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THE PLANNING AND EXECUTION OF A GRAND CHALLENGE SCHOLARS PROGRAMME: A CASE STUDY OF TAYLOR'S UNIVERSITY'S SCHOOL OF ENGINEERING

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Abstract

In 2008 the National Academy of Engineering, USA (NAE) presented 14 Grand Challenges for Engineering in the 21st century. In an effort to prepare future engineers to address and eventually solve these challenges, the Grand Challenge Scholars Programme (GCSP) was created. Over 20 schools of engineering (from North America, Malaysia and Singapore) developed their own GCSPs and gained endorsement from the NAE for their educational models. This paper presents an implementation plan of the Taylor's University's School of Engineering's Grand Challenge Scholars Programme (TGCSP). The aim of this paper is to provide insight into the structure of the TGCSP as well as the details of how the entire programme is governed. Also shared are the best practices adopted by the school and the key results obtained by its scholars to date. The paper will also highlight key areas for improvement, in the spirit of Continual Quality Improvement (CQI) that would lead into the enhancement of the programme in the foreseeable future.

Keywords: Grand Challenge Scholar Programme, Conceive-Design-Implement-Operate (CDIOTM), Project based learning, Engineering Education.

1. Introduction

In 2008, the NAE identified 14 Grand Challenges for Engineering in the 21st Century. The Grand Challenges are a call to action and serve as a focal point for

society's attention to opportunities and challenges affecting our quality of life. The 14 GCs are [1]:

- **Making solar energy affordable**: How do you convert and store the power of sunshine at a cost competitive with fossil fuels?
- **Providing energy from fusion**: How do you sustain a controlled fusion reaction for commercial power generation?
- **Developing carbon sequestration methods**: How do you capture the carbon dioxide produced from fossil-fuel burning, and confine that excess carbon underground?
- **Managing the nitrogen cycle**: How do you develop countermeasures for fertilizer use, internal combustion and other activities that contribute to pollution?
- **Providing access to clean water**: How do you address the short supply of water for personal use and irrigation in many areas of the world?
- **Restoring and improving urban infrastructure**: How do you renew aging infrastructure while bringing cities into better ecological balance?
- **Advancing health informatics**: How do you identify the specific factors behind wellness and illness, and follow through on the promise of personalized medicine?
- **Engineering better medicines**: How do you find new treatments for age-old scourges as well as newly emerging diseases?
- **Reverse-engineering the brain**: How do you unlock the secrets of brain function, to heal human diseases and advance the field of artificial intelligence?
- **Preventing nuclear terror**: How do you head off threats from agents who are bent upon bringing ruin to industrial society?
- **Securing cyberspace**: How do you protect the global information infrastructure from identity theft, viruses and other threats without bogging down the flow of data?
- **Enhancing virtual reality**: How do you use computer technology to create imaginative environments for education and entertainment?
- **Advancing personalized learning**: How do you move from a "one-size-fits-all" style of education to more engaging, computer-enhanced teaching techniques?
- **Engineering the tools for scientific discovery**: How do you improve our methods for exploring the frontiers of life, the atom and the cosmos?

The National Academy of Engineering Grand Challenge Scholars Program is a combined curricular and extra-curricular program with five components that are designed to prepare students to be the generation that solves the grand challenges facing society in this century [2].

The programmes learning components are as follows.

1) Hands-on Project OR Research Experience: Related to a Grand Challenge
2) Interdisciplinary Curriculum: A curriculum that complements engineering fundamentals with courses in other fields, preparing engineering students

to work at the overlap with public policy, business, law, ethics, human behaviour, risk, and the arts, as well as medicine and the sciences

3) Entrepreneurship: Preparing students to translate invention to innovation; to develop market ventures that scale to global solutions in the public interest
4) Global Dimension: Developing the students' global perspective necessary to address challenges that are inherently global as well as to lead innovation in a global economy
5) Service Learning: Developing and deepening students' social consciousness and their motivation to bring their technical expertise to bear on societal problems through mentored experiential learning with real clients

2. CDIO and Project-based Learning

Analytical methods and design charts used for the prediction of zero-lift drag The School of Engineering, Taylor's University (TSoE) offers three Bachelor Engineering Degree Programmes. These Programmes are B.Eng. (Hons.) in Chemical Engineering, Electrical and Electronic Engineering and Mechanical Engineering. The School prides itself on its pedagogy of learning by doing. This is accomplished by practicing project-based learning in all years of all of the School's degree programmes.

