Engineering Elements between First Year and Final Year Engineering Students in Malaysia

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Abstract

From a previous in-depth study using interviews with experts, literature review and factor analysis, it was found that there are four main engineering elements which are inquiry, design, optimisation and sustainability. A further sub-classification includes 10 sub-elements: interest, discovery, inquisitive mind, imagination, problem solving, prototyping, optimising, maintaining, life cycle and sustainable values. An instrument to measure these engineering elements was developed and piloted to 280 engineering students with a high reliability value of 0.9142 using the Cronbach's reliability test. The validated questionnaire called Engineering Elements Survey (EES) was administered to 816 first year and final year engineering students from five higher education institutions in Malaysia who enrolled in various fields of engineering programmes. From the means of all the sub-elements, there is a consistent pattern showing that first year engineering students have lower scores compared to the final year engineering students.

Keywords: Engineering Elements;

1. Introduction

There is a big concern of the participation of students in science, technology, engineering and mathematics (STEM) at school and university levels (New Straits Times, 10 February 2012). In a recent study, Mohd Salleh et al. (2011) reported that the percentage of secondary school students enrolling in science stream is declining compared to the art stream. Similar problem is faced by the Malaysian higher education sector when the percentage of university students enrolling in STEM related study programmes have also deteriorated.

However, a report by the Ministry of Higher Education of Malaysia (MOHE) in 2006 stated that there are only about 80,000 engineers in Malaysia. Yet, the demand for engineers in Malaysia will increase to 300,000 in 2016 (MOHE, 2006). The 2006 figure is based on the assumption that 50% of practicing engineers did not register with the Board of Engineers Malaysia (BEM). Up to today, there are around 60,000 registered members of BEM. Using similar assumption, at present, there should be about 120,000 engineers while MOHE targets that the number should increase to 300,000 five years from now. With the lack of students participating in STEM subjects and the increment of only 40,000 students between 2006 and 2011, the goal seems like an uphill battle.

There have been a few initiatives to introduce engineering in schools. Among others are the Engineering Model Eliciting Activities (EngMEAs) (Hamilton et al., 2008) which emphasizes on team problem-solving and mathematics; Engineering Teaching Kits (ETKs) (Donohue & Richards, 2008) which organizes workshops to school students; INSPIRE (Purdue University), Model & Modeling in Engineering Education (Zawojewski et al., 2008; Mousoulides & English, 2009); Speed School (Rivoli & Ralston, 2009) and so on. Most of the initiatives only describe the aims and methods of the projects, how the projects are able to integrate engineering experience into school curriculum and the skills needed for students to work like engineers (e.g., problem-solving, modeling, thinking skills, team working, etc.). However, what constitute the "engineering experience" is not clearly explained in those initiatives.

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One of the most developed projects thus far is the Engineering is Elementary (EiE) which was introduced in 2003 by a group of researchers from the Museum of Science, Boston (Cunningham, 2009). The project focuses on introducing the engineering design process which constitutes of five steps – ask, imagine, plan, create and improve. EiE has successfully produced curriculum materials to be used in schools in order to introduce the engineering design process to children.

In October 2000, a few institutes headed by Massachusetts Institute of Technology (MIT) introduced an initiative to reform engineering education (Broduer & Crawley, 2009). A CDIO model was introduced for undergraduate engineering education with the objective of restructuring the curriculum, pedagogical approaches and the laboratories. CDIO denotes Conceiving, Designing, Implementing and Operating systems in the enterprise and societal context (Crawley, 2001) and has been implemented by more than 50 higher learning institutions across the world. It promotes a new vision of engineering education and is expected to reduce the gap between engineering curriculum and engineering practice as it refers to how the engineers work (Crawley et al., 2008).

In this research, the four engineering elements that we have established and referred to are Inquiry, Design, Operate & Improve and Sustainability. Inquiry refers to the interest students have in making investigation and discovery in various daily life or technical problems through inquisitive minds. Many scholars who studied philosophy and engineering have agreed that 'design' is the central of engineering (Van de Pol, 2010). In this study, 'design' refers to the ability to solve problems, imagine and plan the solution. An engineer must also know how to operate and improve a system. This refers to the ability to optimize and maintain a system, product or solution. Finally, the element of sustainability is the most important element for an engineer of the 21st century. In solving any problems or suggesting any solutions, an engineer should be able to take into the consideration the sustainability development in terms of physical, economical and social aspects. All these engineering elements can be transformed into the learning outcomes and activities for students at the school level.

