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Assessing Students’ Development of Program Outcomes in an Associate Degree Engineering Curriculum: A Longitudinal Observation

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Abstract—Students’ progress and development in an engineering program is often left unexamined when much of the attention is placed on benchmarking students’ performance against absolute standards. This study aims at tracking students’ development on program learning outcomes across a two-year associate degree engineering curriculum. Nine Likert-scale items were designed to measure students’ perception of development on two clusters of program learning outcomes, namely “Knowledge and Understanding of Engineering” and “Awareness of Professional Ethics.” A total of 94 students in the associate degree engineering program filled in the questionnaire at first joining and graduating from the program. It was hypothesized that students perceived themselves to have developed in the two clusters of learning outcomes across the two-year study. Reliability tests suggest that the designed items are reliable measure of the two clusters of learning outcomes. Repeated measure MANOVA suggests that students perceive themselves to have some longitudinal gain in various program learning outcomes. Results support the value-addedness of program on students’ academic development. Implication of self-reported measurement on curriculum design and revision will be discussed.

Index Terms—learning outcomes; assessment; associate degree; perceived competences

I. INTRODUCTION

In response to the latest demand of the paradigm shift to an outcome-based approach to learning and teaching, there is much attention in using graduate attributes and learning outcomes for benchmarking or accreditation purposes in engineering education [1]. In this light, students’ graduation academic performances are used for qualifying and chartering purposes and the success or effectiveness of a program is largely determined by the overall rate of students attaining these accreditation criteria [2]. Given this model of assessing performances, students’ progress and development and how the curriculum adds value to their attainment of program learning outcomes throughout college years remains unexamined [3]. Students’ learning experience and development across the curriculum, in conjunction with their performance upon graduation, are both useful but complimentary sources of evidence for examining the effectiveness of a program and curriculum. The former provides critical information on the process of learning and teaching, and how well the program caters for individual learning needs and helps students to develop; while the later serves the gate-keeping purpose for assuring program quality. Engineering educators and administrators may derive different insights from these evidences to reflect on and then further refine the curriculum in order to better cater for stakeholders’ needs.

The current emergence of associate degree level engineering award in Hong Kong may further heighten the urgency of examining students’ trajectory and the process of learning and teaching across the curriculum. Associate degree students are generally perceived as less academically able, to have wider learning differences and learning needs when compared to their degree counterparts [4]. It is therefore expected that many of them may have developed substantially when compared with their own entrance baselines nevertheless their graduation performance still may not reach the benchmarks as set by local accredited bodies. Therefore, examining an associate degree program by only the number of students who have successfully attained the benchmarks or rate of articulation to university may appear incomprehensive and have understated the program’s effectiveness and contribution on students’ academic development. There seems to be a need to include self-reported measurement obtained from different time points to understand students’ learning across the curriculum in order to provide a fuller picture of students’ development as well as curriculum’s coherence and intactness.

A. Objectives and Hypotheses

An engineering associate degree curriculum was designed with close reference to two key clusters of learning outcomes, namely “Knowledge and understanding of engineering” and “Awareness of professional ethics.” The current study aims at tracking students’ changes on these two clusters of learning outcomes with the use of self-reported measurement. Nine Likert-scale items were designed to measure students’ self-evaluation of attainment of these two key clusters of learning outcomes at both entrance and exit points of their study. It is hypothesized that students in general perceive themselves to become more able or have higher attainments in these two
clusters of program learning outcomes upon graduation (exit point) when compared to their initial enrolment (entrance point), as it is expected that the current design of the engineering curriculum does have positive impact on student’s academic development.

II. Method

A. Program and Curriculum

Upon analyzing the key role of chartered engineers in society as well as benchmarking against the standards set by a local accreditation body (Hong Kong Institute of Engineers), four major program learning outcomes were derived and namely they are: 1) Understand fundamental principles of mathematics, engineering, computing and apply them to solve engineering problems at a competence level required for an associate engineer; 2) Design engineering components, processes to systems to meet design needs at a competence level required of an associate engineer; 3) Understand the trends of various engineering developments; 4) Demonstrate an understanding of the responsibility and ethics of an associate engineer.