TSoE adopted Project Based Learning (PjBL) as a central educational philosophy. PjBL is used to create an authentic learning environment in which students are given the opportunity to develop and hone real life skills while working on technical endeavours. Encouraged by feedback from students, industry and partner academic institutions, project-based learning was systematically embedded in the curriculum when developing Taylor's indigenous engineering programmes. This ensured that the students will have the opportunity to work on a major multidisciplinary engineering project each and every semester starting with the first semester. Students, operating in multidisciplinary teams are required to conceive, design, implement, and operate engineering systems and products drawing on the knowledge that they are developing in the other core modules that they are studying. Besides a well-balanced programme delivery using lectures, tutorials and laboratory sessions, the curriculum has a distinctive design thread with a design based module offered each semester. The level of complexity of the design modules gradually increases from first semester towards the final year where the final year project is offered. The highlight of each semester is the Engineering Fair, a student organised event at the end of the semester where they exhibit and introduce their projects to a wide audience including representatives of the industry as well as the general public.

The school is an official member of the CDIOTM [3] international initiative. CDIOTM (Conceive, Design, Implement, Operate) is an innovative educational initiative that is initiated by MIT with the goal of educating Engineers who can engineer [4-7]. It currently involves a number of world class universities such as MIT, Stanford, Leeds, Liverpool, Auckland and Sydney. TSoE is the first Malaysian school that is accepted into this initiative. Joining the CDIOTM initiative cemented the regional leadership position of the School and currently the School is assisting universities in China, Vietnam and Thailand to successfully adopt the PjBL. Representatives from these universities visited

Taylor's on study trips with the intention of learning from the TSoE experience. The School currently requires each of each of its students to complete a project based module every semester (for a total of 8 semesters). This would enable achievement of learning component 1. The School's curriculum also has space for its students to complete several electives – these spaces in the curriculum would allow students to address learning component 2. The School has specific modules to address learning components 3 and 5 while learning component 4 requires the student to take the initiative to look for international experiences. As such, the five learning components of the GCSPs were found to be in line with the existing practices of the school and to further enhance its vision of believing in human potential, a decision was made to initiate the process of developing its own GCSP and gaining endorsement from the NAE for it. The Taylor's Grand Challenge Scholars Programme (TGCSP) runs in parallel to the TSoE Degree.

The CDIO^{TM} initiative provides a framework for the schools project-based learning pedagogy. This has resulted in many successful and varied engineering projects designed and built by its students. Naturally, a successful engineering project depends on students' ability in a variety of criteria, specifically; knowledge, skills and attributes that range from technical (or technology) based modules to entrepreneurship based modules. Due to this, the school's curriculum was designed in such a way to accommodate these knowledge areas. Herein lies the synergy between the practices of the school with the GCSPs. The five learning components of the GCSPs were found to be in line with the existing practices of the school and to further enhance its vision of believing in human potential, a decision was made to initiate the process of developing its own GCSP and gaining endorsement from the NAE for it. The Taylor's Grand Challenge Scholars Programme (TGCSP) runs in parallel to the TSoE Degree. A student who enrols into any one the School's degree programmes in year 1 (semester 1) (upon satisfying the School's enrolment criterion) have the option to enrol into the TGCSP, however another application process and selection criterion needs to occur before the student is successful in becoming a TGCSP scholar.

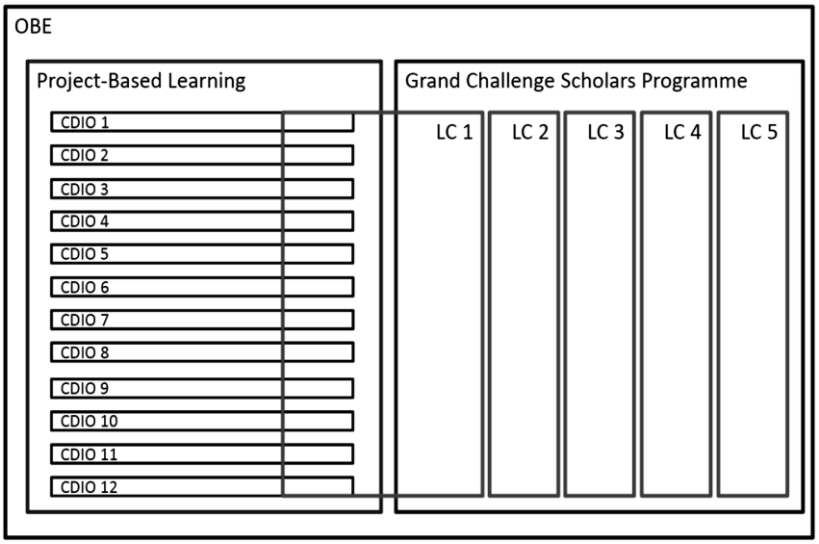

Fig. 1. Illustration of the coupling of school's OBE framework and PjBL pedagogy with the GCSP. (Note: LC is a learning component)

