Ghafour Amouzad Mahdiraji
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Engineering Grand Challenges in Scholar Programs

Springer

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Edwin C. Y. Chung graduated from Monash University (Clayton) with a Bachelor of Science majoring in Computer Science, a Bachelor of Engineering with first-class honours majoring in Electrical and Computer Systems Engineering and a Ph.D. in the area of asynchronous circuit design. He started his career in the semiconductor industry and has experience in both the design and manufacturing sectors of the industry. He has worked as an individual contributor as well as project and team leader for various projects. He has also worked on various products design ranging from a 3G baseband processor, while with NEC Australia, a 32-bit microRISC controller core while he was with Motorola in Adelaide to a firmware for a keyboard scanner for Atmel in San Jose. Prior to joining Taylor's University, he was an Innovation Consultant with Kwerkus Six—a startup he co-founded with five other ex-Intel staff from Intel's IT Innovation Centre. During his time with Intel's IT Innovation Centre and Kwerkus Six, he has introduced

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Mohammad Hosseini Fouladi started his career as an engineer in one of the subsidiary companies of the South Pars Gas Field, Iran. He was a postdoctoral researcher at the National University of Malaysia (Universiti Kebangsaan Malaysia) before joining the Taylor's School of Engineering in January 2010. He bagged the prestigious Vice Chancellor's Award as 'Taylor's Most Cited Academic 2014'. He is a Chartered Engineer and a member of MIMechE, UK. He was promoted to Associate Professor in January 2015. His areas of expertise are sound and vibration as well as machine condition monitoring.

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Chapter 1
The Taylor's Grand Challenges Scholars Program: Preparing for Tomorrow's Solutions by Engaging with Students Today

Douglas Tong Kum Tien, Satesh Narayana Namasivayam and Se Yong Eh Noum

Abstract The National Academy of Engineering (NAE) in the US has identified 14 Grand Challenges in engineering confronting humanity. It is imperative to overcome these challenges in order for humanity to have a sustainable future. Consequently, the NAE through the initiative of several US-based universities has created the Grand Challenges Scholars Program (GCSP) to produce future engineering trained leaders capable of taking on these challenges. What began as a North American initiative has since expanded globally with Taylor's University's School of Engineering (SOE) in Malaysia being the first engineering school outside of North America to receive approval from the NAE to conduct a GCSP. This chapter details the initiatives undertaken by SOE in helping to meet the NAE's objectives through its Taylor's Grand Challenge Scholars Program.

Keywords Grand Challenges Scholars Program · Key competencies
Program outcomes

1.1 Introduction

The National Academy of Engineering (NAE) in the US has identified 14 Grand Challenges in engineering which are required to be overcome for humanity to have a sustainable future [1]. These Grand Challenges were identified by a panel convened

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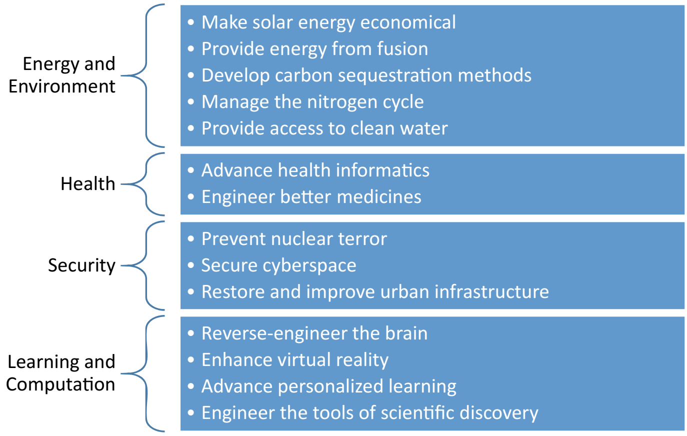

Fig. 1.1 The list of 14 Grand Challenges for engineering

by the NAE consisting of 18 engineers, technologists, and futurists that included Google co-founder Larry Page and genomics pioneer J. Craig Venter. The panel had spent more than a year contemplating how to improve life on earth and this resulted in them developing a list of 14 Grand Challenges [2]. These Grand Challenges encompass four broad realms of human concern, namely, environmental sustainability, health, reducing humanity's vulnerabilities, and joy of living.

As stated by the NAE with regard to the Grand Challenges [1]: "… *the century ahead poses challenges as formidable as any from millennia past. As the population grows and its needs and desires expand, the problem of* ***sustaining*** *civilization's continuing advancement, while still improving the quality of life, looms more immediate. Old and new threats to personal and public* ***health*** *demand more effective and more readily available treatments.* ***Vulnerabilities*** *to pandemic diseases, terrorist violence, and natural disasters require serious searches for new methods of protection and prevention. And products and processes that enhance the* ***joy of living*** *remain a top priority of engineering innovation, as they have been since the taming of fire and the invention of the wheel.*"

Hence, the vision of the NAE [3] regarding the Grand Challenges is about the "*Continuation of life on the planet, making our world more sustainable, secure, healthy, and joyful.*"

The list of the 14 Grand Challenges is shown in Fig. 1.1 [1]:

This massive effort would span more than a single generation and will require multifaceted solutions. Therefore, the NAE through the initiative of several US-based universities has embarked on an initiative known as the Grand Challenges Scholars Program (GCSP) in 2009. Its intention is to produce future engineering trained leaders who would be capable of spearheading the efforts to take on these challenges.

As stated in the draft document for proposing a GCSP [4], "*The explicit objective of the national GCSP is to develop a nation-wide network of Grand Challenge Scholars Programs within participating schools that will educate the future leaders of the NAE Grand Challenges.*" It was apparent from the "*nation-wide*" emphasis that the vision of the NAE at the inception of the GCSP was limited to North America only. However, Taylor's University's School of Engineering in Malaysia caught this vision and has since had the distinctive privilege of becoming the first engineering school outside of North America to have an approved GCSP. Since then the GCSP has become a worldwide phenomenon. Several other engineering schools outside of North America, namely, in Asia, Europe, and Australia, have since also received NAE's approval to conduct the GCSP.

NAE granted Taylor's SOE the approval in 2015. Having received NAE's approval, the students in SOE's B.Eng. (Hons) programs who achieved the requirements of the Taylor's Grand Challenge Scholars Program (TGCSP) would receive certificates as a Grand Challenge Scholar from the NAE.

Although approval was received in 2015, nevertheless, the TGCSP was initially introduced to the first semester students of the School of Engineering (SOE) as early as the August 2012 intake. This introduction preceded the submission of the SOE's GCSP proposal to NAE and its subsequent approval. Obtaining approval took considerable time as it required several rounds of rigorous vetting by the NAE GCSP Steering Committee. One possible reason for the lengthy approval process was that it was the first time that an engineering school outside of North America submitted an application to conduct a GCSP.

As a result, this initial cohort of students and the subsequent cohorts were already exposed to the requirements of the GCSP prior to its official launch. From an initial intake of 16 participants in the unofficially launched first batch [5], three of these students persevered to obtain the NAE award as Grand Challenge Scholars by the conclusion of their final semester in August 2016. It represented a significant milestone and moment of great pride for SOE.

1.2 Key Competencies

The NAE does not specify any curriculum for the GCSP. Instead, the GCSP is meant to be competency based. The student must demonstrate achievement of these competencies in order to graduate as a GCSP scholar. As mentioned in NAE's Grand Challenges Scholars website [3], "*The GCSP simply identifies five competencies that a student must achieve to prepare them to address the Grand Challenges for Engineering found globally. Each adopting university defines its supplemental approach to educating its students about each of the five competencies during its undergraduate engineering degree program framework*."

These key competencies are as follows:

1. **Talent Competency**: mentored research/creative experience on a Grand Challenge-like topic,
2. **Multidisciplinary Competency**: understanding multidisciplinarity of engineering systems solutions developed through personal engagement,
3. **Viable Business/Entrepreneurship Competency**: understanding, preferably developed through experience, of the necessity of a viable business model for solution implementation,
4. **Multicultural Competency**: understanding different cultures, preferably through multicultural experiences, to ensure cultural acceptance of proposed engineering solutions, and
5. **Social Consciousness Competency**: understanding that the engineering solutions should primarily serve people and society reflecting social consciousness.

1.3 Program Outcomes

For the TGCSP, the five key competencies of the GCSP were redefined into five Grand Challenges Program Outcomes (GCPO). This was necessary in order to align with the outcomes-based education model of SOE. The GCPOs of TGCSP are as follows [6]:

1. Demonstrate the competence to undertake project or research activity related to a specific Grand Challenge theme or challenge.
2. Demonstrate the ability to comprehend and apply interdisciplinary knowledge in solving the Grand Challenges.
3. Demonstrate the ability for technical innovation, organizing events, raising funds, and leading teams.
4. Demonstrate awareness of global ethical issues and global interdependence in solving the Grand Challenges. This requires active participation in seeking international exposure.
5. Demonstrate social awareness and the ability to bring technical expertise to bear on societal problems. This requires active participation in activities related to social concerns.

As can be observed, the TGCSP GCPOs are merely the outcomes-based version of the GCSP key competencies. In light of the GCPOs, SOE's curriculum was a review to identify alignment with them. Where the existing curriculum was insufficient to meet the GCPOs, additional co-curricular and extra-curricular requirements were included. From here, a clear pathway for a student to achieve the GCPOs was determined.

In addition to the GCPOs, an appropriate vision statement was also defined for the TGCSP to give it meaning and to guide its implementation. This vision statement of TGCSP is as follows [6]:

"To empower engineers to achieve their full potential and be the solution to humankind's Grand Challenges."

1.4 Implementation

The first step to become a TGCSP scholar is to obtain admission into the program. The application is open to first- and second-year students. The process involves submitting an application form where the applicant is required to provide their personal details including their achievements and values in life. Accompanying the application form, a one thousand word essay about their Grand Challenge of interest is required. In this essay, the candidates elaborate on their passion for a particular Grand Challenge and how they intend to play their role in its solution.

Shortlisted candidates will then be invited to an interview with the selection committee. During the interview, the candidates are required to deliver a presentation related to the essay they submitted and be able to respond well to any queries by the interviewers. Rubrics for assessing the application, essay, and interview are used by the selection committee to ensure consistency and fairness in assessment. Among the criteria in the rubric is passion. It takes passion to want to "change the world" by solving a Grand Challenge. All successful candidates may begin their journey as a TGCSP scholar and they would each be assigned a mentor from among the academic staff.

Mentors are academic staff who volunteer to serve in the TGCSP. Their role is to guide their mentees in meeting the GCPOs and hence successfully graduate as GCSP scholars. They do this by meeting regularly with their group of mentees. Each mentor would be assigned 3–5 mentees. The purpose of the mentorship meetings is to ensure that the students are properly guided and to maintain accountability.

During the mentorship meetings, the mentees update their mentors regarding their progress toward the GCPOs, receive counsel from their mentors as to whether they are proceeding in the right direction, whether their projects align with the Grand Challenge of their choice, present updates from their portfolios, and receive any form of advice deemed necessary by the mentor.

The students are also encouraged to propose initiatives that would benefit themselves and lead toward achieving their GCPOs. One example of such initiative was from a couple of semester 6 students. They proposed and subsequently organized a study and knowledge exchange trip to Japan for themselves and their fellow students with the aim of achieving GCPO 4. While in Japan, the students were hosted by a university where they attended various seminars and made industrial visits including to a sewage treatment plant. These activities were meant to relate to the Grand Challenges that the students undertook, for example, the sewage treatment plant related to the challenge of providing access to clean water. While in Japan they experienced the Japanese culture and learned the Japanese approach to problem-solving. One interesting take away was that the sewage treatment plant was completely odorless and clean reflecting the Japanese people's conscientiousness and priority on hygiene.

The students did not feel that they were inside a sewage treatment plant. This made a huge impression on the students. It is worth mentioning that the Japan trip was successfully carried out and met its objective.

The students in TGCSP are required to maintain a portfolio. This is where they record all their activities and learning related to the GCPOs. It is here that the students log all evidence pertaining to the attainment of the various GCPOs. Besides evidence, reflection is also required. Reflection on learning is a very important component of the portfolio. It is not enough just to have completed various activities but it is also necessary to have learned valuable lessons from them and be able to articulate them.

Finally, to close their GCPOs, the students first consult their mentors to determine if they had completed all the learning requirements of their GCPOs. If the mentor is satisfied with the completion, the students then submit their portfolio for review by the TGCSP committee. This committee comprises mentors of the other TGCSP students. The role of the mentor is strictly voluntary. The initial committee was selected by the Head of School, and subsequent mentors were proposed by the committee. The students would be required to deliver an oral presentation to these mentors at a later date. If the TGCSP committee is fully satisfied with the portfolio contents as well as the oral presentation, then the GCPO will be considered attained by the student and closed.

The GCPO closure process has some flexibility. The students may submit for closure any number of GCPOs at a time, from just one to all five. There is no fixed time duration to complete all the five GCPOs as long as they are achieved within the timeframe of completion of the B.Eng. (Hons) program undertaken by the student. However, completing all GCPOs requires extra effort and commitment from the students since for most of the GCPOs there are additional criteria to be met outside of their regular curriculum.

1.5 Criteria for Achieving GCPO

This section details the criteria that students must meet in order to fulfill each of the five GCPOs. An example of how students would address some of these criteria, specifically GCPOs 3 and 5, would be discussed in the following section.

1.5.1 Demonstrate the Competence to Undertake Project or Research Activity Related to a Specific Grand Challenges Theme or Challenge

To close this GCPO, a student must

- Work on at least one group or individual project that is related to the Grand Challenge that they had selected. This project(s) can be undertaken in any of the

project-based modules such as Engineering Design and Communication, Engineering Design and Ergonomics, Multidisciplinary Engineering Design, Engineering Design and Innovation, Group Projects (Capstone), or Final Year Project.
- Have completed and passed at least one project-based learning module in the curriculum.

1.5.2 Demonstrate the Ability to Comprehend and Apply Interdisciplinary Knowledge in Solving the Grand Challenges

To close this GCPO, a student must

- Identify additional interdisciplinary coursework that may be applied to the Grand Challenge project(s), industrial training, research, an elective module, or any other project or experience.
- Enroll for this coursework through an official channel/route which has been agreed upon with their mentors. This coursework could be one of the completion electives, MPUs (university mandated general study modules not related to engineering), massive open online courses (MOOCs) as well as conferences or events/classes that provide keynote/guest lectures.

1.5.3 Demonstrate the Ability for Technical Innovation, Organizing Events, Raising Funds, and Leading Teams

To close this GCPO, a student must

- Successfully complete an activity related to an entrepreneurial experience. This could be in the form of a competition or in the course of taking a specific module.
- Also have completed and passed the following modules in their curriculum:
  - Managing Projects for Success,
  - Engineering Design and Innovation,
  - Business Skills for Engineers, and
  - Group Project 1 and 2.

1.5.4 Demonstrate Awareness of Global Ethical Issues and Global Interdependence in Solving the Grand Challenges. This Requires Active Participation in Seeking International Exposure

To close this GCPO, a student must

- Perform industrial training abroad or participate in an international exchange, competition, conference, event/activity, or performing research abroad.

1.5.5 Demonstrate Social Awareness and the Ability to Bring Technical Expertise to Bear on Societal Problems. This Requires Active Participation in Activities Related to Social Concerns

To close this GCPO, a student must

- Lead and participate actively in service learning-based activities.
- Have completed and passed the Professional Engineers and Society module in the curriculum.

1.6 The Engineering My Future

As mentioned in previously, the 14 Grand Challenges for Engineering in the twenty-first century have become the core of engineering education in institution of higher learning around the world. In order to ensure engineers of the future are ready both theoretically and practically for the challenges awaiting them, they should be exposed to ideas and projects that address the possible global challenges as early as possible. Conventionally, this can be done through class activities like case study, reflective report on current technology, simulation, role play, group discussion, and so on. Here, the author would like to introduce another approach to enhance the awareness and help engineering students toward addressing the 14 Grand Challenges through a one-day workshop called—The Engineering My Future (EMF) workshop.

The Engineering My Future (EMF) conducted by the School of Engineering, Taylor's University in Malaysia is one of a kind workshop to address the 14 Grand Challenges for Engineering in the twenty-first century. One may be able to discover a handful of activities by the similar name online [7–11]; however, the way they were conducted is quite different from the one to be discussed here. The EMF that the author intended to share here is a one-day workshop conducted by engineering students for participants from young kids to teenagers. The first EMF was successfully conducted in December 2015 (Fig. 1.2) and was conducted biannually since then [12, 13].

Fig. 1.2 One of the sessions in the first EMF in 2015 [14]

Table 1.1 Sample itinerary of an EMF

Time	Activity
9:00–9:15 am	Registration of participant
9:15–9:45 am	Icebreaking
9:45–10:30 am	Sharing session on the 14 Grand Challenges for engineering in the twenty-first century
10:30–10:45 am	*Short break*
10:45–12:00 noon	Group design and presentation
12:00–1.30 pm	*Lunch break*
1:30–3:30 pm	Station games
3:30–3:45 pm	*Short break*
3:45–4:00 pm	Prize giving ceremony
4:00–4.45 pm	Debrief and reflective session
4:45–5.00 pm	Photography session

The one-day EMF workshop consists of various modes of activities that are all related to the 14 Grand Challenges. The workshop normally started with an ice-breaking activity to allow participants get to know each other and as well as sharing the itinerary of the day. Engineering latest prospects, roles of engineer, and the 14 Grand Challenges will be explained to the participant in the briefing session after the icebreaking session. Next, it was group game related to the 14 Grand Challenges so that the participants can visualize what they have just learnt and have a hand on the ways to address one or two of the challenges. Late in the afternoon, the workshop closes with a prize giving ceremony and a debriefing session. Table 1.1 illustrates the sample itinerary of an EMF workshop.