The curriculum of the program was then designed in line with these four learning outcomes. Around 40% of the curriculum space is assigned for general education (Language proficiency, critical thinking, general electives from humanities) as prescribed by the College’s definitive program document while the rest was devoted for engineering program-specific courses. The engineering program-specific courses (including Basic Electricity and Electronics; Engineering Graphics and Computing; Engineering Science; Engineering Management; Principle of Programming and Engineering Mathematics) aim at providing fundamental knowledge in various realms of engineering (electrical, electronics, information, industrial and system, and mechanical) to prepare students sufficiently for further study in one of these areas. It is expected that program learning outcomes that relate to knowledge and application can be attained by the completion of these program-specific courses. However, the instilling of professional ethics relies on both stand-alone course teaching and “embedded teaching” across the curriculum, as it was found that integrative teaching across the curriculum is a more effective mode to teach ethical issues in engineering program when compared to a “standalone” course approach [5]. Specifically, the issue of professional ethics was taught in a compulsory subject named Society and Engineers; and related issues were also brought up in multiple courses. A co-curricular seminar given by ICAC was also included in the program to further strengthen students’ awareness of ethics in real world setting.

B. Procedures and Participants

Lecture(s) of which all students from the cohort of 2009 who enrolled on the Engineering Associate Degree program in a community college in Hong Kong were identified. The questionnaire was administered twice, one at the beginning of first semester of academic year 2009 (Time 1) as entrance measurement; and the other at the end of the second semester of academic year 2010 (Time 2) as exit measurement. Students were briefed by the lecturer and the project assistant prior to filling out the questionnaire and were highlighted that their participation was completely voluntary. A total of 94 students completed the questionnaire at Time 1 and Time 2. Among these participants, 81 were males and 13 were females. Participants’ age ranges from 19 to 22.

C. Instrument

In line with the abovementioned program-level learning outcomes, nine Likert-scale items were developed from various sources of professional bodies, which participants are asked to indicate their level of endorsement to each of the items, with “1” represents “Strongly Disagree,” while “5” represents “Strongly Agree.” The 9 items are clustered into two factors, namely “Understanding the importance of subject knowledge” which includes: a) Understanding of mathematical and physical fundamentals; b) Know the trends of various engineering development; c) Ability to distinguish different types of engineer in terms of job nature and possessed knowledge; d) Ability to apply computer technologies to solve problems related to academic or daily life; e) Ability to apply software packages (e.g., MATLAB, Pspice) to identify and assess the viability of different design options. The other factor “Awareness of importance of professional ethics” with 4 items which includes: a) “Engineers should maintain a working knowledge of current and impending legislation that will involve their work”; b) “Engineers should maintain a working knowledge of standards and codes of practice that will involve their work”; c) “Engineers should observe good practices with regard to aspects of sustainability in the conduct of their own work”; and d) “Engineers should be aware of their employers health and safety policy and practice as they relate to their personal circumstances and to their responsibility to others.” The reliability of the instrument was tested with the earlier cohort of engineering college students (cohort 2008), before the actual longitudinal administration as reported in the current study. The Cronbach’s alphas are 0.802 in “Understanding the importance of subject knowledge” and 0.897 in “Awareness of importance of professional ethics.”

III. Analysis and Results

Reliability test were conducted for the proposed two factors, namely “Understanding of subject knowledge” and “Awareness of professional ethics” at both times. Means and standard deviations by genders at Time 1 and Time 2 were calculated and shown in Table I. MANOVA Repeated Measures was then used to compare within group difference in these two factors simultaneously.