Figure 1 illustrates how the school's pedagogy and framework is coupled with the GCSP. The school's educational framework is based around Outcome-Based Education (OBE) [8-10]. This requires the school to ensure the learning outcome (LO) attainment (at the programme and module levels) are adequately met by its students. LO attainment scores are then used, in the spirit of CQI, to enhance the programme and hence the overall student learning experience. These practices are discussed in detail in [11-15].

3. TGCSP Structure

The vision of TGCSP is encapsulated in the following vision statement; "To empower engineers to achieve their full potential and be the solution to humankind's Grand Challenges". The Vision of the Programme is in line with the TSoE Programme Educational Objectives (PEOs) as detailed in Table 1.

Table 1. SoE's Programme Education Objectives (PEOs).

PEO1	Achieve a high level of technical expertise and excel in positions in Engineering practice, research or other fields they choose to pursue
PEO2	Conceive, design, implement and operate Engineering systems, processes and products that consider functionality, safety, cost effectiveness and sustainability using sound principles
PEO3	Assume and aspire to leadership positions at both multinational companies and enterprises
PEO4	Pursue lifelong learning, such as graduate studies and other continual professional development activities

Table 2 details the TGCSP's learning outcomes (GCPOs) expected of an Engineering graduate upon the completion of the TGCSP. These outcomes are modelled on the five learning components of the NAE's GCSP.

Table 2. TGCSPs Grand Challenge Programme Outcomes (GCPOs).

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

SoE itself prescribes to a set of Programme Learning Outcomes (POs). The POs describe what is expected of a SoE graduate upon the completion of the Programme and are listed in Table 3. The five GCPOs are mapped to SoE's own POs. This is detailed in Table 4.

Table 3. SoE's Programme Outcomes (POs).

PO1	Apply the knowledge of mathematics, science, Engineering practices, innovation techniques, entrepreneurship and human factors to provide value-adding solutions to complex Engineering challenges.
PO2	Identify, formulate, analyse and document complex Engineering challenges to arrive at viable solutions and substantiated conclusions.
PO3	Conceive, Design, Implement and Operate solutions for complex Engineering challenges that meet specified requirements with appropriate consideration for public health and safety, cultural, societal, environmental and economical considerations.
PO4	Conduct research and investigation into complex challenges using methods which include experiment design, analysis of data and synthesis of information to provide valid conclusions.
PO5	Create, select and apply appropriate techniques, resources, and modern Engineering and IT tools, including prediction and modelling, to complex Engineering activities, with an awareness of the accompanying assumptions and limitations.
PO6	Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal, economical and cultural issues and the consequent responsibilities relevant to professional Engineering practice.
PO7	Explain the global impact of professional Engineering solutions in societal, economical and environmental contexts and demonstrate knowledge of and need for sustainable development.
PO8	Apply professional and ethical responsibilities of Engineering practice.
PO9	Effectively communicate complex Engineering activities, both orally and in a written form, in both technical & non-technical contexts.
PO10	Function effectively as an individual and in multidisciplinary settings with the capacity to be a leader.
PO11	Recognise the importance of lifelong learning and engaging in continuous professional development activities in accordance with technological change.
PO12	Effectively manage projects in multidisciplinary environments and apply project management tools and techniques to one's own work, as a member and leader in a team to satisfy stakeholder requirements.

Table 4. Mapping between GCPOs and POs.

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
GCPO 1			✓	✓								
GCPO 2										✓		
GCPO 3												✓
GCPO 4							✓					
GCPO 5						✓		✓				

Based on the mapping, the TGCSP is in line with the current objectives and outcomes of SoE. These outcomes will allow scholars to fulfil their academic requirements while working on complex projects addressing NAE's Grand Challenges.

The TGCSP will continuously support and enhance the school's strengths, particularly in the areas of project-based learning (structured through the application of the Conceive-Design-Implement-Operate CDIOTM framework). By subscribing to the School's POs, the TGCSP will educate qualified candidates who will be able to:

- Gain the Appropriate Fundamental and Advanced Engineering Knowledge (which includes Project Management and Finance).
- Analyse Engineering Challenges.
- Design and Development of Solutions
- Practice Research Based Knowledge when Performing an Investigation.
- Utilise modern Engineering tools and techniques.
- Understand the Role of an Engineer in Society and the Application of Ethics in Engineering.
- Communicate and Function Effectively as an Individual or in a Team
- Practice Life Long Learning.

