by the engineering professional bodies in implementing the proposed solutions (in Task 3) due to the standards, code of practice, and rules and regulations imposed by the local and federal authorities				
		1	**2**	**3**	**4**	**5**
		Identified 1 challenge with no elaboration	Identified 2 challenges with some elaboration	Identified 3 challenges with acceptable elaboration	Identified 4 challenges with good elaboration	Identified more than 4 challenges with excellent elaboration
Task 7: Development of solution to overcome the challenges **(CO4-PO6)**	**WP6:** Extent of stakeholder involvement and conflicting requirements = diverse groups of stakeholders with widely varying needs	Ability to propose ways/means/solution to overcome the challenges posed by the rules and regulations imposed by the professional bodies, authorities, and other stakeholders				
		1	**2**	**3**	**4**	**5**
		Stakeholders addressed but with no consideration of conflicting requirements	Stakeholders addressed but with brief explanation of conflicting requirements	2 Stakeholders addressed with detail explanation of conflicting requirements	3 Stakeholders addressed with detail explanation of conflicting requirements	More than 3 Stakeholders addressed with detail explanation of conflicting requirements

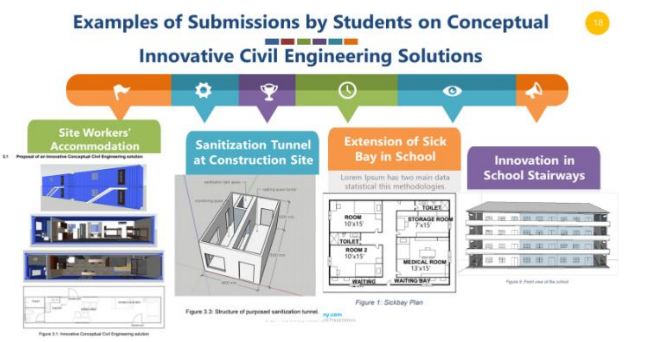

Figure 3. Examples of students' innovative solutions

The instructors play an important role in monitoring and controlling the process of selection the right community for their students to avoid duplication of the project themes. The students proposed a total of 90 different projects related to civil engineering fields. Some of the examples are Innovation in School Stairways, Sanitization Tunnel at Construction Site, Extension of Sick Bay in School, Site Workers Accommodation, Canvas Covered Building System with QR Code, Portable Quarters for Workers, Temporary Health Inspection System (THIS), Malaysia Emergency Special Force (KESF), Social Distancing System, Disinfection Tunnel of Site Workers, Portable Cabin Clinic, etc. Each project is unique in nature, and none of the projects is the same since the students need to choose different communities and observe and identify specific problems faced by the selected community. Next, the outcomes attained by the students for PO6 and PO8 are discussed in the following section.

Course Outcome and Programme Outcome Attainments based on EIS-SULAM Project

Table 4 displays the average grades awarded to each group for each task in the EIS-SULAM project. The following is a breakdown of the group and individual assessments: The group assessment was based on Tasks 1, 2, 3, and 4 and received a total score of 30%, while the individual assessment was based on Tasks 5, 6, and 7 and received a total score of 30%. CO2 and CO4 deal with PO6, whereas CO3 deals with PO8. While group assignments can achieve learning results those individual assignments cannot, they are notoriously difficult to grade properly for a variety of reasons, including but not limited to first, work is generally distributed unevenly among group members. Second, because collaboration limits a single student's ability to "control" the final product, lecturers may require members of a group to individually suggest a grade for "effort" for each of the group members, including themselves (peer assessment); and second, group work may not perfectly reflect the true abilities or effort of either a struggling student or an outstanding student. As a result, both individual and collective accountability were evaluated in this alternative assessment. The average individual achievement is only 61%, compared to 69% for the group. Task 3, which addresses CO2-PO6, has the lowest average mark (64%) in group assessment, while Task 5, which addresses CO3-PO8, has the lowest average in individual assessment. Thus, lecturers must propose an action to improve CO2 attainment for CQI purposes, which is the ability to explain the roles of engineering professional bodies to students, where they must propose an innovative conceptual civil engineering solution to the problem or the new normal, and further elaborate on new relevant issues relating to professional engineering practises for effective implementation of the proposed solution.

Figure 4 shows that, based on the EIS-SULAM project, each group has attained more than 50% of the cut-off point (red solid line) with an average PO6 of 68% (black perforated line). The distribution of marks is quite consistent among all groups with variances between 11 (max) and 8 (min).

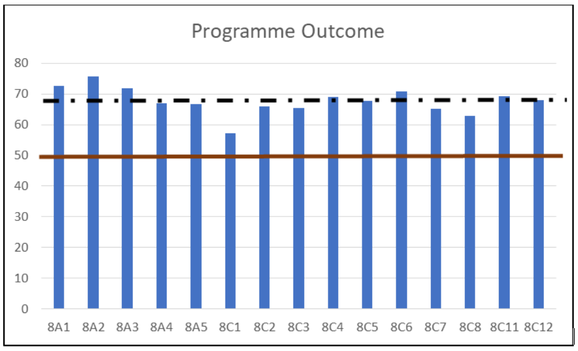

Figure 4. Programme Outcome (PO6) – Engineers in Society

Similarly, Figure 5 shows that, based on the EIS-SULAM project, each group has attained more than 50% of the cut-off point (red solid line) with an average PO8 of 60% (black perforated line).

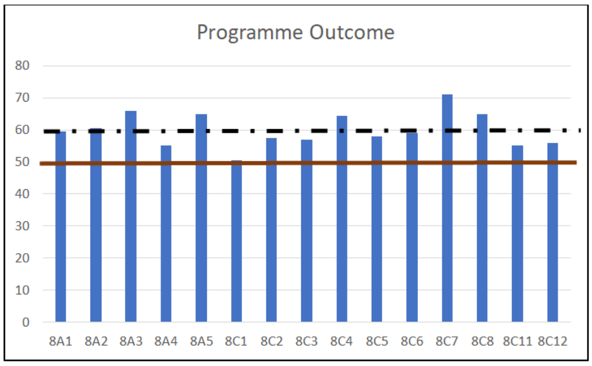

Figure 5. Programme Outcome (PO8) – Ethics

Table 4: Raw Marks for EIS-SULAM Project consisting of Group and Individual Assessment.