The first activity for the workshop right after the registration is icebreaking. As the scope of the workshop was drafted as such, activities during the workshop have to be drafted carefully and as well as having the flexibility of adapting to different age groups of participants. Typical icebreaking activities are self-introduction, team forming, team naming, team flag design, and so on. The intended outcome for the session is for the participants to get to know their team as they will need to work together in various activities after that.

The sharing session that follows normally covers the introduction to the 14 Grand Challenges for Engineering in the twenty-first century and the background of why is it important to humankind continuity on our precious earth and the role engineers have to play to address them. While the content is fixed, the delivery mode is flexible as it is depending on the participants' age and their attention span. For younger kids, the delivery mode will be such that at the end of the session they are aware that there are great challenges at different parts of the world and engineers, though maths and science are putting in great effort in addressing them. Meanwhile, for teenagers, the intended outcome will be more toward reflective on the challenges, the root cause, the consequences, and hence generating ideas as well as interest in addressing those challenges.

Gamification in education has been widely used to improve the motivation and engagement of students toward learning goals [15]. Etherington [16] has shared some of the science and mathematics games in this recent article on problem-based learning. Similarly, for EMF, the author believes that through fun and guided learning activity, participants will benefit most from the workshop. The following paragraph is games from the previous EMF.

The detailed game sheet can be accessed through the following links: https://docs.google.com/document/d/1C5vAbO0H9I1MSHLYKf7AXCzwPb1S42jVq-PQwUUn-P4/edit?usp=sharing

1.6.1 Block-Bridge Design Challenge

The first game the author wanted to share is the Block-Bridge Design Challenge, which is related to the Grand Challenge of Restoring Urban Infrastructure. An incomplete bridge model, build from toy blocks, was given to participating teams. Each team is required to "restore" the structure within the given time taking into consideration the physics knowledge they have learnt before. The complexity of the game can be increased by requiring the team to improve the capability of the structure to withstand a certain load as in Fig. 1.3. The bridge structure can be built from Jenga blocks or Lego pieces as in Fig. 1.4. The main objective of this game is to relate science and maths to real-world application like bridge structure. Through this, the facilitators will explain the importance of restoring the aging urban infrastructure to humankind.

Fig. 1.3 Load testing on bridge built with popsicle sticks [17]

Fig. 1.4 A bridge structure from Lego pieces [18]

1.6.2 Engineer the Missing Pieces

Engineer the Missing Pieces is a game related to the Grand Challenge of Engineer Tools for Scientific Discoveries. Each group of participants will be given a set of puzzle pieces and will be asked to put them together. Upon joining all the blocks, they will find that there is a missing block. By using proper measurement tools and computer-aided engineering design (CAED) software, they will be asked to design the missing piece and 3D print it. The group that is able to design the best-fitted

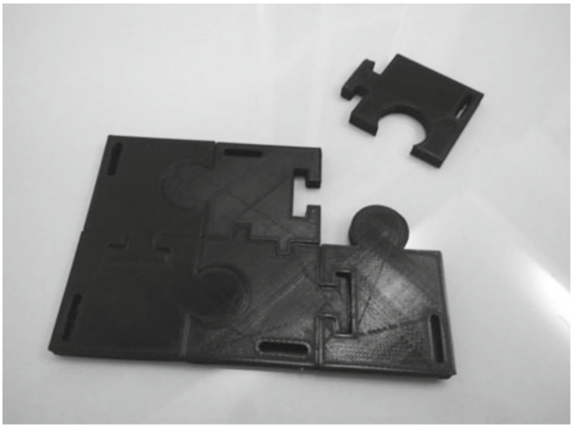

Fig. 1.5 Puzzle blocks with one separately 3D-printed piece detached

piece will win the competition. The complexity of the puzzle is greatly dependent on the participant's background; for a CAED-inexperienced participant, step-by-step guided design learning process is highly recommended. The main objective of this game is to introduce the participant to the engineering design software and printing, though this they will be able to relate the engineering design to a tangible daily object, which leads to many more useful ideations. Figure 1.5 depicts a set of puzzle blocks from our recent EMF.

1.6.3 Design of Water Filtration System

The third game to be explained here is related to the Grand Challenge of Provide Access to Clean Water. Each group will be asked to use the materials provided to design a water filtration system so that they can gather a bottle of clear water from a muddy water source. The quality of the filtered water will be tested by a water turbidity sensor with 5 NTU (Nephelometric Turbidity Units) as the baseline of clean water as recommended by the World Health Organization (WHO) [19]. Other parameter of water quality measurement can be introduced to the participants subjected to the availability of measuring equipment and time. Group using the least materials will be the winner of the game. The objective of this game is to expose the participant to the challenge to purify and preserve water. Through this game, the participant will be able to relate the science and the engineering application.

1.6.4 *DIY* Aloe Vera *Gel*

In order to address the Grand Challenge of Engineer Better Medicine, a DIY *Aloe vera* gel game is included in the EMF. Each team will be taught a simple way to extract *Aloe vera* gel from a fresh *Aloe vera* leaf. Mensuration techniques and the importance of units will be the main focus points for this game. Participants will be told that the extracted gel, once it is done, will be used as body lotion. Through this, the participant will realize that it is important to get the ratio and portion of each ingredient right or else it may not be safe for the user. Groups that are able to use the shortest time to prepare the *Aloe vera* extraction body lotion as instructed will win the game. The objective of this game is to show to the participant that engineers will still have an important role to play in the medical industry, mainly in the research and production.

1.6.5 Hydroponic Self-watering System

The Hydroponic Self-watering System can be mapped to the 14 GC through the Grand Challenge of Managing Nitrogen Cycle and Develop Carbon Sequestration Method. A model of a basic hydroponic watering system will be showed to the participant. They will be asked to improve the design so that the efficiency of the process, such as space saving and the time required to build the system, can be improved. Participant will need to plan the orientation of the system and the way water flows. As the game involves some carpentry and piping works, the game is only suitable for older kids or teenager. The winner for the game will be chosen based on the materials usage and the efficiency of the watering system. The objective of this game is to show to the participant the importance of green plants to the environment, namely, the nitrogen and carbon cycles.

1.6.6 Arduino Robot Cleaners

One of the most exciting games in the workshop is the Arduino Robot Cleaners game. It is conducted to address the Grand Challenge of Advanced Personalized Learning and Engineer Tools for Scientific Discovery.

The participant will be provided with a set of Arduino robotic toy car and the working principle of the toy car will be explained to them. Depending on the age group of the participant, they will be asked to make simple modification to the toy car so that it is capable of completing a specific challenge. A typical challenge assigned to the participants in our past EMF is beach (artificial) cleaning, room cleaning, tennis ball transporter, and so on. Group with the most innovative and practical design will win the game. The main objective of this game is to expose the participant to the engineering design and thinking methods in order to solve a challenge.

The EMF has brought a number of advantages to the society and as well as the organizing team. One of the most prominent ones will be the cultivation of interest in Science, Technology, Engineering and Mathematics (STEM) in children at different age levels, which is one of the main focuses of the New Malaysian Educational Blueprint [20]. Through the activities in the workshop, besides being able to encourage team working through group activity, participants will also have an early exposure to the application of science, technology, and engineering in a fun way. By trying to overcome the challenges given to them during the workshop, they will be trained to adopt critical and structured thinking and hence able to use it in their daily life.

Furthermore, the unique part of the EMF is the benefits intended on the organizing students. Once the organizing team is formed, students who voluntarily joined in will be trained to strategically plan and organize the whole event. Here, they will be able to apply their project management knowledge and entrepreneurial skills. On top of that, as the games are directly related to the Grand Challenges, the organizing team will have a deeper understanding and the way to address each one of them.

As discussed earlier, the EMF workshop may serve as a short medium to cultivate and promote STEM and ways leading to the solutions that may be able to address the 14 Grand Challenges for Engineers in the twenty-first century. The structure of the EMF workshop may be varied with the targeted participants and as well as the intended outcome. One may even expand the workshop into a summer camp or a short course for a greater impact on the participants.

On top of the EMF workshop where participants are expected to be inspired to becoming the Grand Challenges solver, the author and the team at the institution hope that participants would extend their passion and ideas or foundation they gained from the workshop into their tertiary studies. This is extensively essential as project-based learning has become a core learning model in tertiary education, especially in the branch of engineering. The ability of student to adapt to this new learning environment will surely determine the performance. In the following chapters, how project-based learning is conducted in the institution and how great ideas that are addressing the Grand Challenges were exercised throughout the engineering degree study.

1.7 Conclusion

The NAE Grand Challenge Scholars Program was successfully implemented at Taylor's University's School of Engineering. This effort represented SOE's support and commitment to the vision of solving the Grand Challenges for engineering as identified by the NAE, to provide this planet with a sustainable future by developing engineering leaders of the future with the requisite capabilities and desire to take on these challenges.

The key competencies of NAE's GCSP were redefined into GCPOs to suit the outcomes-based education model employed by Taylor's SOE. SOE's B.Eng. (Hons) curriculums were reviewed for alignment with these GCPOs and where necessary co-curricular and extra-curricular activities were added to ensure attainment of these GCPOs. Their attainment in turn ensured attainment of the NAE GCSP's key competencies.

Any first- or second-year student in a B.Eng. (Hons) program may apply to become a TGCSP scholar. Selection into TGCSP is based on assessing the applicants' passion and potential. The selected students are provided with mentorship from an academic staff to guide them through their journey as TGCSP scholars. From the moment of their admission, the students keep a portfolio which serves both as a log for recording all evidence of their activities related to GCPO attainments as well as serving as a journal to reflect on their learning. As the TGCSP is outcomes-based, the students may apply to close any GCPO at any point in time once they and their mentors consider them as having fully attained the GCPO. To date, three students have successfully completed the TGCSP and received their certificates from the NAE.

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Chapter 2
The Design Spine: The Core Design Modules Behind Taylor's School of Engineering Project-Based Learning

Edwin C. Y. Chung

Abstract Taylor's University School of Engineering is a project-based learning school where the syllabus for each undergraduate programme is designed to provide every student with the opportunity to apply theories taught in class. This is realised through a series of design and project modules starting from semester 1 all the way through to semester 8. The design challenges offered to students throughout these eight semesters would progress from one where there are known solutions, to one where it is a real-world challenge with business value and finally to a research challenge where students are expected to publish their findings. In this chapter, how these design and project modules are structured, their objectives and the challenges of offering these modules are discussed.

Keywords Project-based learning · Engineering design
Undergraduate engineering programme

2.1 The Origin of Project-Based Learning and the Design Spine at Taylor's School of Engineering

Taylor's University School of Engineering was once an engineering school at Taylor's College offering twinning programme with the University of Birmingham and the University of Sheffield before that. In 2004, the head of department at the time was also pursuing his Ph.D. At one point, needing some assistance with his experiment, he carved out a small portion of his experiment and offered it as a project to some

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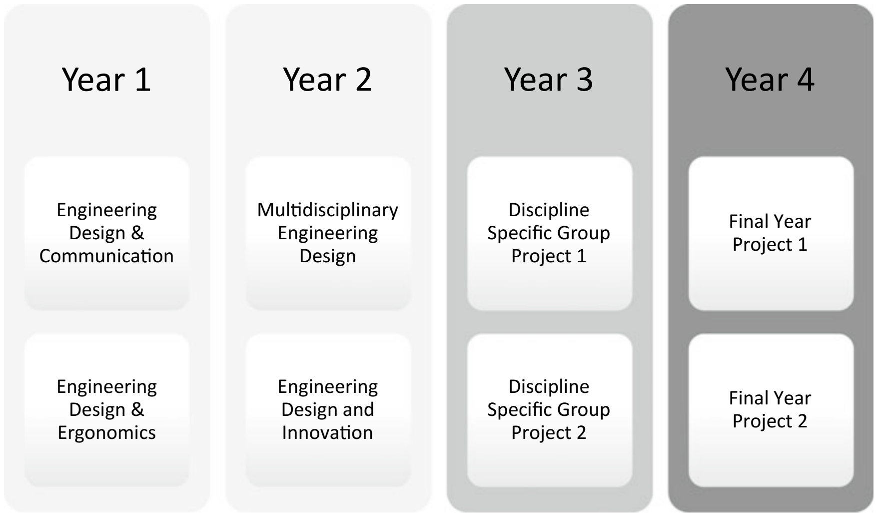

Fig. 2.1 Organisation of the design and project modules

students. He saw how this simple project would pique the interest of students working on the project and he even received complaints from students who were not offered this 'project' of being biased! Over time, he offered more projects and finally with the permission from the University of Birmingham, a project/design module was created.

From experience gained from this project module, this head of department and his team, when they were designing the syllabi for the undergraduate engineering programmes for Taylor's University College,[1] incorporated a design spine consisting of a series of design/project modules spanning from semester 1 all the way through to semester 8. The current structure of the design spine consists of eight modules as depicted in Fig. 2.1. With the exception for Final Year Project 2, which carries a 6-credits weightage, the remaining seven design modules are all 3-credits each. The four design modules in year 1 and 2 are also common modules attended by students from the various undergraduate engineering programmes. These first four design modules are also multidisciplinary and team-based. The modules in year 3 are also team-based but are discipline-specific and are implemented as capstone projects. Final year project, on the other hand, is individual research project where every student is required to publish their research findings.

[1]On its way to becoming a full university in 2010, Taylor's College was awarded the University College status in 2006. Beyond 2010 after Taylor's University College was awarded a full University status, Taylor's College remains as a separate institution offering pre-university programmes.

2.2 Details of the Design/Project Modules

The structure of the design/project modules along the design spine is one such that each module would build on the knowledge and experience students would have gained from preceding modules as they progress through the programme. As a means to illustrate this, details for each of these modules along with their learning outcomes and objectives are detailed in the following subsections.

2.2.1 Engineering Design and Communication

This is the first design module and its objective is twofold. First, it is to introduce students, who would have just completed their high school certificate or other equivalent pre-university qualification, to the basics principles of engineering design and a number of basic skills important to engineering design. In particular, this module emphasises on technical communication skills such as reporting, sketching and drafting.

In this module, all students are organised into teams of five. Each team will consist of students from at least two engineering disciplines. Each team will work on a project on offer or proposed a project. In order to ensure alignment with the module learning outcomes, all proposed projects will need to be approved by the module coordinator.

The learning outcomes for this module are as follows.

1. Produce useful ideas and concepts using Brain Storming.
2. Design a system that solves a complex engineering challenge using a Design Process.
3. Conclude findings from working in a team through technical documentation.

2.2.2 Engineering Design and Ergonomics

Building on top of what students have learned from the *Engineering Design and Communication* module, the objective of this module is to equip students with the knowledge and skills related to human–machine interface in engineering design. Students are organised into teams in much the same manner as Engineering Design and Communication but the projects on offered now have a skew towards human factor, occupational health and safety.

The learning outcomes for this module are as follows:

1. Produce useful ideas and concepts using Cognitive Ergonomics.
2. Design a system that solves a complex engineering challenge with an emphasis on Human Factors.
3. Evaluate the occupational health and safety of an engineering system as well as its success in being sustainable.

2.2.3 Multidisciplinary Engineering Design

The objective of this module is to introduce students to real-life work environments where engineers from different disciplines and backgrounds work together to accomplish a given task. Note that in this module, learning outcome 1 now focuses on very specific techniques.

The learning outcomes of this module are as follows:

1. Apply techniques, such as Trimming, Random Entry and Systems Thinking to Conceive, Design, Implement and Operate a system which solves a complex engineering challenge.
2. Evaluate the manufacturability (in terms of production effectiveness) and sustainability of an engineering system.
3. Explain the role of ethics in engineering design.

2.2.4 Engineering Design and Innovation

With the foundation built over the previous three design modules, the objective of this fourth design module is to introduce students to Design Thinking as the core design process. Other than Design Thinking, the concept of business value, TRIZ and effective presentation technique based on neuromarketing are also taught in this module. Unlike the previous three design modules, students will need to form their own team and proposed their own project. And not only must the proposed project be aligned with the module's learning outcomes, students must be able to justify the business value associated with the challenge they are attempting to solve.

The learning outcomes of this module are as follows:

1. Identify a complex engineering challenge that has business value.
2. Design a system, with the aid of design tools and techniques, which solves a complex engineering challenge that has business value.
3. Explain the importance of intellectual property rights as a legal instrument for commercial monopoly.

2.2.5 Group Project 1

This is the first part of a two-part discipline-specific group project. This module is concern mostly on the analysis of a discipline-specific engineering challenge and the synthesis of a solution to solve the challenge. The challenge offered would need to be complex enough where its solution will involve the application of multiple fields within the discipline.

The learning outcomes of this module are as follows:[2]

1. Analyse and identify root causes of a given challenge.
2. Justify proposals and suggestions based on sound technical knowledge.
3. Develop effective solutions.
4. Analyse the implication of design on manufacturability, testability, usability, ease of maintenance and sustainability.
5. Evaluate design using appropriate method/methods.
6. Organise one's work diligently and thoroughly.

2.2.6 Group Project 2

This is the second part of the two-part discipline-specific project where the focus is towards the construction/implementation of a design developed a semester earlier.

The learning outcomes of this module are as follows:

1. Create a functioning prototype based on design.
2. Evaluate the functionality of prototype against design.
3. Evaluate the design based on performance, cost and sustainability to optimise the design if necessary.
4. Execute project closure.