Since the GCPOs are clearly mapped to the POs, this would mean that the curriculum of the School is also mapped to the GCPOs. The reasoning for this is, in the spirit of OBE, upon the development of a set of POs, the curriculum would be developed and the modules created will consist of a set of module LOs. Since these modules were created with the POs in mind, hence the LOs are linked to the POs and thus the GCPOs.

Each module in SoE consists of a set of assessments that are mapped to the LOs. The LO attainment scores are calculated based on the actual marks of a student's assessment scores at the module level. Because assessments are mapped to the module's LOs and this in turn is mapped to the programme outcomes (POs), both the LO and PO attainment scores can be calculated. As noted previously, the GCPOs are mapped to the school's own POs, hence the scholars PO attainment scores (that are calculated from ESAT) would allow for their GCPO scores to be calculated as well [14]. The School makes use of a tool, called ESAT, which is able to calculate the LO attainment of each of its students.

It should be noted that while the TGCSP LOs are mapped to the School's POs, the attainment of the former is based on tasks and activities that are related to the GCs. This requires a greater sense of initiative and pro-activeness from a TGCSP scholar. Dealing with such activities would require students to have a greater sense of depth and breadth of the curriculum as it would also require more rigor, meaning that a scholar that attains the TGCSP LOs has gone beyond the School's POs to achieve greater heights. A TGCSP scholar will be enrolled and will experience the same programme structure as that of a normal SoE Student, however the requirements that the scholar would need to meet will be different and will addressing the NAE GC five learning components; namely, Research Experience, Interdisciplinary Curriculum, Entrepreneurship, Global Dimension, Service Learning. Below are some of the examples of tasks and activities that scholars are involved in:

- Kuwait Global Technopreneurship Challenge 2015: Scholars participated in the Kuwait Global Technopreneurship Challenge organized by College of Engineering & Petroleum, Kuwait University from 14th to 16th November 2015. The team addressing "Advance Health Informatics" clinched the first prize by exhibiting an automatic accident notifier that reduces the delay between vehicle accident and communication with the city emergency units.
- A Lesson in Service learning: Scholars joined forces with University of Birmingham students to raise RM40k through crowdfunding to support their activity of building a home for an Orang Asli family in Perak, Malaysia, through the EPIC Homes programme.
- Giving Back to the Youth: Scholars organized "Engineering My Future", a community service initiative aimed at introducing engineering to underprivileged children and exposing them to the 14 Grand Challenges as means of motivation. The children had the opportunity to build their own simple water filtration system using common everyday items.
- 14th National Challenge Cup: Scholars presented their solutions at the 14th National Challenge Cup in the theme-based competition of "Smart Green Cities" organized at the Guangdong Science Centre, China, from 16th to 20th December 2015. Contestants were invited to submit a proposal, in which a city in their home country was selected and they gave suggestions on how the city can be improved into a Smart Green City. The projects; namely, "Redesigned Zipper" and "Automated Mechanism to Prevent Pressure Ulcers", were selected via a pitching session to a panel of the school internal judges.
- Global Transformation Forum: Scholars were among the hundreds that watched a large panel of distinguished individuals giving their insights and debating on the needs for transformation in a global environment during the Global Transformation Forum held at the Kuala Lumpur Convention Centre (KLCC) from 21st to 23rd October 2015. The conference gave an opportunity for the scholars to meet and network with notable individuals including government leaders, policymakers, captains of industry and global organizations.

The TGCSP will be governed by the existing administrative and academic structures present in the School. This includes the Schools Academic Services that oversees the administrative execution of items related to scholar documentation and the School's Academic Management that oversees academic execution of items related to scholar experience by enrolling, monitoring, controlling and improving related activities. Each scholar in the School is part of an academic Programme that is managed by a Programme Director. At the core of the TGCSP is its committee members (consisting of TGCSP scholars) and is governed by the Schools TGCSP Director who is responsible for the planning and execution of the TGCSP.