	Group Assessment (30%) (PO6-20% &PO8-10%)					Individual Assessment (30%) (PO6-20% & PO8-10%)							
Task & Group	Task 1 (5%) CO2-PO6	Task 2 (5%) CO2-PO6	Task 3 (10%) CO2-PO6	Task 4 (10%) CO3-PO8	**Total**	Task 5 (10%) CO3-PO8	Task 6 (10%) CO4-PO6	Task 7 (10%) CO4-PO6	**Total**	**Total (PO6&PO8) (60%)**	**PO6& PO8%**	**PO6 (%)**	**PO8 (%)**
8A1 (24)	4.1	3.8	7.9	6.6	22	5.3	6.5	6.7	19	40.9	68	73	60
8A2 (26)	4.3	4.1	7.3	6.8	23	5.3	7.6	7.0	20	42.4	71	76	61
8A3 (30)	3.8	3.9	7.2	7.7	23	5.5	6.7	7.1	19	41.9	70	72	66
8A4 (29)	3.3	3.7	6.6	6.0	20	5.0	6.9	6.3	18	37.8	63	67	55
8A5 (28)	4.6	3.6	5.5	7.5	21	5.5	6.0	7.0	19	39.7	66	67	65
8C1 (12)	4.2	3.2	5.3	4.8	18	5.3	4.1	6.1	16	33.0	55	57	51
8C2 (30)	4.1	3.8	5.8	5.9	20	5.6	6.1	6.6	18	37.9	63	66	58
8C3 (30)	4.4	3.6	6.2	6.6	21	4.8	5.3	6.7	17	37.6	63	66	57
8C4 (31)	4.0	3.9	6.9	7.4	22	5.5	6.4	6.4	18	40.5	68	69	65
8C5 (35)	3.5	3.6	5.8	6.0	19	5.6	7.0	7.2	20	38.7	65	68	58
8C6 (34)	4.0	2.9	7.6	6.3	21	5.5	6.7	7.1	19	40.1	67	71	59
8C7 (18)	3.4	3.4	6.3	8.3	21	5.9	5.9	7.1	19	40.3	67	65	71
8C8 (26)	3.5	3.4	6.0	7.2	20	5.8	6.2	6.0	18	38.1	64	63	65
8C11 (31)	4.5	4.3	6.0	5.7	21	5.3	6.5	6.4	18	38.7	65	69	55
8C12 (31)	4.3	3.5	6.1	6.0	20	5.2	5.8	7.5	19	38.4	64	68	56
Average	**4.0**	**3.6**	**6.4**	**6.6**	21	**5.4**	**6.2**	**6.7**	**18**	39.1	**65**	**68**	**60**

As shown in Figure 6, the mark distribution is relatively consistent among all groups, with variances for both PO6 and PO8. The average attainment of PO6 is 60%, which is lower than that of PO8, which is 68%. PO6 is measured through two (2) course outcomes, CO2 and CO4, while PO8 is measured through one (1) course outcome, CO3. Overall, the EIS-SULAM project constitutes 60% (40% for PO6 and 20% for PO8). The balance of 40% of the mark was from Test 1 (20% for PO8) and Test 2 (20% for PO6).

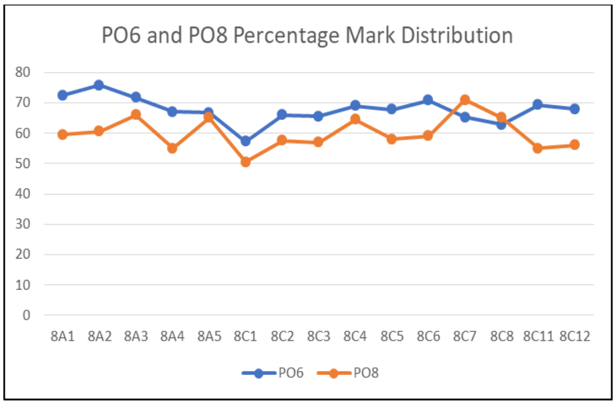

Figure 6. PO6 and PO8 distribution among groups

Figure 7 shows a bell curve that is symmetrical and indicates the normal distribution of grades achieved by the students based on the four assessments. It is concentrated around the peak and decreases on either side. In a bell curve, the peak represents the most probable event in the dataset, while the other events are equally distributed around the peak.

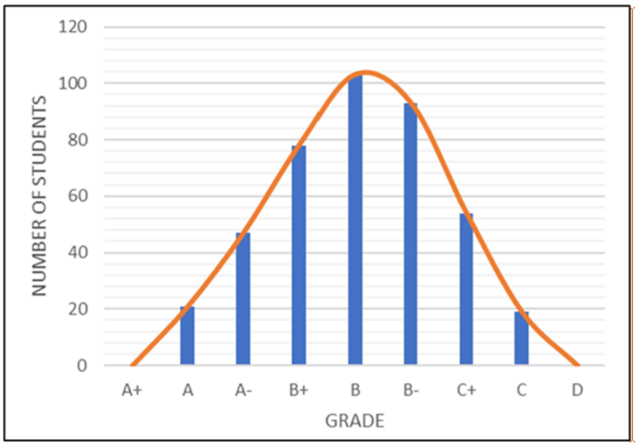

Figure 7. Normal distribution of Grade by Students for March – July 2020 Semester

Conclusions

During the COVID-19 pandemic, this study was carried out to design an innovative alternative assessment instrument for the Engineers in Society (EIS) course that incorporates the SULAM technique (EIS-SULAM) as the key element of the continuous assessment (60%). The instrument was developed to replace the final test in the Open and Distance Learning (ODL) using rubrics with comprehensive descriptors for each criterion. This exercise also served as a dry run for the SULAM project, as directed by Universiti Teknologi MARA (UiTM) and the Malaysian Ministry of Higher Education. Based on the measured course learning and programme outcomes, a document review was conducted to examine the assessment and student performance. Overall, this innovative alternative assessment instrument was utilized to evaluate students' performance in a real-world setting (community service) to develop engineering students' critical and creative thinking. The lecturers evaluated 90 reports submitted by 415 students using the assessment instrument, which was based on criteria established by the intended course outcome, programme outcomes, and the requirements for complex engineering problem characteristics. Students received a normal distribution of grades, with 20% receiving A+, A, and A-, 70% receiving B+, B, and B-, and 10% receiving C+ and C, according to the findings. All students scored higher than the program's 50% cut-off point for PO6 (Engineers in Society) and PO8 (Ethics), with 68 % and 60%, respectively. It is envisaged that the results of this study will be used to improve alternative assessment instruments in engineering courses involving community service learning, with the goal of improving societal well-being. The scope of this research is limited to a document evaluation of one engineering course at a Malaysian HEI. Future studies could include gathering input from students and lecturers on the assessment's implementation to improve the course's quality over time, comparing outcomes before and after SULAM implementation, and expanding to a few HEIs.

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Introducing Arduino as an Effective Online Distance Learning Tool in Final Year Project for Chemical Engineering Student

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Abstract
The Covid-19 pandemic crisis has transformed project-based education into virtual lab and non-experimental work. Student final year project (FYP) course particularly is in critical since it has bigger credit, involves more skill set development and conducted in two semesters. In this work, we highlighted the implementation of Arduino in FYP where the main objective of the work is to investigate the effectiveness of Arduino home based final year project for chemical engineering student's cognitive, psychomotor and affective skills. Comparison on learning satisfaction, obtainment of student skills and reflection from both student and examiners were thoroughly discussed. Surveys showed that student were reluctant to carry out the project in the beginning; however, they began to show more interest on the project as they started to understand the basic principle of Arduino operation. Both students and the examiners agreed that Arduino-based project had given significant impact on student cognitive skills at the level of *Application*, *Analysis*, *Synthesis* and *Evaluation*. On top of that, the psychomotor and affective skills were simultaneously and successfully developed in the remote learning process. It is evident that the proposed Arduino home-based FYP is affordable and effective for the development of student skill sets despite being supervised virtually.

Keywords: Online learning, final year project, project-based learning, Arduino, constructivism.

