

# GRAND CHALLENGES FOR ENGINEERING AND DEVELOPMENT OF CDIO SKILLS

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## ABSTRACT

The National Academy for Engineering announced 14 Grand Challenges for the 21<sup>st</sup> Century engineers to address in order to ensure a sustainable future for the generations to come. These Grand Challenges are in four broad areas, namely, energy and environment, health, security and learning and computation. This paper reports on a Grand Challenges Scholars Programme that is developed to prepare the engineering students to be able to address the Grand Challenges using the CDIO framework and focusing on five components, research experience, interdisciplinary curriculum, entrepreneurship, global dimension and service learning. The programme is voluntary and the candidates are expected to commit additional learning time. The programme was launched with 16 participants who are expected to graduate in 2016.

## KEYWORDS

Grand Challenges for Engineering, CDIO Syllabus, National Academy for Engineering.

## INTRODUCTION

Engineering education has been responding to the needs of the society and industry throughout the past century. Engineering professional and accreditation bodies embraced the increasing set of skills and competencies that employers required in graduate engineers such as communication skills, teamwork and other technical and non-technical skills through the establishment of outcome based education (OBE) standards. International agreements such as the Washington Accord are signed to ensure the equivalency of the standards of engineering education across the national borders. The globalised marketplace and the global challenges such as climate change, security and economic growth set the scene to an emerging global competence that is expected from engineers [1]. With that in mind in 2009, the National Academy of Engineering (NAE) identified 14 Grand Challenges that need to be addressed by engineers for the humanity to make it sustainably into the next century. These Grand Challenges are listed below [2]

### *Energy and Environment*

1. Make solar energy economical
2. Provide energy from fusion
3. Develop methods for carbon sequestration
4. Manage the nitrogen cycle
5. Provide access to clean water

### *Health*

6. Advance health informatics
7. Engineer better medicines

### *Security*

8. Prevent nuclear terror
9. Secure cyberspace
10. Restore urban infrastructure

### *Learning and Computation*

11. Reverse engineer the brain
12. Enhance virtual reality
13. Advance personalised learning
14. Engineer the tools of scientific discovery

Academic institutions, mainly in North America, responded by creating Grand Challenges Scholars Programmes aimed at preparing students to address the Grand Challenges. A Grand Challenges Scholars Programme (GCSP) has five main components; research experience, interdisciplinary curriculum, entrepreneurship, global dimension and service learning. These elements are aimed at providing global awareness and extra edge for the students in order to equip them with the skills necessary to be ready to contribute towards addressing the Grand Challenges.

The alignment between the Grand Challenges Scholars Programme (GCSP) components and the CDIO syllabus and framework [3] is clear and riding on the synergy between the two to provide an enhanced students' experience seems to be logical. A proposed mapping of the CDIO syllabus to the GCSP components is provided in Table 1. This paper reports on Taylor's Grand Challenges Scholars Programme (TGCSP) that is developed using the CDIO framework.

## **TAYLOR'S GRAND CHALLENGES SCHOLARS PROGRAMME (TGCSP)**

The School of Engineering at Taylor's University joined the Grand Challenges initiative in 2011. The School developed "Taylor's Grand Challenges Scholars Programme" to educate a diverse cohort of undergraduate engineering students preparing them for a leading role in addressing the Grand Challenges at both local and global levels. The students belong to three Bachelor Programmes, namely chemical, electrical and electronic and mechanical engineering. Besides the outcomes and objectives of the programmes that they are enrolled in, Grand Challenges Scholars are expected to achieve additional objectives and outcomes that are related to the Grand Challenges. These are outlined below.

### ***Programme Educational Objectives***

The Grand Challenges Scholars are expected to achieve the following within 5 years of their graduation

1. Play a key role in Conceiving, Designing, Implementing and Operating sustainable and innovative solutions for basic human needs, laying the foundation for a sustainable society.
2. Add value through developing new entrepreneurial opportunities.
3. Revolutionise human interactions, promoting understanding and collaboration.
4. Employ technology to serve the global society
5. Use systems thinking effectively to provide innovative solutions taken into account the unintended consequences.

## Programme Outcomes

Upon completion of the Engineering programme, a successful Grand Challenges Scholar will be able to

1. Use engineering, innovation, business and management skills to develop sustainable solutions addressing the Grand Challenges.
2. Conduct research activities related to the Grand Challenges
3. Successfully manage events and projects (including social services) ensuring the achievement of the requirements and the satisfaction of stakeholders.
4. Effectively lead and motivate teams and manage conflict.
5. Lobby for new concepts, rally support of different stakeholders and raise funds
6. Communicate ideas and concepts effectively in verbal, written, and visual format both to groups and individuals.

Table 1. Mapping of CDIO Syllabus to GCSP Components

CDIO Syllabus		GCSP Components				
		Project or Research	Interdisciplinary Curriculum	Entrepreneurship	Global Dimension	Service Learning
Tech	Knowledge of Underlying Mathematics, Science	✓	✓			
	Core Engineering Fundamental Knowledge	✓	✓			
	Advanced Eng. Fundamental Knowledge, Methods, Tools	✓	✓			
Personal	Analytical Reasoning and Problem Solving	✓	✓			
	Experimentation, Investigation and Knowledge Discovery	✓				
	System Thinking		✓			
	Attitudes, Thought and Learning				✓	
	Ethics, Equity and Other Responsibilities				✓	✓
Inter-Personal	Teamwork	✓				
	Communications	✓				
	Communication in Foreign Languages		✓		✓	
CDIO	External, Societal and Environmental Context				✓	✓
	Enterprise and Business Context		✓	✓		
	Conceiving, Systems Engineering and Management	✓	✓			
	Designing	✓				
	Implementing	✓				
	Operating	✓				

## Programme Structure

The Grand Challenges Scholars will undertake a well-structured and systematic programme that will allow them to acquire and develop the skills required to address the Grand Challenges. The programme structure is shown in Table 2.