Based on Fig. 2, and referring to the flow process on the left of the diagram, applicants would have to go through the selection process and if successful, would become part of the TGCSP and hence a TGCSP scholar. It should be noted that potential Scholars (or applicants as stated in Fig. 2) would enter the programme while they are in Years 1 or 2 of their 4-year engineering

undergraduate journey. Scholars would then graduate/exit the programme (upon successful completion of the 4-year degree and the relevant TGCSP requirements) and as alumni (or stakeholder) would have the opportunity in providing feedback to the School, which would be required to further enhance and improve the TGCSP. This is done in the spirit of Continual Quality Improvement (CQI). Relevant CQI action plans would then be channelled through to the TGCSP committee that would then look into improving the administration of the programme based on the CQI action plans. The link between the TGCSP square block and the CQI circle in Fig. 2 illustrates that feedback would also be sought from existing TGCSP students to further improve the programme. In summary, on an annual basis, input would be taken from the TGCSP (i.e. an analysis of the activities completed, overall results of the scholars, TGCSP LO attainment scores etc.) as well as its graduates and an action plan would be developed in the spirit of CQI to enhance and improve the selection of the scholars as well as the administration of the TGCSP.

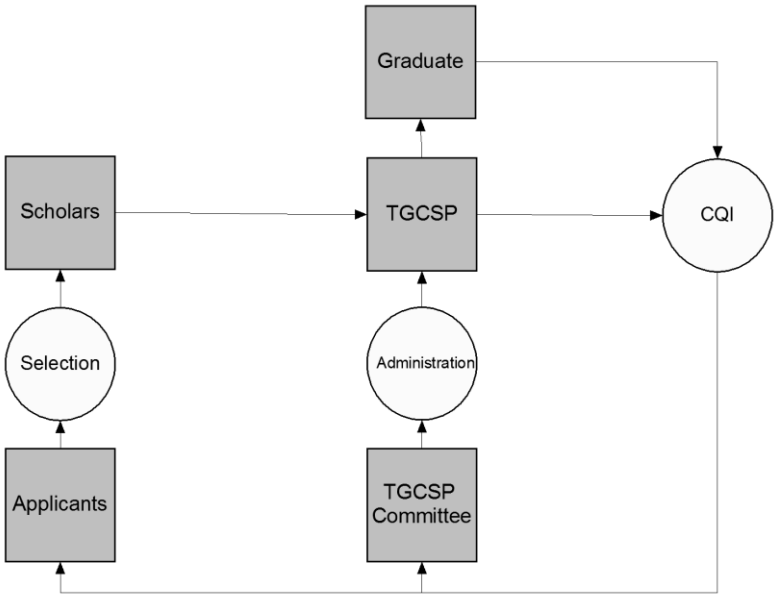

Fig. 2. TGCSP Governance.

If a student wishes to join the TGCSP in Year 2 of their programme, they would need to go through the same selection criteria. It should be noted however that the School would not allow students in Year 3 onwards to enrol into the TGCSP since more than 50% of their knowledge profile (of their degree programme) would have been completed in Year's 1 and 2.

4. Implementation of the Programme Requirements

The following section (in matrix form) describes in detail how a TGCSP scholar would achieve the relevant TGCSP outcomes and requirements. The matrix details the roadmap a scholar would need to go through to successfully complete the TGCSP. It should be noted that a scholar must satisfy all requirements

detailed in Table 5 in addition to the regular requirements of completing an Engineering degree in SoE.

The roadmap is divided into 4 parts:

- The 1st of these reflects the outcomes of the TGCSP (the column in Table 5 which is 1st from the left)
- The 2nd item highlights which learning component/area is addressed by the outcome (the column in Table 5 which is 2nd from the left)
- The 3rd item describes the requirements that are to be fulfilled by the scholar (the column in Table 5 which is 3rd from the left). It should be noted that the overarching requirement is a scholar must select one of the fourteen grand challenges and that all of their activities in the learning components/areas need to be focused on that challenge.
- The final and 4th item details what is the proposed implementation plan a scholar would adopt in SoE (the column in Table 5 which is 4th from the left).

A study of 26 institutions running the GCSP, including Taylor's University, Malaysia, as well as US-based universities such as Texas A&M University, University of South California, University of Texas at Austin, Arizona State University, Duke University and North Carolina State University shows that 34.6% of them require scholars to maintain their CGPA above a threshold decided by the institution while 38.5% may also require a scholar to submit a progress report regularly to evaluate his/her progress in achieving the programme outcomes. The study indicates that 53.8% of the institutions evaluate the attainment of programme learning component "Hands-on Project/Research Experience" through a research study while 42.3% of them offer design projects for the assessment. The learning components "Interdisciplinary Curriculum" and "Entrepreneurship" are delivered and assessed through coursework/electives in 69% of the programmes. A 46% of the programmes require students to study abroad to attain the "Global Dimension" whereby 34.6% of them offer internship/research or electives that have a global focus. In 65.4% of the programmes student are involved in community service initiatives to fulfil the requirements for the learning outcome "Service Learning". Table 6 shows the full list of comparison of requirements between the institutions.