Introduction

The pandemic has affected and changed the landscape of higher education atmosphere. Globally, teaching and learning process is obliged to be implemented virtually and this triggered serious concerns on the readiness and effectiveness of the delivery and acceptance. Engineering courses suffered critically from this occurrence. This is especially in worrying state for courses involving practical sessions that normally require face-to-face interactions such as laboratory work and final year project (FYP). A Final Year Project (FYP) is an academic task and/or a small investigation work carried out by a final year student that is formulated specifically to solve a complex research-oriented engineering problem over the course of a year (Gusau et al., 2019; Tien et al., 2015). Engineering accreditation bodies worldwide has made such a project a compulsory requirement for any engineering undergraduate education programs (Tien et al., 2015). Although such project needs to be completed individually by every undergraduate student, it still requires supervision from an expert which in this case, the professors in the higher learning institute. Clearly, FYP is an essential two-way teaching-learning process. First, it is an opportunity for the student to put all the skills and knowledge he or she has acquired throughout their studies into practice and thus, solving real life problems (Gusau et al., 2018; Tien et al., 2015; Uziak, 2015). Secondly, it is also a chance for the educators to identify the achievement of each student in the content of knowledge gained during their studies and obtainment of relevant graduate attributes (Tien et al., 2019; Uziak, 2015).

Given the significance of such project, it must be carefully designed such that it is consistent with the outcome-based education methodology that enables the student to acquire the desired cognitive, psychomotor and affective skills (Gusau et al., 2018; Isa et al., 2020; Tien et al., 2019). Generally, FYP projects are structured to direct the student towards achieving the problem-solving skills (cognitive), demonstrates the capacity to utilize modern equipment (psychomotor) and developed a good communication skill through their oral presentation and thesis writing task (affective) (Gusau et al., 2019; Isa et al., 2020; Tien et al., 2019). This has never been an issue in the higher learning institution until the pandemic crisis commenced. Traditionally, students received their respective project title from the appointed supervisors and work to meet the project objective in a designated research oriented laboratory (Tien et al., 2019). However, due to the rising cases of COVID-19 pandemic, can the same level of achievements and commitments be achieved from both, the students and the supervisors? In Malaysia, statistic shows that the number of cases has raised to an alarming stage and forces the government to announce a strict movement control order (Singh et al., 2020). Such ruling has a direct impact on the execution of student final year project. Students are no longer allowed to go to the laboratory (Abdullah et al., 2020) and therefore, caused a major problem for engineering students who greatly depends on high-end machinery/equipment in their projects. Moreover, learning environment has now shifted to online education as opposed to the classical face-to-face project supervision (Fidalgo et al. 2020).

Online learning or emergency remote learning is an education that takes place over the internet i.e. a type of distance learning mainly carried out through video conferences, live chatting, streaming, etc. (Sun and Chen, 2016). In the context of FYP, abrupt changes to such e-learning surroundings limit the resources and options to the type of home-based project that have to be done by the students. Efforts have been made by professors in the higher learning institution to adapt to this new paradigm whereby choices are limited to non-experimental research such as simulation work, mathematical modelling, theoretical review study, and/or surveys-oriented research work (Arriafdi et al., 2021; Li et al. 2020; Sultana et al. 2017; Yaacob et al. 2020). Whilst this may fulfil the basic requirements of FYP projects but another issue arises; this sort of project is not really the main forte for engineering students where majority prefer hands-on experimental study. Students are wary on how such projects would develop their cognitive skills. Proceeding down this path especially for those who unwillingly participate would only build-up a negative mind-set for which students are only doing it for the grades and not because they are motivated by the obtainment of specific set of skills and knowledge prior to the completion of the project. By focusing on non-experimental research, the psychomotor skills of the students are not developed and not there to be assessed.

Alternative solution to this problem is to promote the use of Arduino as a tool for engineering student home-based final year project. Arduino is an open-source data acquisition device that could communicate with various sensors and actuators (Bada et al., 2013; Kurelovic et al., 2020; Zainal Alam 2020). It operates on Windows interface and merely cost about RM 30-45 per piece (USD 7 to 11). Coding for Arduino programming are easily obtained from the internet and do not require any software licensing to operate (Bada et al., 2013; Kurelovic et al., 2020; Zainal Alam 2020). Moreover, to certain extent, Arduino can also be linked to the internet and thus, could entice attractiveness of online education. Student can create a project that produces real-time data that is readable not only by the operator but also by anyone that have access to the internet or in other words; the development of IoT projects (Bada et al., 2013; Kurelovic et al., 2020; Zainal Alam 2020). Despite the advantages offered, Arduino is only widely applied by electrical engineering majors i.e. either in their teaching-learning curriculum or as part of their FYP (Husain et al., 2016). Lack of training and exposure by both professors and students of non-computer (or electronics) background could probably be the main reason why such research/educational tools such as Arduino is not extensively utilized by chemical engineering majors (Gunasekera et al. 2018; Reggio et al., 2020; Zainal Alam, 2020). Furthermore, given the choice; majority of chemical engineering students would rather opt for lab work with close supervision from the professors than to independently create their own prototype as their FYP. This limitation needs to be highlighted and solving it becomes the main driving force for the work carried out in this paper.

The aim of this paper is to investigate the effectiveness of Arduino home based final year project for chemical engineering student's cognitive, psychomotor and affective skills. Chemical engineers are technically engineers who involved extensively on production processes in the field of chemical related industry/sectors. Their main task included (but not limited to) process plant design, project cost estimation and scheduling, and handling of a variety of machinery/equipment in production of specific chemical (or biochemical) products. Introducing the basic of Arduino operation as part of their training process would indeed be beneficial. As a result, chemical engineers could then expand their expertise to the field of design and implementation of various process automation which can be applied significantly in any chemical based plants. In order to further justify the outcome of this work, comparison on learning satisfaction, obtainment of student skills and reflection from both student and examiners will be thoroughly discussed as well. Assessment on the study were made qualitatively (questionnaire, survey, and reflection) and quantitatively (interviews and student presentation marks). The paper is formulated to specifically answer the following research questions:

- Would Arduino platform be suitable to be utilized by chemical engineering major –who knows so little about Arduino – as a tool in their home-based FYP?
- Would Arduino be an effective online distance learning tool for self-learning and also for development of higher level student skills (cognitive, psychomotor and affective).

The whole idea is to train the chemical engineering based students to utilize Arduino for their FYP without the need to depending on what is available in the lab and supervision can be carried out using any online video conference platform. This way, the FYP can indeed be conducted online i.e. some kind of do-it-yourself (DIY) Arduino rig from home. Interestingly, such project can also be done face-to-face when there is more restriction related to the pandemic. The paper reported how we conducted the Arduino-FYP for chemical engineering students and assess their performance.

Application of Design

Course Description

The FYP is a core component for chemical engineering program in the School of Chemical and Energy Engineering, Universiti Teknologi Malaysia. It is regarded as an important capstone course. Each project is supervised by a member of the faculty and the outcome of the project is evaluated through written reports and oral presentations. Finding a supervisor for FYP can be a challenging task; nonetheless, it has become a general practice where FYP coordinator will announce number of project suggestions made by the member of faculty to the students. Appointed supervisors are responsible to advise students on any technical aspects of the project. It is also their job to assess the credibility of the chosen project and assist the student wherever is needed prior to the completion of the project.

FYP is a 4-6 credit hours course that is offered to the final year students and typically carried out over a one-year period (or two semesters). In the first part of the project (FYP I), students need to construct a brief project proposal that consisted of relevant background references (literature review on keywords associated to the project), project objectives and planning on how they intend to meet those project objectives. Also, it is the choice of the student to conduct preliminary experimental work to generate proof-of-concept data for the project. On contrary, FYP II (i.e. the second part of the project) will involve more excessive experimental work in which student will work aggressively to produce more data for their thesis. Student will start to analyse, validate and interpret their findings.