2.2.7 Final Year Project 1

This is the first of a two-part individual research project. The focus of this module is very much on the formulation of the scope and objective of the research, literature review and preparation for experiments.

The learning outcomes of this module are as follows:

1. Formulate the scope and objectives of a particular research project.
2. Organise critical literature review.
3. Build a research plan using project management tools.
4. Design and Prepare research methodology.
5. Compile the findings in both written and verbal form.

[2]Though there are variations between the learning outcomes for this module for the three undergraduate programmes currently active at Taylor's University School of Engineering, the essence they capture is essentially the same.

2.2.8 Final Year Project 2

This is the second of a two-part final year project where the focus is very much on the collection and analysis of results. Students are expected to submit a conference paper at the very least on top of a thesis that captures their work for the whole year.

The learning outcomes of this module are as follows:

1. Evaluate results using research-based knowledge and research methods which include experiment design, data analysis and the synthesis of information to provide conclusions.
2. Compile and present a final year project thesis and a peer-reviewed conference paper.
3. Apply project management tools to execute the research plan.

2.3 The Motivation Behind Project-Based Learning

The implementation of project-based learning and the inclusion of the design spine go beyond Taylor's University School of Engineering being part of the CDIO™ Initiative [1, 2]. As mentioned earlier, it was observed that project work help motivates students. Correctly prescribed, it has the potential to draw the best from participating students. A case in point is that of a student whose A-level results were so poor, he could not get a place to study in the UK and had to grudgingly settle for a place at Taylor's University School of Engineering. The project he was working on in semester 1 was so interesting to him he wanted to know more. So much so he started to study. Not only material taught in class but whatever he needed to understand to complete his project. His CGPA at the end of semester 1 was 4.0/4.0. This student completed his study with a CGPA of 3.33/4.0 and was heavily involved with the school's racing team.

We believe our observation with project-based learning is consistent with Dale's Cone of Experience [3]. Projects, correctly prescribed, give student that direct and purposeful experience. They will understand why and the importance of what they are taught in class and hence the observed motivation in students working on projects. It may be interesting to note that Taylor's University School of Engineering attempted to convert lab experiments to be case-based, in other words, a contrived experience in Dale's Cone of Experience terminology. This, unfortunately, due to resource constraints, was never rolled out even after a successful trial.

Though this was the motivation behind the adoption of project-based learning and the creation of the project spine in the syllabus, its impact is best understood from the student and academic staff perspectives. In the following chapter, an alumnus of the school attempts to give reasons behind the effectiveness of project-based learning followed by the perspective from a member of the faculty.

2.4 Challenges in Implementing Project-Based Learning

Just as having a world-class syllabus will not guarantee that all graduates will be world class; having a design spine, even with a well design syllabus for each module in the spine, will not guarantee that all students having successfully completed all modules in the design spine will be well versed with project work. The following are some challenges we have experienced since the inception of the design spine and project-based learning at the school.

Though these challenges can be daunting, the benefit of the design spine in a project-based learning school can have benefit as the feedback from employers of our graduate continues to affirm this.

2.4.1 Module Coordinator

The interpretation of the syllabus and the standard set for each module lies in the hand of the module coordinator. A module coordinator with extensive project experience will be better able to guide students at a much higher standard/level as one who has little to no project experience. We have noticed that a module coordinator who has been involved in commercial/industrial projects, especially those who have experienced bringing a concept to market, generally make good design coordinator. A maker, i.e. a person who likes to make/build things, is another.

2.4.2 Project Supervisor

Project teams will need to be supervised and it is not possible, nor practical in some cases, for the module coordinator to supervise all project teams. A project supervisor may be familiar with the theoretical aspect of the project but not the design process. A solution around this is for all supervisors to be trained in the design process before they are allowed to supervise projects. Our experience shows that even this will take time. An alternative to this is for teams needing technical supervisor to be supervised by a technical supervisor while the module coordinator remains as a co-supervisor assisting these teams with the design process.

2.4.3 Project Offering

Even for a small school with around 100 students per intake, each module will have around 20 teams on average. And with just the first four design modules, the school will need to come up with 80 projects every semester. A solution around this is not to offer specific projects but to offer a generic challenge/theme, such as *tool for old age*, *solutions for natural disaster*, *assess to clean water,* etc. and to allow students to propose projects that are aligned to the assigned theme. Note that you will always allow good project proposal by teams that are not aligned to the suggested theme as long as the activities for these projects will allow them to gain the necessary learning outcomes for the module. Prior to us adopting the approach of providing project theme to guide students with their project proposal, we noticed that there is a tendency for module coordinator to repeat projects and students may copy solutions from their seniors, making minor changes to make it their own! There is also a tendency for module coordinator to repeat project theme but its impact is not as severe as repeating specific projects as there are many possible projects for a given theme.

2.4.4 Students are not Familiar with Engineering Design

Unlike mathematics, physic or chemistry, students entering an engineering undergraduate degree programme would not be familiar project or engineering design. In fact, most undergraduate engineering degree programme will introduce students to project and/or design in year 3 of their 4-year programme. The rationale is that students would need to have the necessary knowledge before they can work on meaningful engineering challenges and as such module introducing students to engineering design is only introduced later in the programme. However, as there are other dimensions of learning associated with engineering design other than technical knowledge, students need also to be exposed to these other learning dimensions, especially the effective learning domain, in order to better prepare students before they are introduced to engineering design involving more complex engineering challenges.

This challenge is a lot more complex than one may expect as students who are introduced to project early will become very familiar with teamwork, always having a challenge to solve and integrate into the workplace after graduation very well. This is confirmed from feedback we received from employers and alumni alike. However, there is a risk of students developing bad habits early in the programme that they are unwilling/unable to correct. Jumping to conclusion and proposing solution(s) from the get-go without verifying what they are trying to solve and/or not having proper basis for their proposal being two of the major bad habits/tendencies we have to deal with. These are natural tendencies common amongst students fresh from high school but need to be corrected if there were to be able to take on complex engineering challenge. How engineering design is gradually introduced to students is detailed in the following section.

2.5 Introducing Students to Engineering Design

How engineers think and what they consider when solving a challenge, though structured, is not structured in a manner that can be described in an algorithm. It is more like a collection of many algorithms coupled with rule and/or experienced based decision-making process where these algorithms can even be mix and match together as and when appropriate. It takes into account as many relevant factors as necessary while considering available options. The impact each option has on the end user, on manufacturability, testability, ease of maintenance, etc. is also considered. The path it takes to arrive at the final solution is also seldom the same and this process is not intuitive to the uninitiated and may even seem, at time, to be contradictory to our natural tendency. Most experienced engineers would have learned this skill over time through years of hands-on experience and it is definitely not something that can be taught to students, fresh off high school, in a module spanning a little over 3 months. Accordingly, the first three design modules within the design spine are very much to put students through a series of projects with increasing level of complexity that will allow them to gain some basic engineering design experience before they are introduced to Design Thinking as a core engineering design process in the fourth semester.

The experience, skills and knowledge that students will gain from the preliminary design modules in the first 3 semesters can be grouped under the following headings:

- Working in teams,
- Design process,
- Technical documentation,
- Thinking tools and techniques, and
- Human factor.

The intention is for students to gain exposure and experience in these areas as they progress through the three preliminary design modules. The rationale behind the selection of these areas is described in the following sections.

2.5.1 Working in Teams

Engineers inevitably work in teams and students need not only to be comfortable with working in team but also to understand the stages team goes through from formation to adjourning. For this, students are not only organised into multidisciplinary teams (team consisting of students from two or more engineering disciplines), they are taught and are assessed on their ability to identify the stage their team is at within the framework of the Tuckman's model [4] on a weekly basis. They are also assessed on their ability to identify the action(s) needed to advance their team towards the performing stage. Conflict among team members is not uncommon and students will have the opportunity to learn to deal with these conflicts.

2.5.2 Design Process

As mentioned above, students who are new to engineering design generally have the tendency where they would propose the first idea that comes to mind as the solution for a given challenge. This tendency is so strong that it takes effort just to get students to trust the design process. Accordingly, students are taught the CDIO design process [2, 5]. Students are required to apply the CDIO design process for their projects from semester 1 to semester 3.

2.5.3 Technical Documentation

Documentation is an important element in engineering design. One must be able to keep detail records so as to allow anyone else skilled in the art to reproduce one's work or to have sufficient evidence that will be accepted in a court to support when an invention was developed, etc. In this aspect, students are taught how to keep an inventor's logbook, meeting minutes and how to write a good technical report. Students are also taught engineering drawing.

2.5.4 Thinking Tools and Techniques

The ability to think critically and the ability to apply thinking techniques to generate new idea are crucial skill in engineering design. Starting with brainstorming and 5 Whys in semester 1, students would be introduced to other thinking tools and techniques, such as lateral thinking and trimming, by the time they complete semester 3.

2.5.5 Human Factor

Products/solutions we design are ultimately used by human and even if it is not used by human are maintained by human. Where our solution interacts with human, it is crucial that these interfaces be designed not only to avoid injury but also a joy to use. Accordingly, students are introduced to the concept of human factor in design and are taught ergonomics specifically.

2.6 Design Thinking at Taylor's University School of Engineering

Following the three preliminary design modules, all engineering students are taught Design Thinking as a core engineering design process in semester 4. They are also introduced to TRIZ [6], but Design Thinking is intended to be the core design process students will use from this point in. Accordingly, it is important that details of Design Thinking at Taylor's University School of Engineering and in particular how the module is structured and run will be described in the following sections.

2.6.1 How Design Thinking Was Introduced to Taylor's University School of Engineering

The very first intake for Taylor's University School of Engineering was in September 2009. Three undergraduate programmes, namely, Bachelor of Engineering (Honours) in Chemical Engineering, Electrical and Electronic Engineering and Mechanical Engineering, were on offer. The founding team had already designed the curriculum for these programmes to be project-based and there were seven design/project modules in these original programmes. At that time, the author of this chapter had only joined the team a few months earlier. He was a co-founder of an IT and innovation consulting company prior to joining Taylor's and was a programme manager with Intel's IT Innovation Centre at Cyberjaya prior to that. He was also a trainer for an in-house Design Thinking workshop at Intel. Noticing the gap in what is now considered the design spine in the syllabi, he suggested incorporating the training material he had developed after leaving Intel to be a design module in the syllabi of these programmes. This module is now the semester 4 Engineering Design and Innovation module.

The content for this module has remained largely unchanged since its introduction in early 2010; however, the way it is conducted has changed tremendously. Classes were earlier conducted like corporate training sessions. Today, classes are flipped and there is no background music before the start of class!

2.6.2 Learning Outcomes and Lesson Plan

Semester 4 Engineering Design and Innovation (ED&I) is the module where Design Thinking is taught at Taylor's University School of Engineering. It may be interesting to note that Design Thinking is not mentioned in the learning outcome for this module as this is not a Design Thinking only module but and engineering design module where Design Thinking is taught as a core design process. In this module, the concept of business value [7] is also introduced.

Table 2.1 Generic lecture plan

Semester week	Delivery
1	Module introduction Lecture 1 introduction to creativity, design & innovation
	Lecture 2 innovation 101 Tutorial examples of innovation
	Lecture 3 design thinking: understand Tutorial Taylor's parking challenge
2	Lecture 4 Design thinking: observe Tutorial Petrol station forecourt & vending machine
	Lecture 5 design thinking: ideate Workshop campus parking challenge
	Lecture 6 design thinking: prototype Tutorial various cases
3	Lecture 7 introduction to business value Tutorial various cases
	Lecture 8 Introduction to intellectual property
	Lecture 9 Neuromarketing presentation technique
4	Lecture 10 Return-on-failure Tutorial review of previous semesters' samples
	Lecture 11 Introduction to TRIZ level 1 (part 1 of 2)
	Lecture 12 Introduction to TRIZ level 1 (part 2 of 2)
5	Lecture 13 Grand challenges for engineering and CDIO a reminder Workshop wallet design
	Workshop water bottle design
	Lecture 14 revision class

The learning outcomes for the module are as follows:

1. Identify a complex engineering challenge that has business value.
2. Design a system, with the aid of design tools and techniques, which solves a complex engineering challenge that has business value.
3. Explain the importance of intellectual property rights as a legal instrument for commercial monopoly.

The intention of these learning outcomes is to equip students with some of the basic skill important to a technopreneur that is also commonly found in experienced senior engineer. Another important skill that is taught in this module, though not captured in the learning outcome, is the technique for effective presentation.

The lesson plan for this module is as shown in Table 2.1. Instead of the usual 2-hour lecture followed by another 2-hour tutorial per week, the lesson plan for this module would have three 2-h our sessions per week for at least 5 weeks. And these sessions are not marked as tutorial or lecture as tutorial and exercises are mixed with lecture as appropriate. The reasons for such an arrangement are as follows.

2.7 Students Cannot Apply Material Taught Late in the Semester

In a 14-week semester, students will need to progress through their project where they could settle on a design sometime around the middle of the semester giving them sufficient time to build and test the design on the later part of the semester. Whatever material taught in the later part of the semester will be too late for student to apply it on their project. Accordingly, it is important that techniques you would like student to apply on their project during the semester had to be delivered before they have advanced too far into their project.

2.8 Validation of Understanding and Efficient Use of Time

Having tutorial exercise or activity immediately after the delivery of the material helps students with a quick revision of the material as well as improves retention. Frequently, some of these activities take no more than 30 min and it would be an efficient use of time just to slot this into the lecture slot.

2.8.1 Projects

As is the case for all design and project modules at Taylor's University School of Engineering, students taking the Engineering Design and Innovation module will need to organise themselves into teams of not more than 5. Each team will need to be made up of students from at least two disciplines. Each team is to propose their own project and the project they propose must be able to show that they are able to identify a challenge, especially one that requires an engineering solution, that has business value. In other words, they will need to show that they have attained learning outcome 1.

Once a team has an approved project, they will work on the project through the semester with regular supervision. Each team will have at least one time slot allocated to them with their supervisor once every fortnight and there is no limit to the number of additional meetings they would like to have with their supervisor in between these allotted time slots. The module coordinator will be the main supervisor for every team and should there be a need for a technical supervisor; these teams will need to be able to convince an appropriate lecturer(s) to be their co-supervisor(s). The rationale for this is that it is crucial that students gain a working understanding of the material taught in class, especially the process for Design Thinking.

As a means to facilitate students with their project proposal, a theme may be suggested. An example could be 'access to clean water' or 'solutions related to annual flooding along the east coast' or 'solutions applicable to refugee camp', etc.

From time to time, there will be team(s) that are not able to come up with a suitable project in the first 4 weeks before the project proposal is due. A reserved list of projects is then used to assign to these team(s). It must be emphasised that by doing so, these teams will miss the opportunity to experience learning outcome 1 on their own and it would not be surprising that these students will tend to have lower scores for their learning outcome 1.

2.9 Flipped Classes

Today, in order to have more time for in-depth discussions with students in class, classes are flipped. Students are required to attend all lectures online prior to each lecture and face-to-face time is reserved for Q&A, in-depth discussion and tutorial. Recording of classes from a previous semester is hosted on OpenLearning and is accessible at https://www.openlearning.com/courses/engineeringdesignandinnovation/.

2.10 Business Value Augmented Design Thinking Process

A Google image search for the phrase 'design thinking process' will produce a number of different Design Thinking processes from various institutions. You may even find variants from the same institution. Each of these processes is essentially the same but with different emphases.

The Design Thinking process that was introduced to Taylor's University School of Engineering is captured in Fig. 2.2. This diagram is to be understood in the following manner. We start at the grey block on the far left. We can only be in a valid black block at any point, and grey blocks are only transitional to connect a valid black block to another. We can only traverse from a block to another adjacent block. Accordingly, starting at the grey block on the left, the first valid step can either be *Understand* or *Observe*. We would then iterate between the understanding and observation steps until we are able to ascertain the business value of the project (the leftmost vertical line). You would drop the project if there is no business value and you will continue to iterate through the understanding and observation steps until you have gained sufficient insight into the challenge that you have understood the root cause or have gained an inspiration that you have some confidence will lead to a good solution. It is only when you have reached this stage would you proceed to the *Ideate* step. Concepts generated from ideation are evaluated in the *Prototype* step. It is common to iterate through the ideation and prototyping steps until we are happy with the solution at hand.

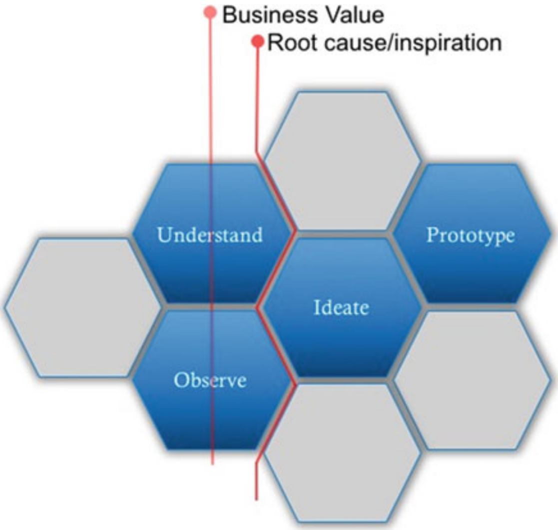

Fig. 2.2 Business value augmented design thinking process

It is not unusual that during ideation or prototyping that we discover we lack understanding or data and will need to return to the understand or the observe stage. You will again return back to the ideation steps once you have gathered a revised root cause or inspiration. This whole iteration will continue until you are happy with the solution at hand.