Two main conclusions are drawn from this desktop study.

1. The requirement for Scholars to maintain their CGPA above a certain threshold is not prevalent at many institutions. From the authors' own experience in executing a GCSP, there is no evidence to suggest that Scholars with a good CGPA also accomplish exceptional projects and activities. This study, also acts as a benchmark for the authors' own GCSP and was used in deciding on whether it would be necessary to remove the CGPA requirement.

2. A more in-depth study is required to understand how more than 50% of the institutions evaluate the attainment of the programme learning outcomes. At present, learning outcome attainment for the authors' GCSP is done via mapping of assessments to specific learning outcomes in a module (or subject). It would be good to analyse how such data is mined at other GCSP schools.

Table 5. Scholar Implementation Roadmap for TGCSP.

TGCSP Outcome	Programme Requirement	Requirement	Proposal
Demonstrate the competence to undertake project or research activity related to a specific Grand Challenges theme or challenge.	One of the five learning components – Grand Challenge Project(s).	A scholar must contribute (for at least one semester) to a group or individual project, which relates to a Grand Challenge. Note that the project selected by the Scholar must be one of the fourteen grand challenges and that all of their activities in this learning component/area need to be focused on that challenge.	SoE has a project-based learning module in each of its eight semesters. The first six modules require a scholar to CDIOTM an Engineering system in a group while the remaining two modules is a Final Year Project. Each project must be related to a Grand Challenge. As such, the assessments are mapped to the relevant LOs which are in turn mapped to the POs and hence the GCSPOs. *Exemplar* All projects in SoE are mapped to a GC area. Examples of such projects include the Taylor's Racing Team and the Thought Operated Wheelchair.
Demonstrate the ability to comprehend knowledge from non-Engineering disciplines and understand their importance in solving the Grand Challenges.	One of the five learning components – Interdisciplinary Experience	A scholar 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. Note that the coursework being undertaken by the scholar must relate to a project that addresses one of the fourteen grand challenges and that all of their activities in this learning component/area need to be focused on that challenge.	Scholars in SoE need to undertake four university wide electives. These electives are from non-Engineering discipline based Programmes. Scholars are also able to enrol in electives that require the application of Engineering knowledge to interdisciplinary areas. It should be noted that the electives should clearly complement the Grand Challenge Portfolio of the scholars. The selection of the electives would be guided by the TGCSP Committee. *Exemplar* Scholars have options to take interdisciplinary modules such as Engineering Biomimetics, Architecture and Nation Building, Entrepreneurship as well as Leading in the 21st Century, to name a few. SoE also has a specific project-based learning module called Multidisciplinary Engineering Design that allows for scholars to CDIOTM a project related to a Grand while being part of a multidisciplinary team.Challenge. Besides, scholars are exposed to a variety of lectures by guest speakers (some of whom are outside the Engineering discipline). These lectures share different approaches in industry and encourage scholars to understand their future role in industry.

TGCSP Outcome	Programme Requirement	Requirement	Proposal
Demonstrate the ability for technical innovation, organizing events, raising funds and leading teams.	One of the five learning components – Entrepreneurial Experience	Scholars need to successfully complete an activity related to an Entrepreneurial experience. This could be in the form of a competition or in taking a specific module. Note that the entrepreneurial activity selected by the scholar must be addressing one of the fourteen grand challenges and that all of their activities in this learning component/area need to be focused on that challenge.	Scholars may take any one of the following initiatives to demonstrate their achievement of the "Entrepreneurial Experience" learning component. • Participation in competitions organized by the School and University that require some form of entrepreneurial skills. • Scholars would need to participate in selected modules and complete assessments that require them to manage a project to its intended success. In addition to this, scholars would need to experience what would entail in planning and executing a business that includes fund raising and leadership. Exemplar Scholars in SoE must enrol in a module that teaches them the fundamentals of project management. This module entitled Managing Projects for Success requires them to manage one of their design projects using the relevant Project Management tools and techniques learnt. Throughout the other design modules, scholars are also required to include a section in their design reports on how they have implemented project management in all of their projects. Scholars would also submit assessment components from the module Engineering Design and Innovation which are related to "Business Value" and "Pitching". In addition to the above, all scholars would need to register for a module called Business Skills for Engineers. In this module, scholars are exposed to a variety of entrepreneurial tools and techniques. The module is offered as a Massive Open Online Course (MOOC) to students outside the university and around the world. Scholars from SoE are required to form a group with the international students to pick a project (that's related to a GC), and source for funding to implement this project.