This paper will focus solely on the development and output of FYP II. FYP II is a project based learning (PjBL) and the general learning outcomes are as follows:

Learning outcomes	Assessment
Identify project objectives and scope (*Cognitive*)	Thesis report & Oral presentation
Perform literature review & background check (*Cognitive*)	Thesis report & Oral presentation
Design & carry out experimental work (*Cognitive & Psychomotor*)	Thesis report & Oral presentation
Justify & interpret results/ findings extensively (*Cognitive & Psychomotor*)	Thesis report & Oral presentation
Derive conclusion & recommends future work (*Cognitive & Psychomotor*)	Thesis report & Oral presentation
Show originality & practice moral ethics (*Affective*)	Thesis report
Communicate effectively through oral and writing (*Affective*)	Thesis report & Oral presentation
Life-long learning (*Cognitive*)	Thesis report & Technical paper
Work independently and confidently (*Affective*)	Thesis report & Oral presentation
Capacity to plan and manage research work (*Affective*)	Logbook & Oral presentation

The execution of movement control order due to the rising cases of COVID-19 pandemic has caused a bit of a hassle in the teaching-learning process of the FYP. Nobody is allowed to conduct any work in the laboratory and FYP must be completed via online distance learning approach. Both supervisors and students have raised some concerns due to this unplanned situation. Among the issues associated to implementation of FYP online included:

- Limited options for the type of FYP for the students. Many decided to go for simulation work and/or theoretical study work.
- Poor internet connectivity prevents sufficient communication between supervisors and students
- Software licensing prevented students from using necessary software for modeling and simulation work
- Lack of motivation and/or idea in creating home-based projects with limited resources.

Theoretical background

Students involved in this project have undergone 3 years of formal fundamental chemical engineering education. Hence, they are expected to apply their problem solving skill via the application of knowledge they gained earlier. To approach this scenario, Constructivism Theory is adopted. In general, constructivism theory involves the building-up of knowledge by learners through real-life action, hands-on experiences and any previous formal learning. Knowledge is effectively gained whilst dealing with a real-world and authentic problem (Jumaat et al., 2017). FYP is a project-based learning that is in-line with the constructivism approach. Teaching and learning activities (including evaluation) of FYP are associated to the development of specific learning outcomes (Jumaat et al., 2017; Roessingh and Chambers, 2011). Each project will trigger student constructive investigation where it includes inquisition, problem solving, decision making, determination and active engagement with the supervisors (Jumaat et al., 2017; Roessingh and Chambers, 2011).

In this work, constructivist principles is incorporated in project-based learning by designing the FYP to focus on authentic or real-life problem that is closely related to their respective engineering program. Moreover, students are required to solve a specific task using a tool and/or technology whereby in this context, Arduino is proposed. Jumaat et al. (2017) highlighted that the use of technology in a project-based learning would sharpen students' problem solving skills. Technology adoption such as Arduino is regarded as educational tools that would assist students construct their knowledge in a real-world setting.

Course Description

Face-to-face meetings and lab work is no longer feasible because of the restriction in the movement control order ruling at the point where this paper is written and since the past 16 months. Due to this unavoidable circumstance, online learning platform is the main settings for the proposed home-based FYP project using Arduino. Since FYP topics related to Arduino is rather new to our targeted chemical engineering students (having no or very little knowledge on Arduino) and also to prevent any research work on non-technical topics, suggestions for Arduino home-based FYP topics were made by the supervisors.

Upon receiving topics for their projects, students had about 14 weeks to complete it. In the first four weeks, video conferencing with the supervisors were organized at least once a week via Google Meet or Webex. Discussions were also held using emails and/or WhatsApp platform. These online meetings were essential to discuss project progress and opportunities for the supervisors to help students understand the scale of the project. Students were advised to do in depth reading on Arduino and started to design the necessary circuit and hardware for the projects in the first two weeks upon initiation of the project. The work was also designed in such way that students would complete their rig within a month time prior to coding and troubleshooting phase which normally is the bottleneck for projects involving the use of Arduino. This is imperative such that students would have ample time to run the setup and generate sufficient data for their thesis between week 8 and week 12.

Once students started to actively engage in the project, frequency for online meetings reduced to once every two weeks. This is simply to let the students focus on the hands-on work rather than to let them ask too many questions about the subject. Students were also advised to record their weekly activities and/or any technical information they discovered in a project-related log book. That information would assist students on their thesis write-up. Students were strongly recommended to start their thesis writing right away while carrying out their work. This is because writing the thesis report is not difficult when students just finished up each milestone rather than to discuss and compiling it at the end of the semester. Finally, students submitted the first draft of their thesis on week 14 in order to allow sufficient time for supervisors to read it and suggest necessary improvements. Further discussion from week 14 onwards was simply about student preparation for their thesis presentation which was held in the week 16 of the semester.

Evaluation of Attainment of Cognitive Level & Project Based Learning

In this study, the effectiveness of the proposed Arduino home-based online FYP was evaluated qualitatively where data were acquired through survey, questionnaires, reflection and interviews. The first evaluation is on the students' project output and the learning process of each student. Evaluations on the student output were carried out in stages i.e. upon achieving each project milestones. Students presented their outcome during online meetings and assessments/recommendations were made based on the students' achievements. This is a type of formative assessment where it helps to track the progress of the PjBL and also help the students to reflect on their learning and its connection to the project objectives and the efforts made. Secondly, a questionnaire survey using multiple choice questions was used to assess student learning process with respect to their FYP progress. Details of the questionnaire are presented in **Appendix A.**

Investigation was also performed to study about student learning satisfaction and feedback on the project they participated in. This was done using Likert scale questionnaire. Details of the questionnaire used are given in **Appendix B and Appendix C**. These questionnaires were structured specifically to assess student responses about the project and to find out to what extent student was able to appreciate the project, Moreover, students were also required to give reflection on the things they have learnt from the project and comment weather such project would benefit them as an engineering student. Thematic analysis was performed on the feedbacks received in which important text/comments were first identified before grouping them into themes that are related to the research questions imposed for the activity (Azizan et al., 2018). In this case, suitability and effectiveness of Arduino as a tool in student home-based FYP could be analysed.

For evaluation on the achievement of the FYP learning outcomes, another set of questionnaire survey using multiple choices questions were given to the students after they have completed their final presentation of the project. The survey aimed solely at the development of student cognitive skills after completing the project. Details of the survey used are shown in **Appendix D**. Additionally, a brief interview was also conducted with the examiners (i.e. those who were appointed to evaluate the students' final presentation) in order to assess their perception on how the proposed Arduino home-based FYP had affected the students critical thinking. The set of question used for the interview are as follows:

COGNITIVE LEVEL – APPLICATION

1) In your opinion, does the student **APPLY** sufficient/necessary knowledge associated to engineering field in formulating the project methodology?
2) Is the student independently capable in **CONSTRUCTING** the hardware/software part of the project?

COGNITIVE LEVEL - ANALYSIS

1) In your opinion, does the student have the capacity to **COMPARE** suitable engineering theory with the practical work conducted?
2) Does the student have the ability to **IDENTIFY** and **ANALYZE** (or trouble-shoot) problems occur in the project?

COGNITIVE LEVEL - SYNTHESIS

1) In your opinion, does the student have the capacity to **DESIGN/FORMULATE** the hardware/software of the project with appropriate engineering elements independently?
2) Does the student have the ability to **RECOGNIZE** any issues pertaining to the project and recommend suitable improvement for future work?