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Chapter 3
Project-Based Learning and Why it Works: A Student Perspective

Kun Yong Ng and Edwin C. Y. Chung

Abstract One of the 14 engineering grand challenges is related to advanced personalised learning and it is defined as 'Instruction can be individualised based on learning styles, speeds, and interests to make learning more reliable'. Project-based learning at Taylor's University School of Engineering seems to lend itself as being able to provide the flexibility for instruction to be based on individual's background, learning speed, styles, interests and preferences (Mushtak and Tien in J Eng Sci Technol, 80–86, 2013, [1]). In this chapter, reason of project-based learning is an effective tool for personalised learning as discussed.

Keyword Project-based learning

3.1 Project-Based Learning at Taylor's University School of Engineering

Traditional education system and its assessment methods have a tendency of inducing students to focus on marks instead of their own learning. Uninteresting lectures can make the whole learning process a nightmare especially for students losing interest in the subject or field. Project-based learning modules at Taylor's University School of Engineering seem to make learning multidisciplinary, real-world relevant and promote higher order thinking. In these modules, a lecturer's main role is to facilitate students' learning as they work towards solving a real-world challenge [2]. Being an alumus and having gone through the process myself, below are what I believe why project-based learning is an effective initiative for personalised learning.

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3.2 Reason 1: Deeper Learning

There is a huge difference between knowing everything about a place from knowledge gained through reading versus having experienced the place yourself. This is the main difference between project-based learning and theory-based learning. Engineering theories are important. However, to make the learning extend beyond theoretical knowledge, the subject matter generally needs to be personally relevant and interesting as our brain tends to remember thing that is important, interesting, meaningful and personally relevant. Neuroimaging studies have shown that the hippocampus, a small organ located within the brain's medial temporal lobe, supports remembering event and information that are meaningful [3]. Lack of interest in learning is the main cause of poor memory retention. As an example, imagine an individual learning about the Arduino microcontroller platform. This individual may have attended a lecture where the features of the Arduino is introduced, followed by a tutorial and/or lab where there are some questions to allow the individual to practise solving some challenge and these to be followed by a final exam. This individual may score an A for this subject, yet it is very likely that little knowledge of the Arduino is retained after a short few months. The absent of personal experience working with the Arduino makes the individual's memory fades faster.

Let us take a suspension system as another example. A vehicle has a suspension system to reduce the perturbation caused when the vehicle is going over a speed bump. Experiencing the perturbation themselves by building a prototype would make the learning personally relevant as compared to the values of overshoot and settling time calculated using some prescribed formulae. The appreciation of the knowledge would also encourage student to be an active learner. In a project setting, this will allow student to learn based on their personal learning speed and preferences while they search for a solution to the challenge they are facing. This is compared to the traditional approach where it is a more passive learning where lecturers 'spoon-feed' students with knowledge. Active learning, where students are hungry for knowledge they need to solve the challenges they are facing in their project, is a better approach. The feeling of satisfaction after having solved a challenge by applying self-taught knowledge makes student appreciate the knowledge.

For the aspect pertaining to learning instruction be vary according to the individual learning ability and preferences, allowing students to select their own project, where they will need to learn certain set of skills and knowledge, might be a better approach than to instruct them to solve a case-based experiment [4]. The rationale being that students are more likely to choose projects they are interested in when given a choice and in doing so, students get to learn by working on project they have interest in. This helps build passion in the subject and encourages further learning even after the assignment. As an example, for those individuals interested in sports cars, there is no need to give them any assignments to encourage them to learn about sports cars, their specification, shape, performance, etc. They will learn it themselves and remember what they have learned. This is because they are interested in that particular topic.

Project-based learning also makes the learning real. Let us take the semester 2 engineering design and ergonomic module as an example. Instead of instructing students on details of ergonomic principles, letting them choose a project that has an ergonomic component will require them to apply ergonomic principles. Designing a chair is not the only ergonomic-related project in the world. For example, universal height adjuster for water dispenser, escalator, bookshelf, automated RFID locker system, door stopper, sleeping pod, multifunction detachable table panel, rolling whiteboard, prosthetic sole, specialised platform for the visually impaired, protective gear for Paralympian, floating watch, stationary bow holder, etc. are examples of other ergonomic-related projects. As compared to a normal degree course assignment that brings no value to society, now these projects are solving real-world challenges. For those project teams that are able to develop good design concept, it could potentially lead to a patent filing or a start-up. Hence, in project-based learning, assignments have become something meaningful to the student and society.

Other than allowing variation based on learners' preferences, project-based learning encourages creativity. Being open-ended, one needs to be able to evaluate design options, developing a critical mindset in the process. This includes making decision under various conditions in various aspects such as project management, budgets, time management and teamwork. Thus, project-based learning has the potential to train better graduate who is better prepared for the workplace as it promotes deeper learning.

3.3 Reason 2: Teamwork Development

Teamwork is important when solving a complex challenge as each individual is limited by knowledge and time. And the best way for students to develop good team-working attitude is to work in a facilitated team-working environment while undergoing their undergraduate study. In a project-based learning environment, students are required to take at least one project every semester. By the end of a 4-year programme, they would have worked on at least five project teams. Experience gained from these teams would help one appreciate the importance of working in team when solving complex challenges as well as how one could benefit from working in such a team environment. Through working in these project teams, students also become familiar with team dynamics as well as team stages [5, 6].

The skill to handle challenges in a team while working with teammates comprising of individuals with varying attitude can only be gained through experiencing it. One would only appreciate the skill of handling conflict when faced with the conflict itself [7]. Figure 3.1 shows the four Tuckman team development stages that teams are expected to progress through over a 14-week semester. The actual timeline depends on each team itself, starting from forming in the first 2 weeks, followed by storming for the next 5 weeks, then norming for another 5 weeks and the performing in the last 2 weeks. The more the teamwork experience, the lesser the duration in storming and norming, with longer time in performing.

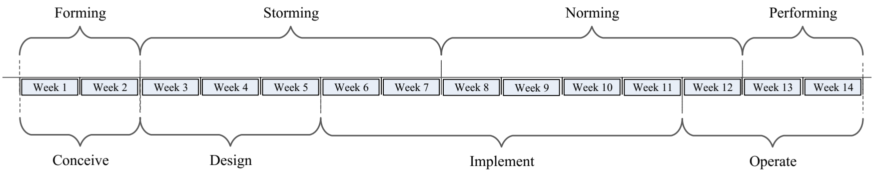

Fig. 3.1 Tuckman's model and CDIO timeline

3.4 Reason 3: Communication Skill Development

While working in a project, besides engineering knowledge and teamwork, communication among the teammates is another important factor that influences the performance of the team. The courage of sharing personal idea and the ability to communicate ideas effectively will slowly build as one gain experience working in teams. Imagine a person who is capable of effectively communicate complex design concepts. One is either gifted or had lots of practise doing artefact presentations. There is no guarantee that everyone will be able to gain this skill fully by the end of 4 years programme, but it would at least provide students a platform for them to enhance their communication skills.

3.5 Reason 4: Understanding of Feasibility and Manufacturability of a Concept While Designing a System

An example of a typical mistake students make is how to select the design for their first prototype to build. After a project challenge is offered, it is not uncommon for students to take only a few hours to complete the design for the system and is very excited about showing the functionality and aesthetics of the design. But when you start questioning them on the feasibility and manufacturability of the design, these students will start to change the initial design and try to fix flaws in the design. What is the point of having a system that is not feasible that cannot be built? The method to make student understand the importance of considering the feasibility of a design, the steps needed to implement the design, budget limitation, project timeline and manufacturability during the design stage, is to allow students to build a prototype of their design. Project-based learning provides opportunity for students to build these prototypes and hence learn the importance of considering the feasibility as well as the manufacturability of each concept during the design stage itself.

The awareness of the feasibility and manufacturability while designing a system can be impactful in some situation. This skill/awareness can only be gained by experiencing the actual prototype building itself. This further emphasises the importance of engineering knowledge like safety factor, strength of material, strength and type of adhesive, and other similar knowledge as important factor to consider during the design stage. These knowledge will never be appreciated unless they have experienced it and understand the consequences.

3.6 Reason 5: Technical Skill in Operating Tools and Machines

Building prototypes will require one to be skilled in operating tools and machines. For instant, skills of operating CNC milling machine that involve G-code, selecting a suitable milling bit, operating a lathe machine requiring the alignment and selection of cutting speed, drilling machine that involve the selection of a suitable gear ratio for a given situation, tapping machines that involves preparing a suitable hole before tapping, hydraulic press, welding machines that has various techniques like spot welding and arc welding, brazing, etc. The confidence in operating these machines requires actual experiences and practices on the real machines itself. This may sound like training an engineer to work as a technician, but imagine an engineer who understands the manufacturing process. This engineer will be capable of coming up with a design taking into consideration the capability and limitations of these machines and can potentially reduce waste during manufacturing the product itself.

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Chapter 4
Implementation of Facilitated Learning in a Project-Based Curriculum

Satesh Narayana Namasivayam

Abstract Unlike learners a decade ago, learners today have access to a wide variety of information through the Internet. This not only relieves teachers from the need to be the source of information but also make it possible for more effective learning initiatives. In this chapter, the implementation of facilitated learning in a project-based environment is discussed.

Keywords Teaching method · Facilitated learning

The current generation of learners has access to a variety of information, quite literally, at their fingertips. Accessibility to such information through the World Wide Web, accessible through smartphones, tablets and PCs, also varies in forms such as online videos, e-books, articles, online courses, etc. With the ease of such information being instantly available for learners, teachers are forced to re-evaluate their roles in classrooms. 50 years ago, teachers were looked at as the source of information, the keepers of knowledge and more importantly were thought to have 'all of the answers'. In today's day and age, this does not hold true anymore and there is a slew of research which supports such claims—not rendering the teaching profession 'useless' but looking at how the profession progresses with technology, adapts and plays a more meaningful role for current learners.

…when students already know the answers…

As such, what initiatives are available? Specific initiatives, to lead the progression of the teaching profession, ensuring adaption with the current generation of learners (for simplicity, such learners will be now known as i-gen), who have immediate access to information. Once again, there is a variety of pedagogical techniques as well as learning tools that would support i-gen learners and more importantly the teacher to ensure that learning occurs in an information-rich and tech-savvy environment. The *X*-based learning initiatives, terms that are coined by teachers globally, aim

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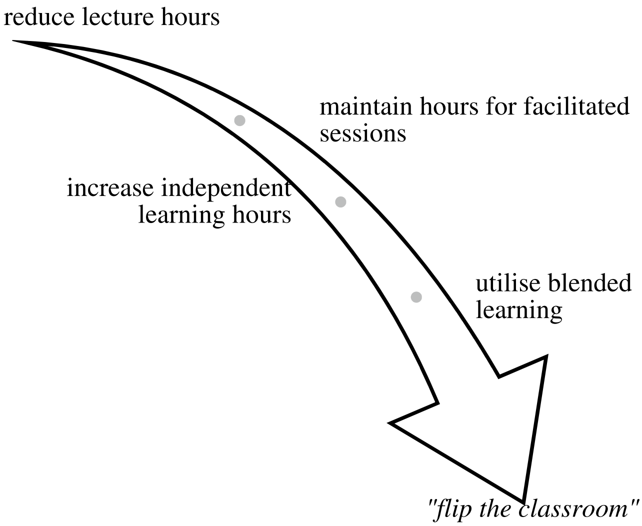
to do so—with the *X* being replaced by project, problem, research, collaborative, active, game, etc. Each *X*-based learning initiative with its own set of guidelines and even tools to assist the teacher in ensuring the learner gets as much learning done with the readily available information. Some of these learning initiatives and in some cases, the pedagogies utilise well-known and well-researched concept of facilitated learning—which essentially means, the teacher acts as the guiding light (or facilitator if you will), ensuring that students do not stray too far off the beaten path, when developing a solution to address a specific challenge that was provided to them during class or as an assignment. Once again, there are many widely accepted and well-researched articles that preach the benefits of facilitated learning in a variety of environments.

One of the guiding principles of facilitated learning is the fact that the teacher does not do as much teaching or 'telling' during a class. More time is dedicated to the learner, guiding them on finding the key information required to solve a challenge—creating inquisitiveness, allowing them to be independent and in group-based activities, interact with their teammate to discuss potential solutions to the challenge, encouraging debate, enhancing their communication skills, building their confidence and reaffirming their soft skills. As such, some literature or initiatives around facilitated learning also utilises the term of 'teach-less, learn-more' [1, 2].

The concept of 'teach-less, learn-more,' within a facilitated learning environment has a number of specific goals.

> *…reduction of content, reducing breadth and increasing the depth of key knowledge and skills…a flipped classroom.*

As mentioned earlier, in order to encourage facilitated learning, the teacher would have to do less 'teaching' and more 'facilitating'—thus the 'telling' part of the class is significantly reduced. This would then require that the teaching plan be reviewed to only focus on key content required for the learner, forcing teachers to eliminate information or content that may not be necessary or does not contribute to the overall attainment of the students learning outcomes. With a reduction in content, teachers can then focus on delving 'deeper' into key content, through facilitated learning, increasing the depth of the content since the breadth of the module in question was reduced. With a reduction of content, the face-to-face contact hours (when hours are mentioned, this is understood as educational credit, or a credit hour) of the teacher would also reduce. For example, the number of lectures within a specific semester may be reduced since the amount of teaching reduces. What would need to be maintained are the facilitated learning sessions, through tutorial or practical classes. Teachers could also make the decision to increase the amount of facilitated sessions and as such the learning occurs, essentially, in tutorial classes and not during lectures, and hence the term 'flipping the classroom'.



…teacher's ability…

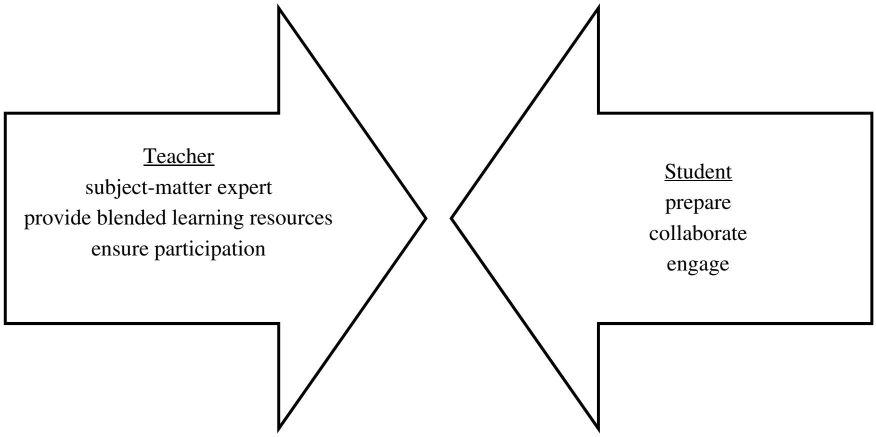
It should also be recognised that in order for the facilitated learning sessions to be meaningful, the teachers themselves must be prepared and should be a subject-matter expert. The reason for this is more collaborative discussions will take place in a facilitated session and teachers must be able to provide thought-provoking answers, which would lead the students in being more inquisitive, requiring more research and discussions amongst themselves when developing their own solution to address a challenge. Teachers may also decide to develop their own online videos for students to use as a resource to assist their solution finding.

…the grand challenge, advancing personalised learning…

The concept of blended learning within facilitated learning is important as students would utilise online content to prepare themselves for the facilitated sessions—this also allows for asynchronous learning, where students may learn on their own, in their own pace and learning becomes more personalised—thus facilitated learning is a proponent to the grand challenge of 'advancing personalised learning'.

…students' commitment…independent learning…

As mentioned earlier, in order for meaningful engagement to occur between the student and their peers as well as with the teacher during the facilitated learning sessions, students would need to use the time they would have had for the lectures (or the teacher-telling sessions) to prepare for the facilitated sessions. It is imperative that student uses this time to prepare for the session, using a variety of blended learning resources. In some cases, teachers may provide their own videos, as mentioned earlier, or create online assignments, tests that students would need to complete prior to the flipped classroom session. Essentially, the reduced face-to-face contact hours, specifically for the lecture, may be moved over to increasing the independent learning hours for the student, since now, students would need to prepare, with the relevant resources for their flipped classroom.



…so what do students and teachers say….

The narration throughout this chapter was applied in its entirety to specific courses or modules in an engineering undergraduate degree programme. Specifically, the modules chosen were that of the programme's design courses or project-based modules. In these modules, students are required to design and build an engineering system using CDIO^{TM} as the overall framework. The details of these modules are similar, from the perspective of credit hour loading alone, however the module learning outcomes, its synopsis and the relevant assessments do differ—however, as mentioned previously, the overall outcome would be for students to embody the knowledge of CDIO^{TM} and utilise it to design and build an engineering system. The division of the 3 credits within this module (which would run over a 14-week semester) is as follows:

- 1 credit: 1 contact hour of a lecture
- 2 credits: 4 contact hours of facilitated discussions.

Thus, in total, this module, with 3 credit hours, constitutes an hour lecture and 4 h of facilitated discussions in 1 week.

In the spirit of facilitated learning, thus flipping the classroom, a decision was made to 'teach-less' by reducing or removing the contact hour for the lecture in its entirety and the 1 credit that contributed towards that lecture hour was replaced by 3 h of independent learning. In order to ensure that students had access to key information and resources for their (now) additional 3 h of independent learning, they were provided with a slew of online videos, most of which were customised e-lectures of content that was specific to only these project-based modules as well as additional reading material.