TGCSP Outcome	Programme Requirement	Requirement	Proposal
Demonstrate awareness of global ethical issues and global interdependence in solving the Grand Challenges. This requires active participation in seeking international exposure.	One of the five learning components – Global Awareness	Performing industrial training abroad or participating in an international exchange or performing research abroad. Note that training participated by the scholar must be addressing one of the fourteen grand challenges and that all of their activities in this learning component/area need to be focused on that challenge.	In order to seek international exposure, one way to accomplish this would be to work in a company outside of the scholar's country of residence. In addition to this, a Scholar may choose to participate in an international exchange or by carrying out research work abroad. Exemplar It is a requirement for all scholars to undergo industrial training in the short semester of their Programme prior to entering the final year. For a TGCSP scholar, it would be a requirement for them to intern abroad. The internship experience is related back to and relevant to one or more of the Grand Challenges and the Grand Challenge concept as appropriate to the individual scholar. Scholars who qualify for this may be able to source for financial assistance from the School. The University's career's services centre assists all of its students in securing internships. Scholars also have the opportunity to participate in the University's student exchange programme as the School itself has accepted students from Finland and Belgium in the past and is working towards sending Malaysian students to the same countries. In addition to this, the scholars have the opportunity to travel abroad and represent the University at prestigious conferences. Students are also free to initiate research collaboration through the selection of key projects.
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.	One of the five learning components – Service Learning	A leadership role in a service oriented activity. Note that service oriented activity selected by the scholar must be addressing one of the fourteen grand challenges and that all of their activities in this learning component/area need to be focused on that challenge.	Scholar's need to lead and participate actively in service learning based activities. Exemplar As part of SoE's module Professional Engineers & Society, scholars are required to participate in performing a service-oriented activity as part of the assessment of the module. A scholar would need to successfully lead a team in completing a service-oriented activity.

TGCSP Outcome	Programme Requirement	Requirement	Proposal
The Creation of individual Grand Challenge scholar Portfolio	A cumulative written document to culminate experiences relating to the attainment of a scholar throughout the TGCSP.	The production of a GCPO Portfolio.	All scholars would need to prepare a GCPO portfolio that details the current GCPO attainment as well as the justifications to why they have achieved a certain GCPO. Scholars are also able to compare their own attainment scores to that of the computed GCPO scores and perform a gap analysis if needed. Exemplar Scholar's will produce a detailed GCPO portfolio at the end of their 3rd year or at the beginning of the 4th year of their Programme. A creative resume would also be produced. This resume will identify their strengths and growth opportunities based on the gap analysis performed on their GCPO attainment scores.
Active contribution as a member of the TGCSP committee.	To participate in the planning, execution, monitoring and improving of the TGCSP.	All scholar s to hold a role and be part of the TGCSP committee.	The formation of this committee will be chaired and membered by the scholars. The advisor will be the TGCSP Director. Exemplar The committee would aspire to: Form a team of scholars and Mentors to help the TGCSP program grow. This could be accomplished by recruiting new scholars, involving alumni or industry in the Programme and collaborate with existing GC Programme around the globe (to facilitate the attainment of their GCPOs). The committee would also be tasked to organize events linked to the GC.

Table 6. Comparison of requirements for programme implementation between 26 institutions.

Elements	%
Scholar Responsibilities	
Maintain Scholar CGPA Requirement	34.6
Annual Symposium	7.7
Monthly/Semesterly Meetings with Mentors	7.7
Bi-monthly Town Hall Meeting (w/ TGCSP Director)	7.7
Progress Plan, Report & Evaluation	38.5
Outcome 1: Research/ Project	
More than One Semester Requirement	15.4
Option: Research	53.8
Option: Independent Study	23.1
Option: Internship	11.5
Option: Design Project	42.3
Option: Coursework	19.2
Outcome 2: Interdisciplinary Curriculum	
More than one course requirement	34.6
Option: Coursework/ Electives	69.2
Option: Experiential (Internships, Volunteering)	3.8
Option: Seminars/ Presentations	7.7
Reflection on relation of Curriculum to GC	11.5
Relate to Outcome 1	3.8
Outcome 3: Entrepreneurship	
Option: Coursework / Electives	69.2
Option: Design/Research Project	19.2
Option: Work/ Student Organization / Program	30.8
Option: Seminars/ Presentations	11.5
Option: Experiential (Getting Funding)	15.4
Option: Competition	38.5
Outcome 4: Global Dimension	
Necessary Travel outside Country	26.9
Option: Study Abroad	46.2
Option: Internship / Research	34.6
Option: Local Coursework/ Electives (Global- Focused)	34.6
Option: International Program	30.8
Option: Conference	15.4
Outcome 5: Service Learning	
Option: Coursework	23.1
Option: Leadership Role in Student Committee	15.4
Option: Non - Profit NGO commitment	11.5
Option: Community Service External Programs	19.2
Option: Service Trip	7.7
Option: Community Service Initiatives	65.4