2. Details of the Research

School students should be introduced to some engineering elements in order to attract them to choose this field. Hence, this research aims to identify the engineering elements that can be introduced to school students. The engineering elements were tested between first- and final-year engineering students to determine the relevance of the elements. Prior to this, rigorous ground works have been done to establish the engineering elements (Phang et al., 2011) through literature review, expert interviews, construction of the engineering elements and sub-elements, designing of the questionnaire, pilot testing and factor analysis. The internal consistency reliability coefficient for the Engineering Elements Survey (EES) questionnaire was established at 0.9142 consisting of 50 Likert scale items. This paper will report the result of the survey of 816 engineering students from five higher education institutions in Malaysia. The important research question in this research is to investigate if there are any significant differences between the first- and final-year engineering students in all the engineering elements and sub-elements. This is carried out in order to determine the relevance of the engineering elements to the engineering students before these elements are accepted to be implemented at the school level.

2.1 Sample

From the total of 816 engineering students, 452 were male students with 5 missing data. There were 466 first year engineering students from several different engineering disciplines namely civil, mechanical, electrical, chemistry, biomedical, petroleum and gas engineering. The five institutions were from various states in Malaysia including Johor, Selangor, Kuala Lumpur, Perlis and Sarawak. Table 1 shows the summary of the sample.

Table 1. Research Sample

	Year		Total
Gender	**First Year**	**Final Year**	
Male	262	204	466
Female	190	151	341
Total	452	355	807*

*9 missing value of gender

2.2 Instrument

As explained earlier, the instrument consists of 50 Likert scale items to measure the engineering elements among the engineering students. The instrument is designed based on the four engineering elements and the sub-elements as shown in Table 2.

Table 2. The Constructs and Items of Engineering Element Survey (EES)

Engineering Elements	Sub-Elements	Number of Items
Inquiry	Interest	4
	Investigation & Discovery	3
	Inquisitive Mind	3
Design	Problem Solving	7
	Imagination	7
	Planning & Prototyping	5
Operate & Improve	Optimization	4
	Maintaining & Improving	5
Sustainability	Sustainability & Lifecycle	7
	Value & Attitude about Environment	5
Total Items		**50**

2.3 Data Collection

The EES was distributed to seven higher education institutions around Malaysia and administered to around 50-100 first year students and 50-100 final year students from each institution. It took the students 7-10 minutes to answer all the items. The questionnaires were returned and later the researchers keyed the data into a data processing software package – SPSS (Statistical Package for Social Sciences). An analysis of means differences was conducted to identify if there were significant differences between the two groups of students in terms of all the engineering elements and sub-elements.

3. Data Analysis and Results

From the means comparison, it shows that there are differences between the first-year and final-year engineering students in all the engineering elements. The means for the final-year engineering students were higher than the first-year engineering students across all the engineering elements and sub-elements as shown in Table 3 and Table 4.

Table 3. Comparison of means of first- and final-year engineering students for all engineering elements

Engineering Elements	Year	Mean
Inquiry	First Year	3.83
	Final Year	3.94
Design	First Year	3.88
	Final Year	3.99
Operate & Improve	First Year	4.02
	Final Year	4.08
Sustainability	First Year	4.01
	Final Year	4.07

Table 4. Comparison of means of first- and final-year engineering students for all engineering sub-elements

Engineering Elements	Sub-Elements	Year	Mean
Inquiry	Interest	First Year	3.92
		Final Year	4.02
	Investigation & Discovery	First Year	3.77
		Final Year	3.88
	Inquisitive Mind	First Year	3.77
		Final Year	3.92
Design	Problem Solving	First Year	3.91
		Final Year	4.03
	Imagination	First Year	3.79
		Final Year	3.92
	Planning & Prototyping	First Year	3.85
		Final Year	3.98
Operate & Improve	Optimization	First Year	4.04
		Final Year	4.10
	Maintaining & Improving	First Year	3.99
		Final Year	4.06
Sustainability	Sustainability & Lifecycle	First Year	4.01
		Final Year	4.08
	Value & Attitude about Environment	First Year	4.00
		Final Year	4.04

In order to determine if the differences are significant, an inferential statistical test needs to be conducted. Before choosing the test, it should be identified if the data can be analysed using a parametric or non-parametric statistical test. This was decided using a normality test. From the Kolmogorov-Smirnov test of normality, all the items showed the sig. value as smaller than 0.05. This shows that the data is not normally distributed. For this, a non-parametric statistical test of independent means comparison called Mann-Whitney U test was selected to analyse if there is any significant difference between the two groups of students at $p = .05$. The results are as shown in Table 5 and Table 6.