Upon completion of these modules in its new form (i.e. in ‘flipped’ mode) the following feedback was obtained from students (taken verbatim):

‘Informative & useful’
‘Better than real time lectures’
‘Easily accessible and repeatable’
‘Valuable for time’
‘Repetitive content’
‘More content on engineering analysis’
‘Long & need more examples’

Overall, the positive feedback revolved around the fact that students were able to personalise their learning and learn the concepts of CDIO^{TM} at their own pace, with the online videos and other e-resources. They also lamented about not having to get up early to attend lectures!

Students also provided valuable feedback in the spirit of continual quality improvement saying to reduce the repetitive content in the videos and include more examples and content on other areas that they felt were key.

…reflections…

It is evident that there is a multitude of research into how facilitated learning, specifically, the flipped classroom initiative by teaching less and learning more addresses the needs of the current generation of learners. However, it should be noted that there must be a good amount of preparation from both students and members of staff to ensure that the facilitated sessions are meaningful and impactful for the learners. Specifically, the change in the method of delivery of the content must not affect the overall attainment of the relevant learning outcomes.

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Chapter 5
Engineering Fair: Going Beyond the Classroom

Kun Yong Ng and Edwin C. Y. Chung

Abstract Engineering Fair is an event where all engineering students at Taylor's University School of Engineering present their final design for their project publicly. At the fair, these projects are evaluated not only from the technical perspective, but also for the effectiveness how key facts about the project are delivered within a limited time. Judges are from both academic and the industry. The score each team received during the engineering fair will contribute to 10% of their design module score. In this chapter, the rationale for having engineering fair as part of the design module and its assessment criteria are discussed.

Keywords Engineering fair · Assessment

5.1 Engineering Fair at Taylor's University School of Engineering

The main differences between Engineering Fair and the standard artefact assessment[1] are the judges and who can view these projects. Judging at Engineering Fair will consist of internal and external assessors from academia and the industry and it is a public display similar to a trade fair. Artefact assessment, on the other hand, is an internal assessment by internal academic staff only. Projects on display at Engineering Fair are the design module projects, from semester 1 to semester 8 as mentioned in Chap. 3. Every project is provided with a booth, and judges are from both academia and the industrial. In a typical of engineering course, assessor(s) for a student project is usually the lecturer of the module. Unless the lecturer has industrial experience, such practice can potentially limit these students to critique from academic perspective.

[1] Artefact assessment is an internal assessment a few weeks before Engineering Fair where every team will need to present their design to internal assessors who will judge and critique their work.

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As such, this project-based teaching approach that incorporates an Engineering Fair with assessors from the industry is a method that is highly supported by our industrial advisory panel (IAP).

5.2 Reason 1: Enhancement of Presentation Skill

The only presentation opportunity for a typical engineering degree course is during artefact assessments at the end of each semester with an audience of only one, the module lecturer, possibly two, a second assessor. It is very often that students will use bombastic or technical terms during the presentation. The module lecturer would understand those words because they are also well versed with the topic. It would, however, be completely alien to someone who is not familiar with the field. Engineering Fair is an event where students exhibit their project publicly. It serves as a platform where students can practice their presentation skill to those not from engineering. The skill of delivering a complex technical content at a level that can be understood by those who not from engineering, such as management or investor, is extremely important.

Students would typically encounter four types of audience during Engineering Fair, and they are judges from the industry, academic who are either judging or checking out students' work, peers (either their junior and senior wanting to know more about their project) and the public with or without engineering background. When students try to convince visitors to their booth of their design concept, it provides them with an opportunity to gain real experience and to build their self-confidence. It is a platform for them to practice various presentation techniques and understand the impact of each technique. By observing, experiencing and comparing the response from audiences, it also enhances their confidence in presenting complex engineering content. This further improves their ability and skill since presentation is one of the common ways to communicate in both industrial and academia.

The various presentation techniques that are covered within the 4 years of engineering course at Taylor's University School of Engineering course are neuromarketing [1], golden circle [2] and storytelling [3]. Neuromarketing uses a four-step preparatory system and utilizes six stimuli targeting a specific part of our brain. Golden circle focuses starting with the why, followed by the how and the what. Storytelling uses a story with a familiar scenario to guide the audience thinking towards a conclusion that the presenter intended! Engineering Fair is an effective platform where students can deepen their application of these presentation techniques. Here, instead of just receiving feedback and comments from a lecturer, Engineering Fair allows students to receive feedback and comment from a much wider and varied perspective.

5.3 Reason 2: Peer Learning

Engineering Fair is also a peer learning session. Students will meet each other at the lab when they are working on their project. However, due to their timetable, there are bound to be many other projects they would not be aware of. As such, Engineering Fair is a time where all projects are on exhibit and it gives everyone the opportunity to learn each other.

During the fair, all projects are on display in close proximity of each other thus making it a good peer learning platform where students from all semester can interact freely among themselves to learn from each other. It is, however, important to note that students overly concern with the manning of their booth may neglect this opportunity to visit other booth and in the process miss out on this opportunity to exchange ideas and learn from each other. Accordingly, it is important that students are encouraged to and arrangement be made to allow students time to learn from each other. Some might argue that such common space like the lab and workshop could deliver the same purpose. The fact is that everyone is busy working on their project and barely have time to explain things in detail at the workshop. Hence, Engineering Fair is still the best time for them to exchange ideas across the different batches of students and learn from each other. It is also very motivating for junior students when they see the work of their seniors. It is very effective for students to learn through peer learning though it is not a formal way to teach students. With limited resources and staffs, Engineering Fair is an approach to enhance the quality of education compared to traditional teaching and learning method. To avoid students get demotivated when working on complex engineering challenges and for them to understand the value of what they are learning in their design module, encourage students to view the projects of their seniors as it will motivate them to take more challenging project in the future.

5.4 Reason 3: Students Experiences

Engineering Fair is a platform for students to showcase their project achievement, a place for them to show the final product of their 14 weeks hard works. It packed within it good and bad memories for the semester. The memories such as conflict with teammates during idea selection; facing the difficult questions from the various judges; disappointment with failed prototype(s); building prototype overnight with teammates, endless updating of presentation slides up until Engineering Fair; defending design concept together with teammates during Q&A sessions; spending more than the approved budget and using personal pocket money to purchase project materials; a component of prototype suddenly failing during Engineering Fair; everyone is wearing the same Engineering Fair T-shirt design; winning awards and receiving round of applause from everyone present at the award ceremony, etc. The memories and feelings are very intense more because it is a public exhibition.

It is not easy for students to have to complete their project under the stress of other module assignment deadlines, tests and final exam preparation. It is to train them to have a good personal time management and to be able to handle stressful work environment in the future.

5.5 Reason 4: Marketing Purpose

This reason is more for the university, but it is also beneficial to students indirectly. Engineering Fair is a platform to promote the quality of its students to representative from the industrial and public. Anyone is able to visit any project booth talk to the students about their project and even critique their idea/concepts is so desired. Photos taken during Engineering Fair are also good marketing collaterals that can be used in website, brochures, news articles and the in-house magazine, 'SPARK' that records all student projects. Some industrial take this opportunity to gather concepts. Winners are also interviewed and the videos used as marketing material eliminating the need to hire actors for promotional video. A smart student sharing something positive is very impactful indeed.

5.6 Assessment Criteria

All group projects in Engineering Fair are judged based on feasibility, viability, desirability and sustainability. Students present their prototype as a proof of concept along with presentation slides during the Engineering Fair. Final year project judging criteria is different from group project assessment. Final year project is judged more on research. The assessment criteria of each design module are provided in the following subsections.

5.6.1 Engineering Design and Communication

The main judging criteria are design factor (from item 1 to 7 in the list below) and design process (8), implement (9) and operate (10).

1. The importance of design factor is clearly demonstrated with application of engineering principles;
2. Technologically feasible: constructive ideas and concepts;
3. Economically viable;
4. Able to solve a complex engineering challenge;
5. Sustainable (make use of recyclable materials and green technology);
6. Desirable and easy to use;

7. Teamwork and communication;
8. Clear application of design techniques to develop engineering solution;
9. Comprehensive testing procedures are planned and operated to assess the functionality, reliability and safety of the artefact; and
10. Artefact is operated at its full potential with clear operating procedures.

5.6.2 Engineering Design and Ergonomics

The main judging criteria are human factor (1–6) and the application of ergonomic principles (7), implement (8) and operate (9).

1. The importance of human factor in engineering design is clearly demonstrated with application of ergonomic principles;
2. Technologically feasible;
3. Economically viable;
4. Environment-friendly and sustainable;
5. Safety and health;
6. Aesthetic, comfortable and easy to use;
7. Clear application of design techniques to develop engineering solution;
8. Comprehensive testing procedures are planned and operated to assess the functionality, reliability and safety of the artefact; and
9. Artefact is operated at its full potential with clear operating procedures.

5.6.3 Multidisciplinary Engineering Design

The main judging criteria are multidisciplinary aspects (1), concepts (2–5) and approach (6–8).

1. The multidisciplinary aspects in the project that includes of chemical/biology, mechanical/electrical and electronic, computing/design/mathematics to solve complex engineering challenge;
2. Technologically feasible;
3. Economically viable;
4. Environment-friendly and sustainable;
5. Manufacturability;
6. Integrating the knowledge of each multidisciplinary aspect to develop engineering solution;
7. Apply thinking techniques such as Trimming/Random Entry/system thinking to conceive, design, implement and operate; and
8. Demonstrate the design project for the validation of concepts or hypothesis.

5.6.4 Engineering Design and Innovation

The main judging criteria are business value (1–2), concepts (3–7) and approach (8–10).

1. The business value of the original challenge the engineering design is attempting to solve is sensibly estimated using the relevant value dial(s) with a clear understanding of its associated burden of proof;
2. The expected outcomes of the design have demonstrated high business values/high impact to the well-being of human society and have high potential to be commercialized;
3. Concept(s) and/or hypothesis for the project are based on sound scientific principles;
4. Technologically feasible;
5. Economically viable;
6. Environment-friendly and sustainable;
7. Legal (Intellectual Property);
8. Information were gathered to understand the engineering challenges from the user's prospective;
9. Ideation techniques, like brainstorming, lateral thinking, TRIZ, etc. were applied to formulate solutions for the engineering design; and
10. Proof of concept was planned and conducted in stages to demonstrate the feasibility of the concepts or hypothesis.

5.6.5 Capstone Project 1 (Mechanical and Electrical Engineering)

The main judging criteria are innovation (1), project idea and design (2–5), design solution principles (6–9) and presentation (10).

1. Innovation in engineering design is clearly demonstrated on artefacts;
2. Technologically feasible;
3. Economically viable;
4. Environment-friendly;
5. Socially acceptable;
6. Artefact/poster where it shows design aesthetics;
7. The use of resources is optimum;
8. The design is easy to be manufactured;
9. Design solutions are clear and complete. Will allow unfamiliar person with the project to reproduce the work; and
10. Exhibition booth and explanation provided by group members were accurate, knowledgeable and clear, and show teamwork cohesiveness.

5.6.6 Capstone Project 2 (Mechanical and Electrical Engineering)

The main judging criteria are project impact (1–6) and prototype evaluation (7–10).

1. It has positive impact on the society;
2. It imposes no health risks to the users;
3. It is safe to use;
4. It has no legal violation;
5. It has economical value;
6. It has considered to cultural values;
7. Artefact shows design aesthetics;
8. All the functions planned in the design are implemented;
9. The solution is robust; and
10. Exhibition booth and explanation provided by group members were accurate, knowledgeable and clear, and show teamwork cohesiveness.

5.6.7 Capstone Project 1 (Chemical Engineering)

The main judging criteria are innovation (1), production, environment and safety (2–4), design solution principles (5–7) and presentation (8).

1. Innovation in engineering design is clearly demonstrated on the plant design;
2. Technologically feasible;
3. Economically viable;
4. Less environment impacts;
5. Accurate and complete mass balance and energy balances data;
6. Able to explain sustainability that is incorporated in the plant design;
7. Able to explain details of improvement made from previous design; and
8. Exhibition booth and explanation provided by group members were accurate, knowledgeable and clear, and show teamwork cohesiveness.

5.6.8 Capstone Project 2 (Chemical Engineering)

The main judging criteria are technical information and process selection (1–3), safety in process plant design (4–6), economic impact analysis (7–8), process control design (9–10) and plant design layout and scale (11–16).

Ability to justify the selection process from the perspective of

1. Safety impact
2. Environmental effect
3. Economic viability

A complete safety feature design according to

4. Material and Process Hazards analysis
5. Hazard & Operability study (HAZOP analysis)
6. Risk Assessment

Ability to explain the following:

7. Complete cost estimation for project life
8. Profit and Loss analysis and Sensitivity analysis

Process control design analysed according to

9. Key control parameter identification and control loop designed for steady plant operation
10. Description of control mechanism

Plant design layout and scale

11. 3D Prototype model
12. Model plant built to scale
13. Artefact built as per Plant Layout design in report (Attached with drawing design)
14. Ease of access point for transportation (Loading and unloading)
15. Emergency response (emergency exit/fire escape route and assembly point)
16. Design for process safety (control room location, safety distance between unit operation, ease of access for each unit operation, containment equipment).

5.6.9 Final Year Project 1

The main judging criteria are engineering research aspects (1–6), data validation (7), fundamental knowledge (8), research difficulty level (9) and poster design (10).

1. Introduction.

Does the background of the project describe resolution of significant problems arising from technical, engineering and other issues?

2. Literature Review.

Are there evidences of research gap identification including its contribution to the body of knowledge?

3. Research Questions and Objectives.

Are the research questions clearly defined and the objectives clearly derived from the research questions?

4. Research Methodology.

   Is the research methodology clearly presented and consistent to the objectives?

5. Expected Outcomes.

   Are the expected outcomes clearly stated and aligned to the objectives?

6. References.

   Are references up to date, relevant and in proper format?

7. Data validation.
8. Fundamental knowledge.
9. Research difficulty level.
10. Poster design.

5.7 A Summary

In conclusion, Engineering Fair is an assessment tool, a product of project-based learning to make the learning more reliable. It enhances presentation skill and creates an avenue for peer learning and variation in learning experiences. It is also training for students to always consider feasibility, viability, desirability and sustainability while working on a project.

Taylor's University Engineering Fair first started in December 2009 and it is organized twice a year. We have had a total of 18 Engineering Fairs at the time of writing, and a total of 2160 projects have been completed and exhibited thus far as shown in Table 5.1. The latest engineering group photo on 4 December 2017 is shown in Fig. 5.1.

Fig. 5.1 Taylor's engineering fair group photo on 4 December 2017

Table 5.1 Taylor's engineering fair record

No.	Date	No of awards	No of projects
1	2009 Dec	4	13
2	2010 May	7	37
3	2010 June	8	14
4	2010 Dec	13	54
5	2011 June	24	70
6	2011 Dec	20	73
7	2012 July	21	87
8	2012 Dec	15	130
9	2013 July	13	127
10	2013 Dec	15	122
11	2014 July	39	140
12	2014 Dec	47	132
13	2015 June	41	189
14	2015 Nov	41	210
15	2016 July	41	233
16	2016 Dec	41	221
17	2017 July	32	155
18	2017 Dec	32	153
	Total	454	2160

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Chapter 6
Capstone Project at Taylor's University School of Engineering

Siew Wei Phang, Ghafour Amouzad Mahdiraji, Yoke Kin Wan, Edwin C. Y. Chung and Mohammad Taghi Hajibeigy

Abstract Engineering Group Project I and II are the two design/project modules that come after the four foundational design modules from semester 1 to semester 4. Together, this year-long project is taken as the capstone project in which students worked in teams to solve a real industrial or social challenge. Details pertaining to these modules that make up the capstone project, including samples of students achievements, are described in this chapter.

Keywords Capstone project · Group project

6.1 Capstone Project in General

Capstone project, also commonly known as culminating project, is a year-long project students worked on in their final year of study. It is multifaceted and serves as a culmination project in that students are required to apply a wide range of knowledge they were exposed to previously to investigate/solve a complex challenge. In an engineering programme, capstone projects are usually experimental in nature with the objective of finding a solution that addresses an industrial/community challenge, or is an exploration research [1, 2].

The term capstone is an architectural term, and it refers to the final stone placed on top of a structure to symbolise the completion of the structure. Similarly, in academics, it means the culminating experience students gain at the end of their academic programme [1]. As described in the Glossary of Education Reform [2], '*Capstone projects are generally designed to encourage students to think critically, solve challenging problems, and develop skills such as oral communication, public speaking, research skills, media literacy, teamwork, planning, self-sufficiency, or goal setting*'.

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These skills are highly aligned with the Grand Challenges for Engineering and that is Advance Personalized Learning [3].

6.2 What Is Implemented at Taylor's University School of Engineering?

Engineering Group Project I and II, known collectively as the capstone project, is a compulsory core module for all undergraduate students at the School of Engineering at Taylor's University. However, unlike most capstone projects, which are individual project in the final academic year, capstone project at the School of Engineering at Taylor's University is a discipline-specific group project with each team consisting of three to a maximum of five students. With the exception of Chemical Engineering, where this capstone project is a final year module, Electrical and Electronic Engineering and Mechanical Engineering students are scheduled to complete their capstone project in year 3 of the 4-year academic programme.