5. Scholar Achievements

To date, the Scholars have completed a variety of projects and activities surrounding the learning components of the GCSP.

Several service-learning based activities were planned and arranged by the Scholars, which resulted in benefiting close to 60 underprivileged youths. The Scholars were also able to raise a significant amount of funds to assist in the execution of these activities. Several scholars also made the effort to source for funding to attend international conferences and national forums that were related to the Grand Challenges. Scholars in the past and present continue to plan and execute summer programmes within the School of Engineering, related to the Grand Challenges. In addition to the above, the Scholars, together with students from a U.K. based university, built a house for the indigenous people in Malaysia. In total, scholars participated in close to 10 international conferences and forums. These activities assisted in addressing learning component 2 for Scholars who participated.

A group of Scholars participated in a variety of competitions linked to the Grand Challenges. This resulted in two of them winning a national event (emerging as the Malaysian champion) and another winning an international event. A few scholars participated in a research exchange programme (with a Japanese-based university), which enabled them to travel and spend 3 weeks in Japan. The total funding secured for this exchange was equivalent to USD35,000. Such international participation resulted in these Scholars addressing learning component 4.

All Scholars have also made the effort to complete research projects relating to the Grand Challenges. These include the design and build of the dynamic systems for race cars, the evaluation of new refrigerants for heating ventilation and air-conditioning (HVAC) systems as well as the development of innovative motors for electrical vehicle applications. These projects resulted in conference paper publications (for all projects) and a patent (for the project on electrical motors).

The above represents a summary of what the Scholars were able to achieve through the GCSP platform.

Based on the data obtained through the benchmarking study (section 4 above) and from the experience of the School in administering a GCSP for 2-years, the following CQI actions were proposed for 2017.

1) To review the requirement of Scholars needing to achieve a CGPA of 3.0 and above each semester.

   This CQI action point was decided upon due to the availability of a number of Scholars who were able to excel in addressing the learning components while having a CGPA of less than 3.0. It is also worth noting that the CGPA requirement is only prevalent in 1/3 of the engineering schools that have a GCSP.

2) To eliminate the need for a written essay in the application process for becoming a GCSP Scholar.

   This CQI action point was based on feedback from existing Scholars and how they would have preferred to prepare a video on why they are passionate about the Grand Challenges instead of a 1000-word essay (on the same topic). Through a video, the Schools GCSP committee could clearly assess the affective component of each applicant in comparison to a written essay, where only written communication was assessed.

3) To increase the weightage of the GCSP Portfolio component in the final assessment component rubric.

   Prior to graduation, all Scholars would need to submit a GCSP portfolio to the School's GCSP committee for evaluation and to be assessed. A rubric was designed in order to determine whether the projects and activities accomplished (compiled in the portfolio) throughout the Scholars' journey do indeed meet the requirements of the 5 learning components. Observations made from the first set of portfolios submitted suggested that a significant amount of time and effort was placed in compiling many valuable and worthwhile projects and activities. As such, a decision was made to increase the weightage of the portfolio contribution to the overall final assessment component (which also consisted of a presentation component). The amount at which this weightage should be increased to in still under discussion and is to be determined in July 2017.

6. Conclusions

The paper discussed process of applying NAE GC scholar programme at TSoE, Malaysia. CDIO and PjBL are the two important ingredients of the engineering curriculum at TSoE, and the study shows that they come hand-in-hand to support the establishment and implementation of TGCSP. The TGCSPO LOs and POs attainments are measured regularly using an in-house software to quantify students' level of achievements throughout their study at the programme. These outcomes together with the students and alumni feedbacks are acquired to identify areas needing improvement and infuse CQI into the programme. Thereafter the roadmap of a scholar throughout the TGCSP is detailed. It described the requirements to fulfil each learning component, the corresponding implementation plan at TSoE followed by an exemplar. Finally, the programme implementation requirement is compared between 26 institutions and the similarities are highlighted. This provides an idea to the reader on how most of the institutions are running the programme.

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