Table 2. Taylor's Graduate Scholars Programme (TGCSP) Structure

Code	Module Name	Credits	Semester	Status
ENG1513	Engineering Design & Communication	3	1	Core
TGCSP01	Engineering for the Grand Challenges	1	1	TGCSP Elective
ENG1523	Engineering Design and Ergonomics	3	2	Core
TGCSP02	Communication for Impact	1	2	TGCSP Elective
ENG2513	Multidisciplinary Engineering Design	3	3	Core
TGCSP03	Managing Events	1	3	TGCSP Elective
ENG2413	Managing Projects for Success	3	4	Core
ENG2523	Engineering Design and Innovation	3	4	Core
TGCSP04	Engineering and Community	1	4	TGCSP Elective
ENG3913	Engineering Group Project 1	3	5	Core
TGCSP05	Technopreneurship 1	1	5	TGCSP Elective
ENG3923	Engineering Group Project 2	3	6	Core
TGCSP06	Business Skills for Engineers	3	6	Core
TGCSP07	Technopreneurship 2	1	6	TGCSP Elective
ENG3815	Industrial Training	5		Core
ENG4916	Final Year Engineering Project 1	6	7	Core
ENG4613	Globalisation, Innovation & Creativity	3	7	General Elective
TGCSP08	Engineering Leadership 1	1	7	TGCSP Elective
ENG4926	Final Year Engineering Project 2	6	8	Core
TGCSP09	Engineering Leadership 2	1	8	TGCSP Elective

### **Selection Criteria**

To qualify for the TGCSP, a candidate should apply in writing and be

1. Engineering student in good standing.
2. Committed to engineering of the Grand Challenges.
3. Passionate about positively contributing towards social and global issues.

### **Programme Content**

For the first semester of this programme, students took two modules, "Engineering Design & Communication" which is a core module taken by all the engineering students and "Engineering for the Grand Challenges" which is specific to the Grand Challenges scholars. The objective of the first semester is to develop understanding, awareness and Grand Challenges focus and the students were involved in a variety of activities including talks, workshops, design and build activities and team building and discussion sessions related to the Grand Challenges. They were required to develop a personal mission statement and personal SWOT analysis and maintain a portfolio to track the development of the achievement of the programme outcomes.

For the design activity, the students were required to work in a group to design and build a remotely operated model solar boat. Working within the design requirements and limitations, the students develop a boat that needs to perform a certain set of manoeuvres in a lake.

The TGCSP participants developed a website for the programme as well as a logo. This is to ensure that the programme has its own identity and character.

## PRELIMINARY ASSESSMENT OF THE PROGRAMME

To assess the effectiveness of the Grand Challenges Scholars programme in developing CDIO skills, the students were requested to complete a survey. The survey is outlined in Table 3 and it was designed to assess the development of CDIO skills as perceived by the students. The respondents were required to indicate their response on a 5-point Likert scale with 1 denoting strong disagreement and 5 representing strong agreement. Table 3 also shows the number of respondents who opted to select each of the different points on the scale.

Table 3. Assessment Survey

My involvement with TGCSP helped me....	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
Improve my knowledge underlying mathematics and science	1	1	3	8	0
Improve my problem solving skills	0	0	6	5	2
Improve my ability to discover new knowledge	0	0	1	5	7
Develop holistic thinking capabilities	0	0	3	7	3
Improve my decision making capabilities	0	1	4	4	4
Improve my leadership skills	1	0	3	7	2
Develop an awareness of social responsibility for engineers	0	0	3	6	4
Improve my teamwork skills	0	1	1	7	4
Improve my English writing skills	1	2	5	4	1
Improve my English oral communication skills	1	0	1	7	4
Improve my presentation skills	1	0	1	5	6
Develop a global understanding and perspective	0	0	3	8	2
Set goals and achieve them	0	0	3	5	5
Manage projects and achieve objectives on time and within budget	0	2	6	4	1
	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
I found my involvement with TGCSP very fulfilling and rewarding	0	1	4	3	5
I shall recommend my juniors to join the TGCSP	0	0	1	6	6
I shall continue to be a member of TGCSP	0	0	0	4	9
My involvement of TGCSP was very time consuming	1	5	5	5	0

## RESULTS AND DISCUSSION

Although the Grand Challenges Scholars Programme at Taylor's (TGCSP) is still in its infancy, there are numerous signals that indicate its success. Thirteen out of the sixteen participant responded to the survey and their responses were generally very positive. There seems to be an overwhelming agreement on the willingness to continue with the programme and recommending it to the juniors. To the delight of the author, the participants did not seem to perceive their involvement at TGCSP as time consuming.

The top 3 areas of development (with the highest number of participants agreeing or strongly agreeing- 4 and 5) seem to be knowledge discovery (N=12), oral communication in English (N=11) and presentation skills (N=11). In contrast, the bottom 3 areas of development are project management (N=5), writing in English (N=7) and problem solving (N=7).

These results seem to indicate that TGCSP is showing signs of health and success. Future modules will attempt to address areas like writing skills in English, as it is a common area of weakness for Malaysian students.

## CONCLUSIONS

A Grand Challenge Scholars Programme was initiated at Taylor's University to provide students with a global awareness and to enhance the achievement of CDIO skills. After the first semester, the results indicate that the participants found the programme useful in developing an array of CDIO skills. The School intends to continue offering this programme.

## REFERENCES

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## BIOGRAPHICAL INFORMATION

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