6.2.1 It Is a Competition!

Each cohort of the same discipline will generally be provided with a challenge to work on. Every team from the cohort will need to work on the same challenge provided. From time to time, the same challenge may be offered to students from different disciplines with each discipline solving the aspect relevant to their discipline. The design of lunar lander being one example where Mechanical engineering students worked on the design of the structure while Electrical and Electronics engineering students worked on the design of the communication and control system for the lander. A vastly complex challenge that cannot be completed in an academic year may also be partitioned into smaller challenges and these challenges offered at the same time. The intention of getting all teams to work on the same challenge is that embedded into the philosophy of the capstone project is the concept of a competition. Every team is essentially competing among themselves to produce the best design.

6.2.2 Source of Projects

The challenge offered to each cohort is usually a challenge from the industry and from time to time, it may also be one that is provided by the module coordinator. These industrial projects are derived from working with our industrial partners, understanding the challenges they are facing and drafting a challenge in a manner that is suitable as a capstone project yet sufficient to yield a solution that has the potential to be useful to these partners. A constraint that we need to consider is that being a member of the NAE GCSP, these challenges offered need to be related to at least one of the NAE's 14 grand challenges. The module coordinator will also need to present details of the challenge to be offered to the project-based committee for approval before the start of the semester. Each module coordinator will also need to work with the cohort through the two semesters of the capstone project.

6.2.3 Group Project I (GP1)

This is the first part of the two-semester capstone project and it starts with team formation. This is done by the module coordinator, by first selecting the top students (based on academic achievement) as group leaders, followed by randomly assigning the remaining students into the various groups. This randomised selection approach (other than the group leaders) is to simulate 'real' working environment where the employee does not get to choose who they will be working with. This gives students the opportunity to experience and learn to work with others in their group. The task of the group leaders, on the other hand, is to lead and manage the group. Group leaders are project leaders that manage project. They plan and coordinate tasks, organise meeting, track progress, reporting, etc. It is noticed that chances for conflict among team members are high, hence another good training ground for interpersonal and communication skills where students learn to work with each other.

Based on the CDIO framework, GP1 would mainly involve students in the conceive and design stage, as it is at this stage that they will need to understand the challenge involved and ideate for a suitable solution. As such, teams completing GP1 would not have a final design to exhibit come Engineering Fair, but proof of concept prototype(s), built during the design stage, are commonly exhibited for ease of explanation of their concept at the fair. Feedback from judges and visitors during the Engineering Fair is used to help students improve their design in the following semester.

6.2.4 Group Project II (GP2)

It must be stressed that even though GP2 is the second part following GP1, a student must pass GP1 in order to register for GP2. Following the conceive and design stage, GP2 focuses mainly on the implementation and operation stage of the project. Students may continue to refine their design multiple times before they arrived at the desired solution. In GP2, students focus on system integration combining different parts of the design together. In addition, depending on the project, students may need to consider factors such as safety, health, economic and environmental sustainability.

6.2.5 Assessment

Assessment components for GP1 and GP2 are as summarised in Tables 6.1 and 6.2, respectively. Majority of the assessment are group assessment where group marks contribute to 70% and 60% of a student final score in GP1 and GP2 respectively. Individual component is assessed through student logbook (i.e. portfolio), presentation and peer assessment while the group achievement is assessed based on their interim report, final report and artefact assessment. Rubric for each assessment is detailed in a project handbook. This handbook, along with the other important artefacts, is uploaded and made available via the university online Moodle platform.

Logbook is assessed individually. Students are to update their logbook regularly and progressively. Each student is required to meet with their module coordinator individually to present their logbook from week 2 to week 12. Other than getting their logbook signed-off by their module coordinator, their module coordinator will also provide them with the necessary feedback as well as suggestion for improvement.

Final Report is a group assessment. This final report is written and compiled by the team, and it documents all the technical aspects of the project in such a manner that it will allow others, skilled in the art, to understand and reproduce their work.

Interim Report is also a group assessment. It is also written and compiled by the team, and it is meant to be an early version of the final report. The interim report is an assessment in GP1 in the middle of the semester.

Table 6.1 Assessment for GP1

Type	Details	Mark (%)
Logbook	Individual	10
Interim report	Group	20
Final report	Group	30
Presentation	Individual	15
Peer assessment	Individual	5
Artefact assessment (Engineering Fair)	Group	20
Total		**100**

Table 6.2 Assessment for GP2

Type	Details	Mark (%)
Logbook	Individual	15
Final report	Group	40
Presentation	Individual	20
Peer assessment	Individual	5
Artefact assessment (Engineering Fair)	Group	20
Total		**100**

Presentation is an individual assessment. Each student is required to present to the module coordinator and other internal judges his/her contribution to the project.

Peer Assessment is an individual assessment where each student evaluates the contribution of their team members towards the project.

Artefact is a group assessment. Each team is required to showcase their project at the Engineering Fair, and this is the score the team received from judges that assessed them.

6.2.6 Example of Capstone Project in Chemical Engineering

How capstone projects are conducted specifically will vary from programme to programme. In this section, details pertaining to how capstone project in the Chemical Engineering programme is conducted are discussed. Here we have chosen the challenge of a process plant design as an example.

Figure 6.1 details a process flow utilised for process plant design in capstone project for our Chemical Engineering programme. As illustrated in the diagram, once the product for the process plant is confirmed, students will plan for the entire project cycle using project management tools. Students are then given 5 weeks to conduct the feasibility and sustainability study of the project. This includes the market outlook for the product, demand and production in the previous 5 years and the forecast market outlook for the next 10–20 years. Alternative process design is compared from the perspectives of sustainability, environmental impact, chemical toxicity, as well as its commercial value.

Completion of the feasibility study will direct students to the main focus of the design project—the process design itself. Here, students will require knowledge they have acquired in the previous three academic years in order to complete the design phase. The plant design is captured in a number of reports. The mass and energy balance report being the first. This is followed by that for process integration and waste management. In the process integration report, pinch analysis is adapted to minimise energy consumption of the process plant via heat integration. The intention here is to reduce energy usage hence an improved economic performance of the plant. The next report focuses on the waste minimisation followed by the design of waste management system through the 3 R's concept: Recycle, Reuse and Reduce. This report also concludes the design phase for GP1.

The mechanical design of individual unit operation for major and minor units is conducted in the GP2 after process optimisation is completed. The final mechanical design is captured in a set of engineering drawings that compliance with British Standards BS8888 [4]. Figure 6.2 shows a 1:100 scaled 3D-printed model of one such design. The entire design process is complete once the safety, health and economic analysis for the design are completed.

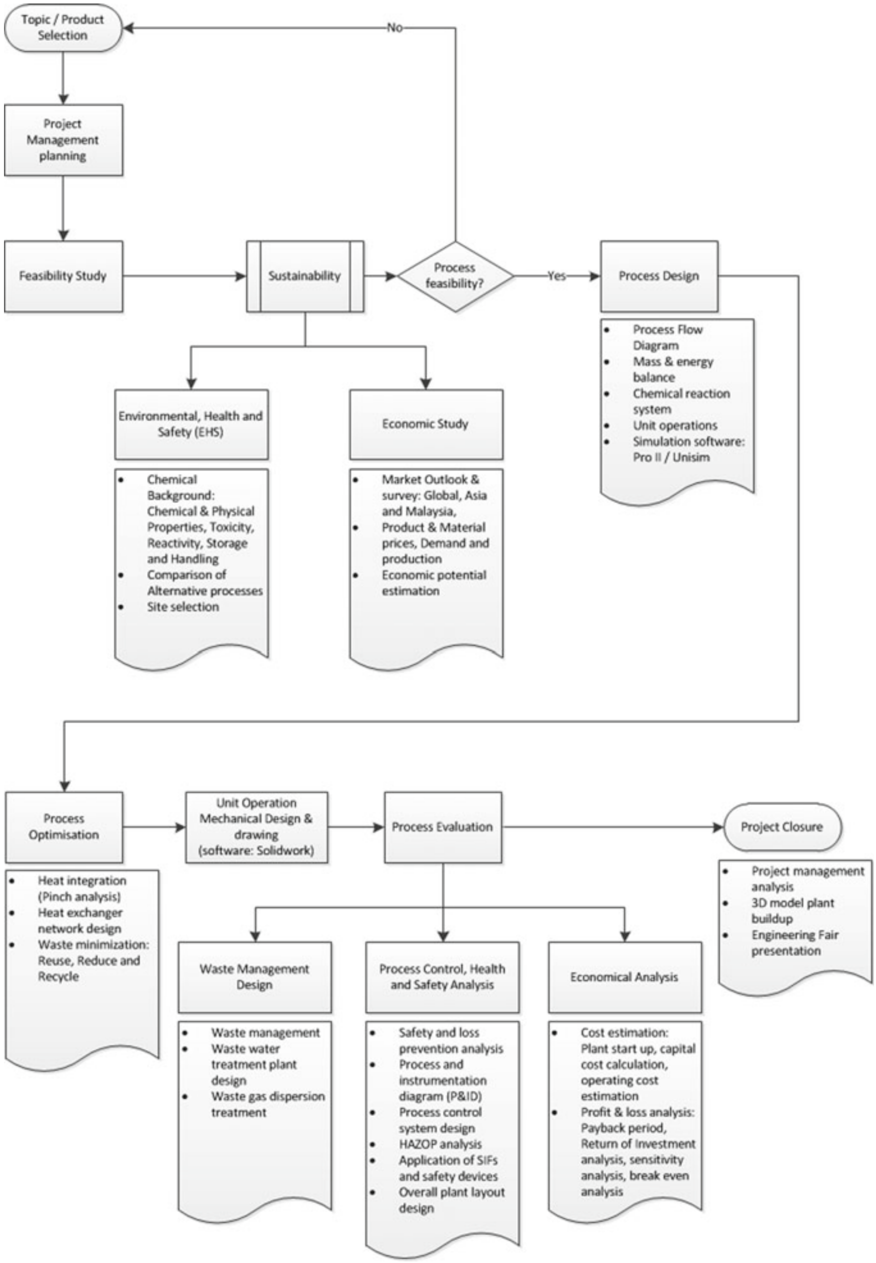

Fig. 6.1 Example of a capstone project conceptual plant design process flow for Chemical Engineering

Fig. 6.2 Miniature 3D model sample in accordance with students' design

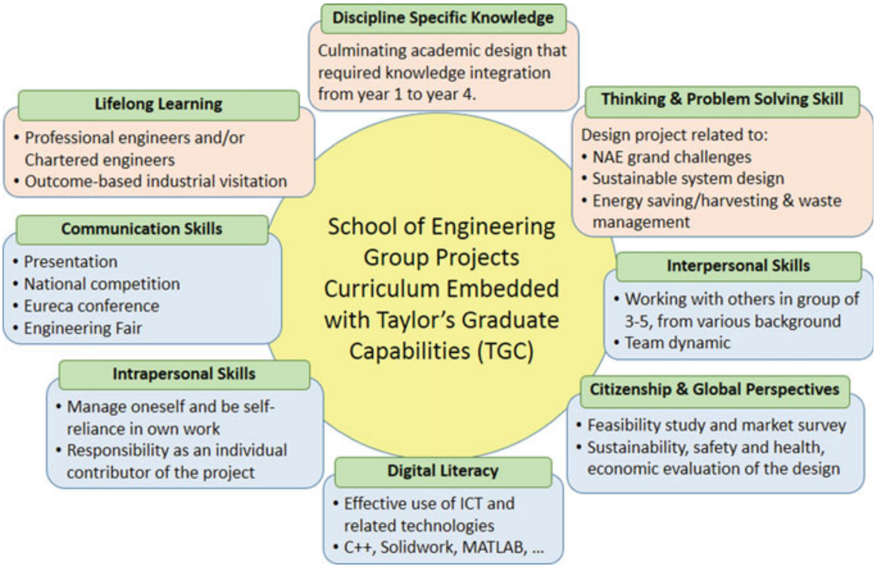

Fig. 6.3 Capstone projects embedded all of Taylor's Graduate Capabilities (TGC) in its curriculum and assessments

6.2.7 Taylor's Graduate Capabilities (TGC) in GPs

The capstone projects were designed embedding all eight Taylor's Graduate Capabilities (TGC) in the curriculum [5].

Figure 6.3 illustrates these TGC in relation to the capstone project.

(a) (b)

Fig. 6.4 **a** A remarkable achievement for the champion team with (from left) Chia Wan Teng, Shanggary Rajendran, Ameena Ali and Mariam Hafeez in 3rd IEM Chemical Engineering Design Competition. **b** Another finalist shortlisted team from Taylor's University, Goh Sze Ting (from left), Alicia Cheok Pei Yin, Tam Sue Wern, Chan Yen Min and Tang Shiaun Leh

6.3 Student Achievement

In 2015, a group of four students from Chemical Engineering GP2, led by Shanggary Rajendran, bagged the championship of the 3rd IEM Chemical Engineering Design Competition Nationwide—an event organised by the Chemical Engineering Technical Division (CETD) of The Institution of Engineers, Malaysia (IEM). This event was held at Heriot-Watt University, Putrajaya (Fig. 6.4a). Another team, led by Goh Sze Ting, was shortlisted in the finalist stage (Fig. 6.4b). The design theme Shanggary's team worked on was to enhance the sustainability of a biodiesel plant by converting crude glycerol, the main by-product of the plant, to value-added products. Shanggary and her team decided to convert these wastes into citric acid—an item that is present in many household products.

In the following year, two teams from Taylor's Chemical Engineering GP2, led by Janice Low Jie-Ni and Isobel Soo Hui Qing, won the second and third prizes in the 4th IEM Chemical Engineering Design Competition Nationwide (Fig. 6.5). The participants must design a manufacturing plant that converts small alkanes gases into hydrocarbon C6+.

As another achievement on Dec 2017, three students from Electrical GP1 led by Taghi Hajibeigy competed in the ABB Intervarsity Innovation Challenge which was held in Kuala Lumpur Conventional Centre. The Taylor's University team (Fig. 6.6) managed to be shortlisted as one of the top five finalists out of 72 teams from various universities in Malaysia. The objective of this competition was to stimulate creativeness and innovative thinking among undergraduates apart from building an interactive platform between the academic circle and industry experts with the core theme of 'Writing the Future of Digitalization and Smart Technologies'.

The above achievements show the level and significance of the capstone projects in SoE, at Taylor's University.

Fig. 6.5 The Winning Teams in 2016 4th IEM Chemical Engineering Design Competition (left to right: Yap Jun Jie, Dianne Priya A/P Lawrence Thangathurai, Merisa Gunawan, Isobel Soo Hui Qing (team leader); Eunice Phang Siew Wei (Supervisor); Chia Wei Qian; Janice Low Jie-Ni (team leader), Archana A/P Aravinthen, Jason Low Wai Kit, Leroy Liaw)

(a) **(b)**

Fig. 6.6 **a** From left: Taghi Hajibeigy GP coordinator, students Lou Wei Jun, from right, Bryan Chang and AnG Zhe Han and ABB competition manager. **b** The Award is given to the students for winning the top five finalists

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Chapter 7
The Final Year Engineering Project's Impact on Students' Learning Experience

Douglas Tong Kum Tien, Nurhazwani Ismail and Bee Lin Chua

Abstract The final year project represents a very significant milestone in the education of a final year engineering student. For the first time, he or she is required to undertake a research-oriented project entirely on their own. While projects in the earlier semesters were primarily group projects of a design and build nature, the final year project is different in that it is an individual research project. It requires the student to manage it to completion by themselves and to develop the requisite research skills to undertake it successfully. This chapter elaborates on the final year project module at Taylor's University's School of Engineering with regards to design and implementation of the module and how this influences the learning process of the students.

Keywords Final year project · Engineering · Assessment · Learning · Supervision

7.1 Introduction

The final year project (FYP) at Taylor's University consists of two modules, namely, Final Year Project 1 (FYP1) which is offered in semester 7 and Final Year Project 2 (FYP2) which is offered in semester 8. They contribute 3 credit hours and 6 credit hours respectively. These are the only modules where the students are required to undertake an individual research project by themselves over the course of two semesters. The challenge posed to the student is considerable and likewise, the learning opportunities available are substantial. This chapter elaborates on the design and implementation of the FYP at Taylor's University's School of Engineering (SoE) and how this would influence the learning process of the students.

The FYP covers a wide range of learning outcomes (LO). Taken together, the combined 12 LOs of the FYP1 and FYP2 addresses 11 out of the total 12 programme

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outcomes (PO). The LOs for the FYP1 and FYP2 can be found in Chap. 3. The only PO not addressed by the combined FYPs is PO8 which is related to engineering practice. This is mainly because the FYPs are research- rather than practice-oriented.

FYP1 focusses on performing a literature review, identifying the gaps and contribution, clarifying the research questions and objectives, developing a methodology, ascertaining the budget and resources, defining the expected outcomes, and familiarizing with the software, tools, and techniques to be used.

FYP2 focusses on execution. The student purchases the material, builds the system, performs the experiments or conducts the simulations, analyzes the results, discusses it, and comes to reasonable conclusions.

7.2 Project Proposal and Selection

The FYP process begins even before the semester starts when the academic staff of SoE is invited to submit their FYP proposals. The content of these proposals would include the Grand Challenge being addressed, the synopsis of the project, the research questions, the research objectives, the expected outcomes, the resources needed, and the budget requested.

The submission of FYP proposals is not limited to SoE's academic staff. SoE's industry partners are also invited to submit. However, these proposals will require an academic staff willing to be the academic supervisor of the FYP. The academic supervisor will need to vet these proposals as to their suitability as an FYP with regards to their level of complexity and research intent before submitting them on behalf of the industrial partner. The industrial partner assumes the role of industrial supervisor to provide guidance to the student on all industry-related matters. The academic staff takes on the role of an academic supervisor. This role is explained in Sect. 7.2.