COGNITIVE LEVEL - EVALUATION

1) In your opinion, does the student shows the capacity to **INTERPRET** the results of the project appropriately and creatively link it to relevant engineering knowledge?
2) Does the student have the ability to **EXPLAIN** the output of the work in orderly fashion?

A thematic analysis was also performed on the student reflection on the work given. A deductive approach was carried out to identify and/or search for repetitive keywords. Patent or keywords of interest in our analysis are the ones closely related to the development of student cognitive, psychomotor and affective skills.

The Results and Discussion

Students Output and Learning Process

The effectiveness of carrying out Arduino home-based projects as FYP on the development of student cognitive levels was investigated. Evaluation was performed on ten different projects that were carried out by Chemical-Bioprocessing students from Universiti Teknologi Malaysia (UTM) for the period of 2 years. Due to limited resources, it was decided early on that titles for the students FYP were restricted on the topics that are associated to online monitoring in the area of agriculture and basic engineering works. It was believed that these types of projects can easily be implemented at home and low cost. The student performance exceeded our expectations and some of the examples of Arduino home-based FYP implemented are shown in **Figure 1** where one of the FYP topics were on the online monitoring of energy input from the solar panel. The project is closely related to one of the sustainable developments goals (SDGs) i.e. the use of affordable and clean energy (SDG7). In this project, student built a data logger using Arduino to continuously monitor the energy generation (in DC voltage values) from a 100W solar panel. The student also investigated the effectiveness of using solar energy to operate a water pump for watering a back yard size home garden. The second FYP example is the establishment of monitoring of water flow and quality of an aquaponics platform using Arduino. Additionally, a 50W solar panel was utilized for the water pump operation as well. Both projects were fully funded by our team and the cost of each project was less than RM 200 (USD 48).

Figure 1. Output of FYP Arduino home-based projects where student work on the establishment of online monitoring of solar energy generation (left) and online monitoring of bench-top aquaponics platform (right).

Overall, all students participated in our Arduino home-based FYP projects undergone different stages of learning. Upon receiving their task (topic), students were a bit intimidated at first. This is because most of them did not have any experience with Arduino. The students were only taught about the basic of Arduino

(Kurelovic et al., 2020). Clearly, the students were lack of confidence to work on the project on their own. Initially they asked so many questions rather than to look for answers on their own. The learning curve on various aspects of the project is illustrated in **Figure 2**. In the first couple of weeks, we had to guide them and fully supported their work. Students found that they were unable to initiate the project. Nevertheless, it changes as the project progresses. Students started to build-up interest on the topic and started working on building their rig. The essential part of supervising this type of FYP is that we have to let them explore the project and allow them to realize the experimental setup on their own. 'Word-for-word' instructions are not necessary as most of the information needed for them to realize the project is available in the internet. Materials for the rig can be attained from local hardware store and coding for Arduino programming work can be learned from various open source platform (e.g. *YouTube*). It can be seen in **Figure 2**, students mind setting on the difficulty of the project they were working on changes significantly from 'extreme' to 'relatively easy' over the period of 14 weeks. Our hypothesis on the fact that there was a significant improvement on student mind setting and skill sets as the progress progresses from week 2 until week 14 was also confirmed statistically where results attained were compared using the two level independent-means t-test. Data showed that the result on the two groups tested (i.e. between week 2 and week 14) was significant in which the p-value is 9.555×10^{-21} ($p < 0.05$).

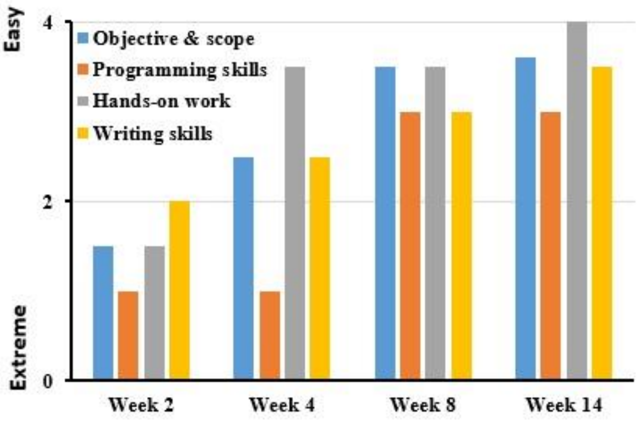

Figure 2. Summary of formative assessment to track student learning progress during FYP.

Student Learning Satisfaction and Reflection

Learning satisfaction depicts the student feeling and their reflection after the teaching and learning sessions. It can promote a positive environment and boost the student's morale if they enjoyed the process. Therefore, it is important to measure the student satisfaction on this hands-on Arduino project. **Figure 3** shows the summary of the assessment made on student learning satisfaction in working with Arduino home-based FYP. The first question in the questionnaire is about difficulty level on learning how to operate Arduino. Half of student (52%) agreed that learning Arduino was easy. This gave a positive impression on Arduino based project. The result from survey found that majority of student which was 84% of them did not prefer modeling work or simulation based project. It is aligned with the fact that 85% of the students were happy to participate in hands-on Arduino project. After 14 weeks completing the task given, 95% of the students found that learning Arduino is fun. Where, 85% of them strongly agreed that hands-on (DIY) project based could improve their skills as engineering student. All students agreed that they learned a lot from Arduino project. More than half of the students found that DIY Arduino based project is interesting and requires minimal supervision during completion of the task. Majority of them are happy to participate in this Arduino based project again in future and also, three quarters of the students will share their knowledge and findings with friends while working on the project.

Meanwhile, **Figure 4** summaries the assessment made on student feedback in working with Arduino home-based FYP. At the beginning of the project, there were mixed responses as whether the students have experience or not working with Arduino. It was found that 43% of the student did not have any experience with Arduino program. However, they think positively where majority of them reckoned that the assembling hardware/software was not difficult. They were willing to learn a new thing and need minimal supervision from the supervisor. Nearly 80% of them could solve technical problem and hands-on problem on their own. On the other hand, it was found that most of the students were not comfortable with algorithm thinking - where they have problem in coding writing and designing a program. This was probably a result from lack of practice after completing their fundamental courses in programming taken back when they were in their first year of their study. Despite of that problem, they still enjoyed to explore this Arduino project and passionately seeking solution to a problem that was given to them. Majority of them strongly agreed that they did not complete this hands-on Arduino project just for the grades, which is a pleasant feedback.