Table 5. Results of Mann-Whitney U test for all engineering elements

Engineering Elements	Mann-Whitney U	Asymp. Sig. (2-tailed)
Inquiry	66841.000	.002
Design	59888.500	.000
Operate & Improve	69060.000	.160
Sustainability	70705.500	.100

Table 6. Results of Mann-Whitney U test for all engineering sub-elements

Engineering Elements	Sub-Elements	Mann-Whitney U	Asymp. Sig. (2-tailed)
Inquiry	Interest	73633.000	.056
	Investigation & Discovery	71313.000	.008
	Inquisitive Mind	67065.000	.000
Design	Problem Solving	67210.500	.003
	Imagination	65531.000	.000
	Planning & Prototyping	66568.000	.000
Operate & Improve	Optimization	73070.500	.200
	Maintaining & Improving	73299.500	.263
Sustainability	Sustainability & Lifecycle	69981.500	.038
	Value & Attitude about Environment	76848.500	.391

From the results tabulated in Table 5, it is clear that only the engineering elements of Inquiry and Design show significant differences between the two groups of students. However, if we focus into the sub-elements of Inquiry in Table 6, Interest does not seem to show a significant difference between the two groups while other sub-elements of Inquiry and Design produce significant differences. Although the elements of Operate & Improve and Sustainability are not showing significant differences, referring to Table 6, the sub-element of Sustainability & Lifecycle yield a significant difference.

3.1 Institutions

When the analysis was split among the higher education institutions, a very interesting pattern emerged. Three technological-based universities showed the general pattern where final-year engineering students demonstrated higher mean scores across all the engineering elements and sub-elements. Two other universities showed entire opposite pattern where first-year engineering students exhibited higher mean scores across all the engineering elements and sub-elements. Both universities yielded a significant difference for the engineering element of Inquiry and all the sub-elements through the Mann-Whitney U test.

3.2 Gender

Interestingly, when the data was compared between genders, the male students showed higher means across all the engineering elements and sub-elements as tabulated in Table 7 and Table 8.

Table 7. Comparison of means between genders for all engineering elements

Engineering Elements	Gender	Mean
Inquiry	Male	3.95
	Female	3.80
Design	Male	3.95
	Female	3.90
Operate & Improve	Male	4.07
	Female	4.02
Sustainability	Male	4.05
	Female	4.02

Table 8. Comparison of means between genders for all engineering sub-elements

Engineering Elements	Sub-Elements	Gender	Mean
Inquiry	Interest	Male	4.04
		Female	3.86
	Investigation & Discovery	Male	3.88
		Female	3.74
	Inquisitive Mind	Male	3.89
		Female	3.76
Design	Problem Solving	Male	3.98
		Female	3.94
	Imagination	Male	3.88
		Female	3.81
	Planning & Prototyping	Male	3.92
		Female	3.90
Operate & Improve	Optimization	Male	4.08
		Female	4.04
	Maintaining & Improving	Male	4.05
		Female	4.00
Sustainability	Sustainability & Lifecycle	Male	4.06
		Female	4.03
	Value & Attitude about Environment	Male	4.03
		Female	4.00

However, when the Mann-Whitney U test was conducted to determine if the differences are significant, only the element of Inquiry and all its sub-elements showed statistically significant differences.

4. Discussion & Conclusion

The findings show that Inquiry and Design are the two most important engineering elements and sub-elements to be incorporated into the school level curriculum in order to identify students interested to study engineering. If we plan to sustain the enrollment of students in the fields of engineering, these two elements must be inculcated into the present school curriculum.

On the other hand, universities which offer engineering programmes must be able to maintain these engineering elements. In this study, two non-technological-based universities are unable to increase these elements after the students have come to the end of their study. In this case, these elements showed a declining pattern. It is interesting to note that technological-based universities are able to increase these engineering elements. A more detailed study needs to be conducted to identify the reasons and approaches on how to sustain and increase these engineering elements through the engineering study programmes.

In term of gender, male students possess richer engineering elements especially in Inquiry, Interest, Investigation & Discovery and Inquisitive Mind. Special training may be given to female engineering students in order to foster their interest in engineering because these elements are important in the engineering programmes.

The establishment of the four engineering elements is expected to assist curriculum developers in designing curriculum materials and teaching supplements in order to integrate engineering elements into the school curriculum, especially in science and mathematics. This development is crucial in our present study because the ultimate aim of our research project is to integrate the engineering elements into the Science and Mathematics subjects in Malaysian schools.

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