Apart from academic staff and the industry, the students themselves are allowed to submit FYP proposals based on their own area of research interest which may not be covered by the projects on offer. However, the student must first seek for an academic staff who is willing to supervise their proposed project, vet, and revise the proposal if necessary and submit it on the student's behalf.

These FYP proposals are reviewed by the programme director of the respective programmes. Approved proposals are disseminated through the student portal for the students to make their selection. The students may select up to five projects in the order of their choice although only one project will be assigned. The FYP module coordinator assigns the projects to the students according to their choices. The priority of project assignment is given to the student who has a higher CGPA in the event if more than one student had selected the same project. This procedure was adopted to ensure transparency in the project assignment.

Some examples of FYPs including the title, student and the supervisor information, grand challenge addressed, engineering problem, research questions, objectives, and research findings can be found in Chap. 8.

7.3 Supervision

Supervision is vital to an effective learning experience. With this being the case, students are expected to meet with their supervisors on a weekly basis. To ensure that the meeting is productive a **meeting record form** is utilized to document the contents of discussion and for subsequent follow up. The progress since the last meeting, the items discussed at the present meeting, and the actions for the following week are documented in the form by the student. The use of this form is common to both FYP1 and FYP2.

The supervisor would comment on the completion of the progress plan since their last meeting, a section in the form being allocated for this. Both the student and the supervisor sign off on the form and the student will bring the form for follow-up and for accountability at the next meeting. It is the student's responsibility to keep all these forms and submit them to the supervisor at the end of the semester for assessment. The supervisor assesses based on the total number of meetings that had transpired and also on the completion of work agreed upon from week to week as recorded in the forms.

The meeting record is worth 5% of the entire marks of the FYP. This 5% represents the full contribution of marks to the FYP by the supervisor. The remaining 95% is obtained from other assessment components. These other components are assessed by two different assessors who are the academic staff of SoE but not the supervisor. Some assessments like the Engineering Fair poster presentation and EURECA conference presentation, also involve assessments by external parties from industry and academia.

This 5% contribution by the supervisor may be considered as among the lowest for an FYP anywhere in the world. Hence the FYP assessment could be deemed to be free from any influence arising from any form of the positive or negative effect of a student–supervisor relationship. It is therefore assured that the FYP assessments are fairly conducted as they are performed by unbiased third-party assessors. As an added benefit, the students also have the opportunity to learn from these experts as the assessors are required to give written feedback as part of the assessment process.

With regards to students' responsibilities, they are expected to own the project instead of merely taking step-by-step instructions from their supervisors. The students are regarded as researchers in their own right albeit a novice researcher. The supervisor's role is primarily to guide the student, to evaluate if the student is on the right track, to provide advice as often as it is needed and to ensure that the student remains accountable. However, the supervisor is not expected to do the students thinking for them.

7.4 Supplementary Lectures

Apart from their weekly meetings with their supervisors, the students are required to attend one lecture class per week on topics related to their FYP. These talks are carefully arranged by the FYP module coordinator. They are intended to assist the students in developing the knowledge and skills required to undertake research. The topics covered would include research planning, literature review, referencing, methodology, research ethics, plagiarism, results evaluation, error analysis, thesis writing, oral and poster presentation, etc., and also matters related to the assessment of the FYPs. The students are then able to apply these knowledge and skills on their ongoing FYP in real time.

These lectures also help the supervisors in that they do not need to teach these topics individually to every student that they supervise. These lectures are delivered by the FYP module coordinator as well as by other lecturers of the School invited by the FYP module coordinator. They would be the lecturers, whom the FYP module coordinator is confident, can contribute significantly to these topics due to their experience and their expertise.

7.5 Assessment

To be effective, assessments need to be carefully designed. Effectiveness is a product of both the assessments' ability to adequately and accurately measure students' learning outcomes as well as its ability to guide the students' learning process. The latter is accomplished through the use of carefully crafted assessment rubrics which are made available to the students in advance and also through the feedback that the assessors give in the feedback form that accompanies the rubrics. Feedback has been proven to play an important role in enabling improvement. In addition, this compulsory feedback mechanism provides assurance that the assessors are fair in their marking since each rubric criterion where marks are given has its corresponding feedback section.

7.5.1 FYP1 Assessment

The assessment components of FYP1 are shown in Fig. 7.1.

The first assessment component in FYP1 is the **Initial Proposal**. This exercise is akin to having the students sell their project ideas to imaginary stakeholders. Through thinking about and developing their Initial Proposal the students begin to assume ownership of the project. They begin to apply basic research skills such as formulating the research background, performing a literature review that leads to gap identification and crafting a suitable research methodology. They also have the

Assessment Methods	Distribution	(%)	LO 1	LO 2	LO 3	LO 4	LO 5	
	Meeting record	5					X	
	Initial proposal	15	X				X	
	Abstract for EURECA Conference	5					X	
	Oral Presentation	15					X	
	Interim Project Report	50		X	X	X	X	
	Engineering Fair Poster	10					X	
	Total	100						

Fig. 7.1 Assessments in FYP1

opportunity to apply their project management knowledge through preparing the Gantt chart and the budget. The Initial Proposal concludes with an elaboration of the project's expected outcomes.

Towards the end of the semester, the students prepare an **Abstract** for the EURECA Conference. This abstract is made into an assessment component where marks are awarded. The students will participate in this conference in the following semester when they are undertaking FYP2. Having the students participate in a research conference is helpful in developing them to be future researchers. While not every student will aspire to a career in research nonetheless this experience can still benefit them.

An **Interim Report** is also required at the end of the semester. This report carries the highest percentage of marks in the FYP1. It extends from the Initial Proposal and serves as a midpoint report. For this report, a full-fledged critical literature review is required. This review goes beyond merely reporting what they had read. The students are required to read the literature critically and identify gaps in the body of knowledge. Also required is a fully developed methodology. This includes a discussion of the assumptions made as well as any limitations pertaining to the methodology. Justification is also needed for the methodology adopted.

The assessments conclude with an **Oral Presentation** of the project followed by the poster presentation at the **Engineering Fair**. The Oral Presentation is made to two internal assessors and is related to the contents of the Interim Report. The assessors would have had a week to read the Interim Report before attending the students' Oral Presentations. A PowerPoint presentation is required and adequate time is allocated for Q&A. On the other hand at the Engineering Fair, which is an end semester event to showcase all students' projects, the presentation for FYP1 is made in poster form. One of the two assessors for this poster presentation would be an external assessor either from the industry or academia.

Hence the students are trained to make different forms of presentation, namely the written report form, the PowerPoint form, and the poster form. It is worth mentioning the poster presentation is probably the most challenging to do well as all the information must be concisely contained in a single poster. The remaining form of presentation, i.e., the conference paper will be made in FYP2 when the students submit their full conference paper to EURECA having already submitted their abstract in FYP1.

These assessment components are assessed by two academic staff who are not the supervisor. Carefully crafted rubrics are used for the assessment. Having two assessors ensures that the assessments are fairly marked. A moderation process is put in place for the Interim Report as this assessment is the most important component in the FYP1 contributing 50% of the total marks. Should the marks in the Interim Report differ by more than 10 between these two assessors, a moderation process ensues. The moderation involves the two assessors reassessing the report. However, if they cannot come to an agreement then a third assessor will be assigned by the programme director to independently assess the report. Otherwise, if the difference between the two assessors is less than 10 then the average marks of both assessors will be adopted as the final mark of the Interim Report.

7.5.2 *FYP2 Assessment*

The assessment components of FYP2 are shown in Fig. 7.2.

The **EURECA Conference Paper** is required by Week 8 of the semester. For most students, this represents the first research paper they have ever written. The conference paper is put through a review process of similar rigor as that of any reputable research conference. The review is undertaken by two reviewers who could be either external or internal reviewers, internal referring to SoE's academic staff. The reviewers' comments are conveyed to the student. The students would be required to respond to the reviewers' comments officially through a feedback form.

The **EURECA Paper Presentation** is made in Week 14 during the EURECA Conference. The students present their work to two assessors, one of whom is an external assessor from either the industry or academia. As this is a conference, an audience of interested parties would also be present in addition to the two assessors. For the students' presentations, it is expected that the assessors will pose very challenging questions and be quick to highlight any shortcomings. This has been the practice thus far at every EURECA Conference. Apart from this questions could also be posed by members of the audience.

Assessment Methods	Distribution	(%)	LO 1	LO 2	LO 3	LO4	LO5	LO6	LO7
	Meeting record	5							X
	EURECA Conference Paper	10		X					
	Thesis	60	X	X	X	X	X	X	
	Oral Defence of Thesis	15		X					
	EURECA Paper Presentation	10		X					
	Total	100							

Fig. 7.2 Assessments in FYP2

The EURECA paper is revised based on these feedbacks as well as the feedback from the assessors of the Thesis and the Oral Defense. Following the revisions made the paper would be published in an appropriate publication with the student being listed as the first author and the supervisor as the second author.

Furthermore, as an incentive for the students to perform well, prizes are awarded at the EURECA Conference for best papers in these categories: Commercial Potential, Environmental Impact, Fundamental Research, Innovative Research, Industry Relevance, High Impact Research, and Best Technical Paper. A token sum of money accompanies each award.

The **Thesis** is a complete report of the entire project. This is due in Week 12 of FYP2. At this stage, the literature review and the methodology are expected to be well established and clearly presented. More emphasis is now given to the results and discussion. This section of the Thesis should highlight the students' ability to correctly analyze and interpret results and to evaluate their findings in accordance with the relevant theories and principles. The analysis should indicate the extent to which the research questions and objectives have been addressed. In addition, the students are also expected to discuss matters related to sustainable development and impact on society with regards to their project.

Two internal assessors will assess the Thesis. Should their marks differ by more than 10 out of 100, a similar moderation process as described in Sect. 7.4.1 for the Interim Report is likewise employed for the Thesis. Otherwise, the average marks of both assessors are taken. The Thesis carries the highest weightage of any FYP assessment at 60% of the total FYP2 marks. Hence a fairly conducted assessment is essential.

The **Oral Defense** follows the Thesis submission by a week. The two internal assessors who assess the Thesis also assess the Oral Defense. For this assessment, the students are not required to prepare any presentation slides although they could have some slides on standby if the assessors decided to ask for an overview. What the students need to bring with them are only their Theses. Each assessor will bring their copy of the students' Thesis into the session with them. They would have had a week to read these Thesis in advance. The assessors ask questions based on what they had read and assessed the students based on their ability to answer. The initiative is on the assessors to ask questions and assess the students' answers accordingly. Similar to FYP1 all assessments in FYP2 utilize carefully crafted rubrics and this includes the assessment for the Oral Defense.

It is worth mentioning that at present only 5% of the marks are contributed by the supervisor through the **meeting record** while the remainder is given by assessors other than the supervisor. There are two assessors assigned to each of these assessment components. This practice is similar for both FYP1 and FYP2. Hence assessment subjectivity is minimized, fairness is ensured and assessment standards are always maintained. Students will have the opportunity to receive feedback on their assessments from assessors who are not their supervisor. This enhances learning opportunities.

7.6 Eureca

It is not enough to have completed an FYP research project. It is also necessary to communicate the findings to the public. The FYP is intended to contribute towards the body of knowledge and not just to serve solely as a student project. Hence the Engineering Undergraduate Research Catalyst conference (EURECA) is organized to provide the students with a complete research experience.

The reason for organizing the EURECA conference instead of having the students participate in existing conferences is because the conference paper and the conference presentation contribute towards FYP2's assessment marks. The timeline of the conference must be in perfect alignment with the timeline of FYP2 otherwise it will affect the timeframe for the release of results. Moreover, the conference paper and conference presentation assessments must align with the FYP module learning outcomes. These requirements can only be met by organizing our own conference.

The EURECA conference is different from other conferences in that the focus of the conference is on undergraduate research work carried out in the FYPs. They form the majority of the papers submitted. There are also postgraduate students and academic staff participating however these are organized as separate categories. The conference is open to external participation and there have been both local and international external participants at the conference. The external participants compete equally for the prizes including for the undergraduate category if they are undergraduate participants. Hence this also provides beneficial exposure and benchmarking for our students.

The entire range of conference experience is available to the student. It begins with writing an abstract in FYP1, followed by writing the full a paper in FYP2. The paper is reviewed and the reviewers' comments are returned to the students for their responses and necessary amendments. They then present the paper at the conference to two judges and audience. The judges will critique their work, ask questions, and expect reasonable answers. The audience may also pose questions. The entire experience is especially valuable to prepare students for their future careers and for those who plan to embark on an academic career it furnishes them with a foretaste of how to communicate research findings. The students learn to communicate effectively both orally and in written form. They also learn to receive feedback well. These are indispensable skills for future success.

In the past, these student conference papers were published in the EURECA conference proceedings while a few selected papers of high quality were published in the Journal of Engineering Science and Technology (JESTEC), a SCOPUS indexed journal. The selected papers will be expanded to full journal papers and are required to undergo the double-blind peer-reviewed process of the journal. At the present, the objective is for all EURECA papers to be published in indexed publications, with the exception of a few papers which the supervisors may deem to be not meeting the required standard.

Hence the FYP is not just meant to be a rehearsal for the students in preparation for a future research experience but it is meant to serve as a full-fledged research experience conducted under the guidance of the School's academic staff.

In conclusion, through the EURECA conference, the students have their work publicly scrutinized, critique, and benchmarked. Therefore they are naturally motivated to deliver work that meets these expectations. Consequently, an FYP experience becomes more than that of completing their assessments, getting good CGPA scores, or satisfying their supervisors' expectations although these will continue to remain valid as their primary concerns. The EURECA conference helps transcend their FYP experience into something larger and more meaningful.

7.7 Learning

The FYP is a challenging module delivered over two semesters. It has been intentionally designed to achieve the desired learning outcomes and to provide the students with the best possible learning experience. While it is a research-centered module, however, the learning process is holistic in nature and manages to affect all three domains of learning, i.e., the cognitive, the affective, and the psychomotor learning domains. This was based on a survey conducted by Tien et al. [1] on SoE's students. This finding indicated that a well-designed FYP is helpful to the overall development of a student and acknowledges that the benefits to the students can extend significantly beyond acquiring research skills.

7.8 Conclusion

The FYP process at SOE has been elaborated with regards to project proposal and selection, supervision, supplementary lectures, assessment, and learning. The assessments have been explained in detail. It can be observed that the FYP process has proven effective in delivering the intended outcomes. The end result is that the students receive a realistic and comprehensive research experience. This experience not only increases their knowledge but also helps them develop holistically.

Reference

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Chapter 8
Samples of Final Year Projects Addressing Engineering Grand Challenges

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Abstract This chapter presents a few examples of Final Year Projects that students have taken in the final year of their study. A summary of each project is discussed by highlighting the engineering grand challenge addressed by the project, the engineering problem(s) that supposed to be solved, the research questions that needed to be answered at the end of the study, objectives of the study and a short summary of the research findings.

Keywords Engineering grand challenge · Final year project

8.1 More Natural Sunlight to the Home

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Supervisor's name	Ghafour Amouzad Mahdiraji
Grand challenge addressed	Make Solar Energy Economical

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8.1.1 Engineering Problem

Natural sunlight is beneficial and vital to any living organism. However, in the current era, most people live and work in apartments and towers that there is not enough opportunity to be exposed to sunlight.

8.1.2 Research Questions

- How to bring more natural sunlight into the home especially in towers and high-density apartments where there is not enough sunlight due to lack of enough windows.
- Usually, large-core bundled optical fibers are used for sunlight transmission. However, fabrication of large-core bundled optical fibers is very costly.
- How to fit more solar panels to increase the solar energy harvesting when the space is limited like rooftop area of apartments.

8.1.3 Objective

- To propose an efficient, and more economical solution for bringing more sunlight into the home and workplace.

8.1.4 Research Findings

In this study, a new sunlight concentrator apparatus equipped with a cost-effective and higher performance efficiency optical fiber has been proposed to bring more natural sunlight to home and workplace. The proposed solar concentrator includes two transparent layers, one layer to hold the Fresnel lenses and another layer to hold the optical fibers. With the proposed system, natural sunlight can be distributed to homes and offices for lighting purposes via optical fibers. A new type of optical fiber is proposed and fabricated using pure silica rod coated with low refractive index polymer. The performance of the proposed fiber is compared with large core Ge-doped fiber. The proposed fiber provides higher core area compared to the conventional Ge-doped core fiber. Thereby, the proposed fiber can transmit a higher amount of solar energy compared to the conventional fiber. In terms of the raw material's cost, it is shown that the proposed fiber is about seven times cheaper compared to the conventional structure fiber. Further cost reduction is proposed to be done by using small diameter Fresnel lens concentrating on a large diameter single optical fiber to avoid using bundled fibers as the cost of fabricating bundled fibers is high. The fiber and lens holder apparatus are proposed to be made with a fully transparent material that allows being placed on top of another layer of the solar panel. This can increase overall energy harvesting efficiency of the system by optimizing space utilization, especially where the space is limited. The proposed system can significantly reduce the cost of solar concentrators and bring more natural sunlight into the home with higher efficiency and lower cost.