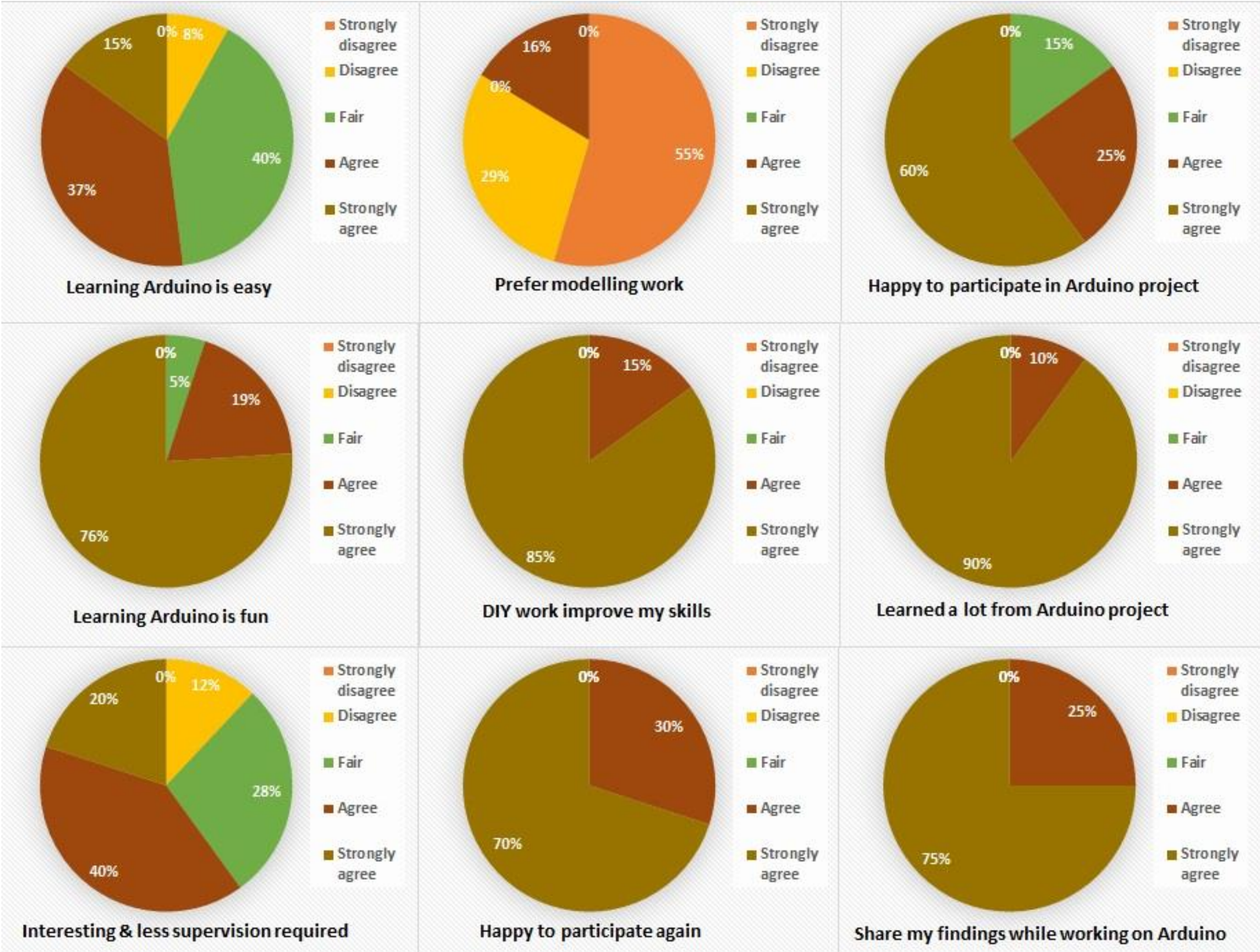

Figure 3. Student learning satisfaction in working with Arduino home-based FYP.

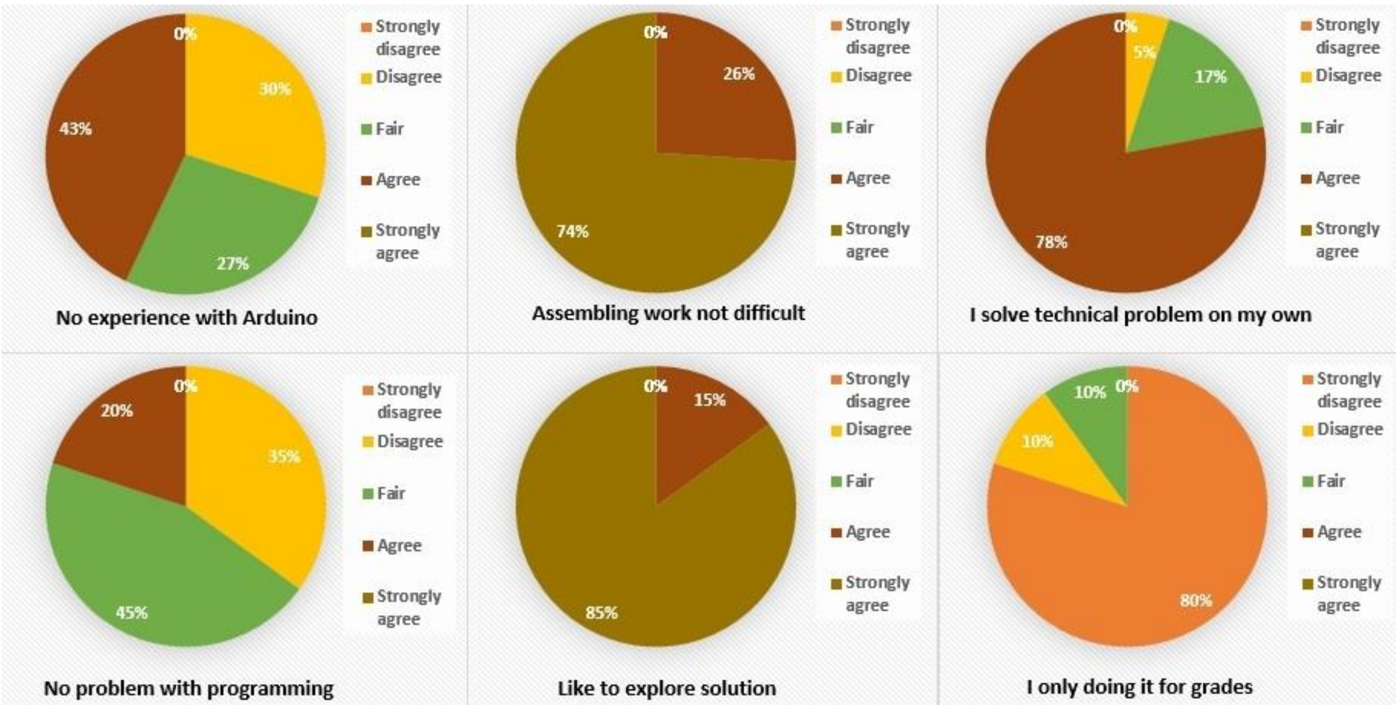

Figure 4. Feedbacks from students that worked with Arduino home-based FYP.

Table 1 shows the reflections of the students who participated in this study. It can be concluded that most of the students looked at this project as a new line of work (or subject) and the task is very challenging. It is difficult at first and they needed some time to digest the concept of Arduino. However, with only minimal supervision, they managed to overcome all the challenges and completed the project. This project fulfilled the learning outcomes which focus on work independently and confidently, which could encourage student's lifelong learning skill. At the end of the project, students enjoyed the task and explored new tools willingly by themselves. They reckon that this is useful for their future career and helps improved their hands-on skills. From **Table 1**, the skills attained by students based on the keywords can be quantified as follows -Cognitive: 16; Psychomotor: 11; and Affective: 15. The result indicates frequency the keyword that reflected to the specific skill domains category have been mentioned or indicated by the students. It is imperative to take note that in general Arduino based FYP project successfully managed to extract the core skills required for this course even though it was conducted remotely. Cognitively, students managed to deeply learn as they were able to apply, analyze, synthesize and evaluate their research work. While other FYP projects opted for non-experimental research that contributed zero psychomotor skills to the students, this Arduino based FYP project manage to yield psychomotor skills for its student. The affective skill domain which deals with emotional aspects such as feelings, values, appreciation, enthusiasms, motivations, and attitudes can also have been obtained from the inference of the student's reflection. Student 1 and 7 did highlight that they have prior knowledge and experience on working on Arduino; however other students did not mention anything about it. Other students may have indirectly used their programming skills knowledge from their first year to successfully bridge their comprehension on Arduino programing. These indicates the support and realization from the Constructivism theory.

Table 1. Reflections from the students about aspects they learned and benefited from the work.

Reflections	Keywords
Student 1 I have got some basics about Arduino and decided to do something a bit more complex. It is not so difficult and I managed to solve everything on my own with very little help from my supervisor. Got to learn new hands-on skill.	got some basics * complex [a] not so difficult [c] managed to solve [a] got to learn [a] hands-on skill[b]
Student 2 I really like it. A lot of independent design work though. Easy to gain knowledge because work everything from scratch.	like it [c] independent design work [a] gain knowledge [a] work everything from scratch [b]
Student 3 Not really my first choice. However, it gets interesting and I get to practice my hands-on skills. Have to be independent to make the project work.	gets interesting [c] get to practice / hands-on skills [b] be independent [c] make the project work [a]
Student 4 Nice project. Good for those who likes to design stuff. A bit challenging with coding.	nice project [c] design [a] challenging [c]
Student 5 Arduino project is really cool. Coding and hardware makes you good in hands on. Work everything on my own and sometimes difficult but good project.	really cool [c] hands on [b] work everything on my own [b] sometimes difficult [a]
Student 6 It needs a lot of hard work in the beginning but paid off in the end. Really like the work and very different from running typical experiments using complex equipment.	hard work [c] paid off in the end [a] like the work [c] very different [b]
Student 7 Arduino is very interesting project. Plus, I have learned a little bit about it in my second year. The project helps me to work independently, explore new tools and improve my hands-on skills.	very interesting project [c] learned a little bit [a, *] work independently [c] explore new tools [a] hands-on skills [b]
Student 8 Learned about Arduino before. Luckily have basics to can build my setup on my own with not much supervision. Enjoy it as I get to explore many new things and good hands on project.	Learned [a] before * build my setup [b] not much supervision [c] explore [a] hands on project [b]
Student 9 I was nervous when starting working on the project. Don't know anything about Arduino. However, was surprise everything can learn from internet and I built my setup using stuff from hardware store. I enjoyed the project.	nervous [c] can learn from internet [a] built my setup [b] enjoyed [c]
Student 10 It's a very good project. I managed to learn about new skills and new knowledge on solar and renewable energy.	good project [a] new skills [b] new knowledge [a] good for my future [c]

This is good for my future as engineer. Glad I picked this.	

* Constructivism Theory
a Cognitive
b Psychomotor
c Affective

Assessment on Development of Cognitive Skills

After completing the project, all of the students voluntarily filled-up the general survey form given to them. The surveys were conducted to assess the student on the development of specific aimed cognitive skills during this home-based Arduino FYP work. As previously described, four different levels of cognitive skills associated to FYP i.e. *Application*, *Analysis*, *Synthesis* and *Evaluation* were assessed in the survey. The results of the survey were analyzed and depicted in **Figure 5**. According to the results attained, majority of the students (i.e. more than 70 %) claimed that they have excellent achievement in the *Application*, *Synthesis* and *Evaluation* cognitive levels through the proposed FYP. The rest were convinced they had good accomplishment in the same levels. It is suspected that student direct involvement on the Arduino project has nurtured their skills on the matter.

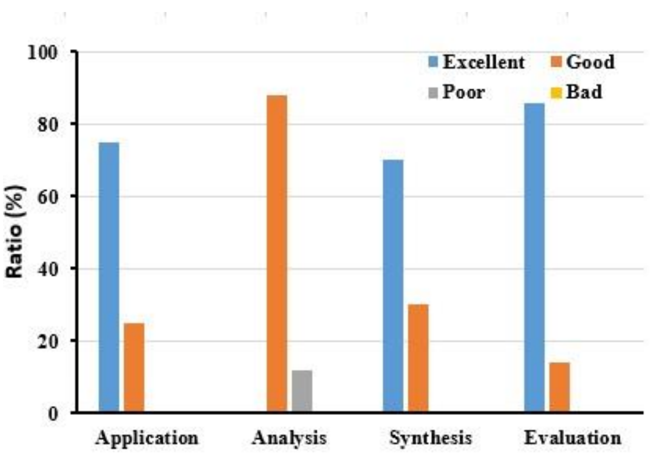

Figure 5. Summary of the general survey conducted to determine the development of student cognitive levels upon completing the FYP work.

Student designed their own rig based on their creativity. Ability to formulate and realize their own setup enabled them to reach the *Synthesis* levels. The '*Application skills*' were obtained through application of knowledge (gathered after searching through the internet for relevant information). The information is mainly about circuit diagram and coding prior to realize their setup. The final phase in building-up their rig was the troubleshooting stage where student evaluated the workability of their setup. Any problem occurring was solved independently and thus, allowing them to excel in the '*Evaluation*' cognitive skills. With high percentage (86%) of excellent achievement in evaluation skill which is the highest level of Bloom's taxonomy means, that most of the student are independently able (without help) to interpret the output of the project and make necessary comparison to evaluate its functionality after they have completed the design and create their own algorithm in the Arduino-based FYP.

Contrary to other cognitive levels achievement, students were less convincing on their achievement for the '*Analysis*' skills. About 88 % of the students have achieved good in analysis skill through Arduino home-based online FYP, which means, with some help, the students are able to identify most of the components/parts accurately and able to code/ trouble shoot a program properly. Only 12 % of the students have responded that they poorly perform in the analysis skill. This is probably because of lack academic background on electrical/electronic component and computer programming which made it a bit difficult for them to identify any components/ parts accurately and trouble shoot a program properly even though they receive help from their peers and supervisors. Nevertheless, this did not impose any major obstacle for the student in completing their project.

At the end of week 14, students presented their work to several examiners in a formal evaluation setting. After evaluation, we conducted an interview session with the examiners to get hold on their perception on how the Arduino home-based FYP had affected the student's cognitive skills development. Selected comments from the examiners are summarized in **Table 2**. Their comments were analyzed and relevant keyword related to the student skills developments were categorized accordingly. It was found that majority of the examiners expressed their satisfaction with student involvement in the Arduino home-based FYP as enjoyable and amazing project. While the FYP was carried out in home-based mode, most of the examiners found that the students were able to work independently and present their project in great details.

The examiners collectively agreed that the students working on the Arduino home-based FYP had achieved most of the important skills required. The cognitive skill levels assessed covered the application skill up to the highest level of Bloom's taxonomy, which is evaluation skill. However, examiners highlighted that the communication skills of students were average and require more practice for significant improvement. Students lack of confident in presenting the information about Arduino perhaps due to the differences in their academic background. It was also suspected that less training and time were spent on supervising the students on the best way to present their home based project which was done virtually (Webex platform). The fact that students dwelled in their home since the pandemic is also believed to influence the student's emotion, communication and presentation skills as they interact normally with each other drastically lesser compared to when they were face to face in university. Collaboration of both supervisors and FYP coordinator are required in helping and supporting student's to overcome issues that require improvements.

Table 2. Examiner's comment on the performance of student's working on Arduino home-based FYP.