8.2 Design and Simulation of Harmonics Filter for PT Gajah Tunggal Tbk, Indonesia

FYP student's name	Omar Mohammed Omar Basharahil
Supervisor's name	Reynato Andal Gamboa
Grand challenge addressed	Advance Personalised Learning & Restore and Improve Urban Infrastructure

8.2.1 Engineering Problem

The aforementioned project was conceived based on the student's industry internship experience in PT Gajah Tunggal Tbk, Indonesia sometime in January–March 2014. He was made aware of the power quality problems of the company through the help of his industry supervisor Mr. Taufik. The company's distribution system experienced burnout of its transformer–generator set due to high harmonics level which was measured to be at 22.8%, way above the allowable harmonics level of 5% for 69 kV and below. This problem motivated the student to use the company as the subject of his final year project. He proposed to conduct an assessment study on the origin of the problem and analysis of its impact using power system analysis software, and proposed a solution on how to mitigate such power quality issue.

8.2.2 Research Questions

- How is the proliferation of harmonics in the system affects the PT Gajah Tunngal Tbk operations?
- What is the design specification of a harmonic filter that could mitigate system harmonics to an acceptable level?

8.2.3 Objectives

- To analyze proliferation, source, and effects of harmonics level in PT Gajah Tunggal Tbk that experiences intolerable harmonics level.
- To analyze the single line diagram of the industry to check the individual harmonics distortion (harmonic order) that has high contribution to the THD of the system using ETAP software.
- To design and simulate harmonics filter using ETAP software to mitigate system harmonics to an acceptable level.

8.2.4 Research Findings

The proliferation of harmonics in the system was analyzed using the Electrical Transients Analysis Program (ETAP). Analysis of the system revealed that the proliferation of harmonics occurred in main distribution board feeder 7 (MDB7) in bus 4 of the distribution network. The ETAP simulation showed that the total harmonic distortion (THD) totalled 23.38% with 5th harmonic component of 23.11%, 7th harmonic component of 2.27%, 11th harmonic component of 1.94%, and 13th harmonic component of 1.57%. The THD is way above the acceptable level (IEEE-519) of 5%. Thus, a harmonic filter was designed to reduce the THD to acceptable level. After rigorous simulation and analysis, it was found that a single-tuned LC filter is needed to be installed at the same bus where harmonics proliferation originates. Putting the filter in place after conducting the simulation, the system harmonics THD level was reduced to 4% in the 5th harmonic's level.

In this research, the student needed to invest time and effort to learn the network components specification, network building and simulation features of ETAP to be familiar with the software. A regular consultation with the in-house supervisor and industry supervisor is needed to fully comprehend and to mitigate the problem. This is how the grand challenge "Advance Personalized Learning" was addressed. The mathematical analysis, filter design, and simulation of the system were carried out by the student in order to reduce the system harmonics addressed the grand challenge "Restore and Improve Urban Infrastructure".

8.3 Optimization of Fan Configuration by Box-Behnken Method for Maximum Energy Efficiency

FYP student's name	Shahrooz Eftekhari
Supervisors' name	Azadeh Ghadimi & Mohammad Hosseini Fouladi
Grand challenge addressed	Engineering a Tool for Scientific Discovery

8.3.1 Engineering Problem

In the manufacturing sector, fans use about 78.7 billion kilowatt-hours of energy each year. This consumption represents 15% of the electricity used by motors. Similarly, in the commercial sector, the electricity needed to operate fan motors composes a large portion of the energy costs for space conditioning. Therefore, it is crucial to understand the fan performance in order to design an efficient system since fans are the sources of high energy consumption in the HVAC systems and it is mandatory to bring their energy efficiency within an optimum range. The fan performance requires further enhancement by optimizing the energy efficiency of the fan through adjustment of the fan configuration parameters such as fan speed, damper angle, and ambient temperature.

8.3.2 Research Questions

- How is the fan energy consumption and efficiency governed by the fan configuration parameters?
- What is the best fan configuration to maximize the energy efficiency?

8.3.3 Objectives

- To obtain a general fan efficiency curve and power consumption based on different fan setups.
- To investigate the influence of airflow and fan head (friction pressure loss, bending, and fitting) pressure loss of the centrifugal fan.
- To optimize the energy consumption of the backward curve fan based on comparison of analytical and experimental results.
- To recommend a design arrangement for the fan and ducts to provide minimum pressure loss.

8.3.4 Research Findings

In this research, a fan efficiency curve is obtained and the effects of different operating configurations are studied at various operating speed, damper angle, and ambient temperature. A compromise of effective parameters on the fan efficiency is predicted through numerical simulations and predicted achievable optimized points are validated by fan experiments. Based on the analysis of the research findings, the following points are concluded:

- Increasing the damper angle results in an increase in the total pressure generated at the fan outlet which results in reduction in fan power. Hence, the total efficiency is increased. However, excessive increase in the total pressure results in increase in fan noise and vibration level which leads to increased fan maintenance cost.
- The fan operates more efficiently at lower ambient temperatures ranging from 18°C to 20°C despite the variations of damper angle and fan speed. However due to laboratory air conditioning system limitation, minimum temperature of 20° Celsius is achievable and validating experiments are conducted at temperatures ranging from 20° to 22° Celsius.
- Analysis of the efficiency response surfaces at low temperatures of 20° to 22° Celsius shows that the fan operates with optimized efficiency of 28.1% to 29.0% of the fan speed ranging from 1400RPM to 1500RPM despite the changes of damper angle respectively.
- Comparison of the predicted numerical results with experiments shows minimum and maximum errors of 0.1% and 9%, respectively. Such small inaccuracies may be caused by the insignificant errors in damper angle and ambient temperature setting.

8.4 Enhancement of Vibration Comfort for FSAE Race Car Driver

FYP student's name	Farah Rahman bt Danial Raman Raj
Supervisors' name	Mohammad Hosseini Fouladi & Satesh Narayana Namasivayam
Grand challenge addressed	Restore and improve urban infrastructure

8.4.1 Engineering Problem

Vibration is a continuous cyclic motion of a structure or a component. In a racing car, there are numerous parts that are constantly in a continuous cyclic motion, for example, the drive shaft and the crankshaft in the engine and tires. Vibration is not always undesirable, however, in the case of a racing car, vibration has adverse health effect on the drivers and excessive deflections and sometimes failure on the parts in the car. Therefore, this project specifically highlights the sources of vibration from the FSAE racing car and enhancement of the vibration for the drivers. Formula Society of Automotive Engineers (FSAE) is a competition whereby students design, build, and race the car; almost similar to a real F1 car. By comparing the theoretical and experimental data and understanding the possible sources and vibration, enhancement on the positions of the sources can be done in order to reduce the negative effect on the drivers and increase the efficiency of the race car.

8.4.2 Research Questions

- What are the attributes of vibration affecting the comfort of FSAE drivers?
- How the vibration comfort of FSAE drivers can be improved?

8.4.3 Objectives

- Identify parameters affecting the vibration comfort for an FSAE racing car driver.
- Evaluate the vibration comfort for an FSAE racing car in a variety of riding conditions.
- Recommend the optimum design conditions to enhance the vibration comfort for the FSAE racing car driver.

8.4.4 Research Findings

In the current research, the experimental analysis is done on a fully functional race car with the mounting of accelerometer and NI DAQ. As this analysis is done on a working race car, the vibration amplitude decreases, this is possibly due to the fact that vibration has already been transferred to other parts of the mounting system or a structural member. The most common mounting design that is used in the commercial vehicle is known as the elastomeric design with EPDM60 durometer rubber. As FSAE race car competes in high-intensity tracks that require the car to constantly accelerate and decelerate quickly, a more medium damping coefficient is applied for the second design. Hence, the other design consists of a layer of carbon steel and rubber for it to be able to dampen the excitation shocks as a part of FSAE race car nature. The research shows the capability of carbon steel and rubber combination to dampen most of the vibration at its source, which leads to enhancing the overall vibration comfort for the FSAE race car drivers. The outcomes of this project may be applied to a wide range of transportation systems, from racing to passenger cars, and will enhance and improve the urban infrastructure.

8.5 Automated Attendance Capture System

FYP student's name	Jonathan Chin Eu Tsun
Supervisors' name	Chew Wei Jen, Florence Choong
Grand challenge addressed	Engineer the Tools of Scientific Discovery

8.5.1 Engineering Problem

There have been many attendance capturing systems created throughout the years. Most of the systems mainly work by having the user tap a card to a reader at the door or have their thumbprint captured by a scanner before entering the room. However, these types of systems do not monitor the presence of any particular person after the initial input scan process. In a situation like a classroom, essentially a student can have his/her attendance captured and then leave the premise. Therefore, the goal was to engineer a solution that would improve on the current systems.

8.5.2 Research Question

- How can the attendance of a student in a classroom be accurately determined using image processing techniques?

8.5.3 Objective

- To capture the attendance of students in a classroom using facial recognition and a tracking system.

8.5.4 Research Findings

A continuous monitoring process was proposed to be added to an attendance capturing system to ensure that a person is at that location for the majority of time before his attendance is taken. The most practical method to achieve this is by processing the image captured from a video recorder since they are easily available and they are noninvasive which makes it suitable for a continuous monitoring process. Also, to make the system more robust and portable, the complete system will be packaged into a standalone GUI that can be installed in any computer with a video recorder as an external equipment.

The system proposed first uses face detection and recognition system to determine the identity of all the students in a classroom. The system will then continuously monitor the presence of all the students throughout the entire class session. Once the class has finished, the system will sum the number of times each person was identified throughout the whole session. If the person was present most of the time his/her attendance will be considered. This will ensure that anyone attending the class should stay throughout the session instead of slipping out once his attendance was initially taken. The results obtained show that the system was able to continuously track the student in the class and determine that a student was absent if he/she was not in the class for a certain length of time.

In conclusion, an improved scientific tool in the form of the proposed attendance capturing system was created to help solve the issue of capturing the attendance of students in a classroom more accurately.

8.6 Low-Cost Hybrid Photovoltaic Thermal (PVT) for Sustainability

FYP student's name	Mohammed Al-Jabri
Supervisor's name	Mohammad Taghi Hajibeigy
Grand challenge addressed	Make Solar Energy Economical

8.6.1 Engineering Problem

As the population of the world increases and people are more dependent on the technology compared to the past, the energy consumption demand is on the rise as well as energy costs. This rise brings about a serious burden to an environmental issue. At the same time, the environmental issue forces the consumption of renewable energy in place of fossil fuel which later harms the environment. This alarm requires long-term potential actions for sustainable development. Due to low efficiency and high cost of Photovoltaic (PV) module, it is costly to convert this environmentally friendly and abundant source of energy to a useful and applicable energy source.

8.6.2 Research Questions

- How can increase the efficiency of photovoltaic modules?
- What is the hybrid design system to extract more energy from the existing photovoltaic modules?
- What is the method to convert wasted thermal energy into a useful energy source?

8.6.3 Objectives

- To investigate parameters and factors that affect the efficiency of a photovoltaic thermal (PVT) system.
- To investigate the hybrid PVT system.
- To design a hybrid PVT system.

8.6.4 Research Findings

Renewable energy resources appear to be one of the most efficient and effective solutions to the continuous existing of high energy demand and environmental issues. It is well recognized that solar energy availability is significantly more than the global energy demand. The available technology has limited capabilities of harnessing this boundless and free energy. While solar radiation causes to generate electrical energy by PV, at the same time elevates the temperature of the PV module significantly, consequently drop in PV electrical energy efficiency. This considerable generated thermal energy from solar radiation on top of the PV is wasted as heat and reduces the electrical conversion efficiency of the module. With every additional 1°C after the nominal temperature of the PV, the electrical efficiency of the PV drops 0.4%. With the newly proposed design PVT system, this wasted thermal energy will be mostly removed and be used in industry or in the household. Employing thermal system in PV to remove the high thermal energy from the PV module helps to maintain the electrical efficiency while the stored thermal energy can be used for a commercial or household purposes. The physical design of the PVT system consists of heatsinks attached to the bottom of the PV to absorb the heat from the PV, thermal container which contains heatsinks submerged in coolant in the thermal container, pump which transfers the high temperature coolant into and out of the heat exchanger, heat exchanger made of copper that is submerged in the water in the thermal storage tank to release the heat stored in the coolant in the thermal container to the water in the thermal tank storage tank, and PV array.

Overall, it can be summarized that by a newly PV thermal system, the thermal energy of the PV will be removed, which not only maintains the electrical efficiency of the PV module but also the wasted thermal energy can be used for a commercial or household purpose. This will increase the total efficiency of the module which is equal to the electrical plus thermal efficiency of the module.

Hence, by extracting the high wasted free thermal energy from PV, both the drop of electrical energy efficiency of PV will mostly be prevented and the obtained thermal energy could be utilized for different applications while the life expectancy of the module will be enhanced. The mentioned student in his Final Year Project conducted experiments in the lab. He used water as coolant and thermal transfer media and his finding are as follows:

- Used water as coolant (Thermal efficiency + electrical efficiency; 44.4 + 13.3 = 57.7%)
- Used nanofluid as coolant (Thermal efficiency + electrical efficiency; 52.8 + 13.3 = 66.1%)

The results clearly show that PVT system with different coolant increases the overall efficiency of the PV enormously. Hence, by extracting higher free energy from the PV module, the availability of the energy usage is higher which helps the cost of the energy usage.

8.7 The Application of Image Processing for In-store Monitoring

FYP student's name	Lau Kah Heng
Supervisor's name	Chew Wei Jen
Grand challenge addressed	Engineer the Tools of Scientific Discovery

8.7.1 Engineering Problem

In the retail business today, customers have many options when it comes to buying a product. Therefore, it is important for a business to know the interest and habits of their customers to help them determine which item sold is popular at the moment to help in stocking decisions. Traditionally, businesses try to determine their customer's needs by observing their behavior in the store or conduct surveys. However, this process can be time consuming and the data obtained will need to be manually processed. Therefore, the goal of this research was to engineer a more accurate and efficient system.

8.7.2 Research Question

- How does the application of image processing on human activity improve in-store monitoring and business?

8.7.3 Objective

- To monitor the movement of customers in a shop for shopping behavior purposes.

8.7.4 Research Findings

A monitoring system that tracks the customer's movement throughout the whole store was proposed to help determine the customer's behavior and preferences. This can be achieved by placing a video recorder on the ceiling to avoid any occlusion from ground level and also to minimize the number of cameras used. This proposed system should start tracking from the front door and anyone entering will first be determined if he is a staff or customer. Only a customer's movement will be tracked throughout the store until he leaves. The setup of the system should be simple with just a computer and video recorders placed at strategic locations.

The proposed system uses two cameras. One camera will be placed facing the front door at eye level to capture the image of the face entering. Then, the captured face will run through a face recognition process to compare with a database of employee's faces. If the person is determined to be an employee, the system will not track the movement of this person around the store. However, if this person is determined to be not an employee, then his movement in the store will be tracked. The tracking process will be performed by using the video captured by the second camera mounted on the ceiling. From this video feed, each frame can be captured and a background subtraction is done to determine the location of the customer in the store. Specific regions in the store will be tagged in the video and each time the customer is determined to be at the region, the counter for that particular region will increment. In the end, the popularity of each region can be determined by looking at the counter number. The higher the counter number, this means more customer were in that region and interested in the products placed at that specific location. This will help determine customer's preference and product popularity.

In conclusion, an improved scientific tool, in the form of a customer tracking system, was created to help solve the issue of determining the shopping behavior of a customer in a store.

8.8 The Application of Image Processing for Hand Gesture Recognition Using Microsoft Kinect

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Grand challenge addressed	Engineer the Tools of Scientific Discovery

8.8.1 Engineering Problem

Gestures like pointing or waving are instantly understood everywhere around the world and are a type of nonverbal communication method used by everyone without a second thought. However, for deaf people, hand gestures become their main form of communication since they use sign language to express their thoughts to each other. For people trying to learn sign language, usually, they will need a knowledgeable person to inform them if the gesture they are making with their hand is correct or wrong. However, this may limit the time that they are able to practice by themselves. Therefore, the goal in this project was to engineer a system that is able to detect the hand gesture performed by a person and to inform that person if the gesture made was correct or wrong.

8.8.2 Research Question

- What degree of accuracy can the depth image sensing for sign language recognition achieve compared to conventional 2D image processing?

8.8.3 Objective

- Design an algorithm for recognition of ASL alphabets signed by a hand using depth images.

8.8.4 Research Findings

A hand gesture recognition system using image processing was proposed. This is because the image of the hand gesture can be captured without the use of any sensors that need to be attached to the hand, which makes it more convenient and comfortable to be used. Since the camera capturing the gesture will be at a close distance, it was decided that a 3D image of the hand be used. This is to make use of the extra depth value as well as to avoid any issue with lighting which might cause a gesture recognition in 2D images to fail. To make it marketable, this proposed system will be packaged into a standalone GUI that can be installed in any computer.

After the 3D image of the hand is captured, it will need to be segmented out from the rest of the background. The depth value was used since the depth value of the hand should be nearer to the camera compared to the rest of the background items. After that, the gesture captured will need to be compared with the database of gestures previously created to determine which gesture was being made by that person. A GUI was then created to make it easy for everyone to use. The proposed hand gesture recognition system was tested using an alphabet database. First, the GUI will work by having the user choose which alphabet he wants to sign. Then, the Kinect sensor will start up and capture the hand gesture made by the user. Next, the designed system will compare the gesture made with what was kept in the database.

If the hand gesture made matches the one in the database, then a message stating the gesture made is correct will be shown. If the gesture made does not match the database, then a message stating that the gesture made is wrong will be shown instead.

Overall, an improved scientific tool which is meant to be used as a teaching tool to help people learn sign language themselves was successfully built. Instead of requiring another person to inform the user if the gestures made were correct or incorrect, this system was able to do that automatically, which will help people in learning sign language at a faster pace.