Comments from examiners	Keywords
It seems that these students really enjoyed working with Arduino. They can surely translate what they have been working on and has no problem linking their findings with actual theory. Everything was built by themselves and definitely have achieved a solid cognitive level of synthesis and evaluation.	really enjoyable [c] can translate what they have been working on [a] linking their findings [a] built by themselves [b] achieve solid cognitive level [c]
They did an amazing FYP work. The students did manage to describe every details of the project they worked on. It shows the project has trained them on achieving cognitive level of application, synthesis and a solid analyses level.	describe every detail [a] the projects have trained them [a]
They can definitely present their work because they work on their project independently. They understood and knows very well on how to apply (and evaluate) basic engineering knowledge even though Arduino is very new to them. Needs more practice in their communication skills.	present their work [b] work on their projects independently [a] understood and knows [a] how to apply [b] need more practice [b]
The students did understand everything they built. Some still needs to do a bit more reading. Communication skills on knowledge sharing is still average. Nevertheless, the FYP surely improved their cognitive levels of analyses, application and evaluation.	understand everything [a] Communication skills [b] Improved their cognitive [a]

[a] Cognitive [b] Psychomotor [c] Affective

From **Table 2**, the skill domains attained by students based on the keyword gathered from examiner's comments can be quantified as follows - Cognitive: 8; Psychomotor: 5; and Affective: 2. In general, the examiners acknowledged the psychomotor domain achieved by the student's FYP project. This finding is consistent with previous discussion on **Table 1** earlier. Since the evaluation is always more on checking of student's cognitive ability, examiners commented more on this while the affective domain was low because this was not the main focus of the formal evaluation. Overall, findings gained from this study provided useful information that proved the effectiveness of Arduino implementation on the home based FYP for the development of chemical engineering student's cognitive, psychomotor and affective skills in the context of remote learning. Arduino platform can be utilized by chemical engineering major even they knew very least about Arduino.

Conclusion

The suitability of applying Arduino in non-electrical (electronic) engineering students FYP and its effectiveness as a home-based project for development of final year student cognitive skills was investigated. Surveys show that student were reluctant to carry out the project in the beginning (due to lack of knowledge and skills on Arduino); however, they began to show more interest on the project as they started to understand the basic principle of Arduino operation. Students did not show any major issues in assembling the hardware needed in realizing their rig. Coding of the Arduino setup posed some challenges but students managed to overcome it through online resources and sharing of knowledge with their peers. Both students and the examiners agreed that such Arduino-based project had given a significant impact on student cognitive skills at the level of *Application*, *Analysis*, *Synthesis* and *Evaluation*. Apart from this, student also showed creativity in solving problems pertaining to the project and less relying on their supervisors. Clearly, not only the proposed Arduino home-based FYP is affordable but it also supported the idea of online distance learning that offers a valuable skill sets for the student.

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Appendix A. Rubrics of the questionnaire used to evaluate student learning process

	EASY	MODERATE	DIFFICULT	EXTREME
Defining project objective & scope of work	Able to determine objective and define the boundaries of the project without any supervision.	Able to determine objective and define the boundaries of the project with very minimal supervision.	Would require significant amount of help from the supervisor to determine project objective and scope of work.	Unable to formulate the project objective and scope. All information comes from the supervisor.
Programming skills	I have learnt about such programming before and have a strong basis to work on it independently.	It is a bit out of my forte but willing to learn about it from the open sources.	It is a little bit confusing at times but with constant help from the supervisor I can manage.	This is completely beyond my capacity and need constant help and supervision.
Hands-on/ practical work	I do not have any issues assembling the setup and get my hands dirty.	It is a bit challenging but with minimal supervision, I can manage.	This is completely beyond my capacity and need constant help and supervision.	Irrelevant. No practical / hands on work needed.
Write-up: Results & discussion	I have no issue in presenting my data and discuss my results in the thesis.	It is a bit challenging but with the guidance from my supervisor and information from the literature I can manage.	I am not able to do this without some assistance from my supervisor.	This is completely beyond my capacity and need constant help and supervision.

Appendix B. Likert scale questionnaire used to evaluate student learning satisfaction on the Arduino home-based projects they participated in.

1. Learning how to operate Arduino is very easy.	1	2	3	4	5
2. I would prefer to do modelling or simulation based project	1	2	3	4	5
3. I am happy to participate in a project involving Arduino.	1	2	3	4	5
4. Learning how to operate Arduino is fun.	1	2	3	4	5
5. Hands-on and DIY work does help me to improve my skills as an engineering student.	1	2	3	4	5
6. I learned a lot from this Arduino based project.	1	2	3	4	5
7. DIY Arduino based project is interesting and do not requires much supervision.	1	2	3	4	5
8. I would be happy to participate in this Arduino based project again.	1	2	3	4	5
9. I shared my knowledge and findings with my friends while working on the project.	1	2	3	4	5

(1-STRONGLY DISAGREE, 2- DISAGREE, 3- FAIR, 4-AGREE, 5-STRONGLY AGREE)

Appendix C. Likert scale questionnaire used to evaluate student feedback on the Arduino home-based projects they participated in.

1. I do not have any experience working with the subject.	1	2	3	4	5
2. Assembling the hardware/software is not a problem for me.	1	2	3	4	5
3. I solve technical and other hands-on problem on my own.	1	2	3	4	5
4. I have no problem with algorithm thinking and programming (coding).	1	2	3	4	5
5. I like to explore and find solution to a problem related to the project.	1	2	3	4	5
6. I found learning this type of project is a bit frustrating and I am only doing it for the grades.	1	2	3	4	5

(1-STRONGLY DISAGREE, 2- DISAGREE, 3- FAIR, 4-AGREE, 5-STRONGLY AGREE)

Appendix D. Questionnaire survey used to assess the development of student cognitive skills upon completing the Arduino home-based online FYP.

Cognitive levels	Excellent (4)	Good (3)	Poor (2)	Bad (1)
APPLICATION Apply engineering knowledge learnt in class to **construct** circuit and hardware needed for the project.	I am able to apply basic engineering knowledge to construct the circuit/ hardware accurately with no errors and do not need any help.	I am able to apply basic engineering knowledge to construct the circuit/ hardware accurately with few or no errors and may need some help.	I am barely able to apply basic engineering knowledge to construct the circuit/ hardware accurately even with some help.	I don't know how to apply basic engineering knowledge to construct the circuit/ hardware accurately even with some help.
ANALYSIS Trouble shoot the workability of a project/equipment constructed and **identification** of coding and parts.	I am able to identify every components/ parts accurately and able to code/ trouble shoot a program properly without help.	I am able to identify some but not all the components/ parts accurately and able to code/ trouble shoot a program properly with some help.	I barely can identify any components/ parts accurately and code/ trouble shoot a program properly even with help.	I can't identify any components/ parts accurately and code / trouble shoot a program properly even with help.
SYNTHESIS Ability to **design** a functional device/project to perform a specific task. Integrate training and various resources to solve a problem.	I can design and create my own algorithm properly and project without help.	I can design and create my own algorithm properly and project with some help.	I can barely design and create my own algorithm properly and project even with some help.	I can't design and create my own algorithm properly and project even with some help.
EVALUATION				

Make judgements and **interprets** on the output and the functionality of the project.	I am able to interpret the output of the project and make necessary comparison to evaluate its functionality without help.	I am able to interpret some of the output of the project and make necessary comparison to evaluate its functionality with some help.	I am barely able to interpret the output of the project and make necessary comparison to evaluate its functionality even with some help.	I can't interpret the output of the project and make necessary comparison to evaluate its functionality even with some help.