A. Reliability

The Cronbach’s alphas of “Understanding the importance of subject knowledge” are 0.776 at Time 1 and 0.803 at Time 2. The Cronbach’s alphas of “Awareness of importance of professional ethics” are 0.841 at Time 1 and 0.887 at Time 2. The values are considered satisfactorily high so that the items under the dimension measure the construct convergently. Therefore items under that dimension can be used to create composite score for measurement. The composite score is the
average score of the items in a dimension and is used in the following analysis.

**TABLE I. MEANS AND STANDARD DEVIATION FOR EACH DIMENSION BY TIMEPOINT AND GENDER (N=94)**

<table>
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<tr>
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<th>Understanding of Subject Knowledge Mean (SD)</th>
<th>Awareness of Professional Ethics Mean (SD)</th>
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<tr>
<td><strong>Time 1 Mean (SD)</strong></td>
<td></td>
<td></td>
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<tr>
<td>Male (N=81)</td>
<td>3.020 (0.071)</td>
<td>4.077 (0.060)</td>
</tr>
<tr>
<td>Female (N=13)</td>
<td>2.985 (0.178)</td>
<td>3.942 (0.149)</td>
</tr>
<tr>
<td>Overall (N=94)</td>
<td>3.002 (0.096)</td>
<td>4.010 (0.080)</td>
</tr>
<tr>
<td><strong>Time 2 Mean (SD)</strong></td>
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<td></td>
</tr>
<tr>
<td>Male (N=81)</td>
<td>3.417 (0.071)</td>
<td>4.154 (0.058)</td>
</tr>
<tr>
<td>Female (N=13)</td>
<td>3.646 (0.177)</td>
<td>4.365 (0.145)</td>
</tr>
<tr>
<td>Overall (N=94)</td>
<td>3.532 (0.095)</td>
<td>4.260 (0.078)</td>
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B. **Within (Time point) and Between (Gender) Group Comparison**

Repeated measure MANOVA was used to test the group effects across “Time point” and “Gender.” Results show that the interaction effect between Time point and Gender was found not significant (Wilks’ Lambda=0.952, p=0.104), and the main effects of Gender effect (Wilks’ Lambda=0.996, p=0.838) was also not significant. However, as hypothesized, the main effect of Time point was significant (Wilks’ Lambda=0.734, p<0.001). Univariate tests of the two dimensions for Time point effect suggest that the overall effect can be attributed to both dimensions, “Understanding the importance of subject knowledge” (F=29.198, p<0.001) and “Awareness of importance of professional ethics” (F=7.163, p=0.009).

**Figure 1.** Estimated marginal means of the dimensions by time point.

**Figure 2.** Estimated marginal means of the dimensions of male by time point.

**Figure 3.** Estimated marginal means of the dimensions of female by time point.

IV. **DISCUSSION AND CONCLUSION**

One of the objectives of the study is to track students’ development across a two-year associate degree engineering curriculum by using Likert-scale items specifically designed in alignment with the program learning outcomes. Results suggest that the items can reliability measure students’ self-perceived competence of the learning outcomes. Longitudinal comparison suggests that there is a substantial growth in students’ self-perceived competences in knowledge, application and ethics in relation to engineering.
The longitudinal result serves as a good source of evidence that the existing curriculum contributes positively in developing and preparing students either for vocation (associate engineer) or for further study. The trajectory of students’ experience in learning is particularly critical for associate degree program given its diverse students’ background and because of this, the effectiveness of a program (as well as teachers’ teaching) cannot be solely evaluated by students’ performance or articulation rate with absolute standards, but can be more appropriately reflected by some “value-addedness” measurement – the like of what has been used in the current study. In this light, less able students may have achieved and gained a lot through participating in the program though their final performance remain less competitive than some of their more able classmates. The current effort makes an initial step in understanding engineering students’ learning trajectory across different time points at associate degree level, and it will be meaningful, in future, to measure other relevant teaching and learning constructs so as to better inform practices and design of curriculum. Specifically, the result may support the use of an “embedded” mode of teaching professional ethics at associate degree level, given such effort is carefully orchestrated among academic staff teaching the program. The result also provides additional indicative information to refine the new engineering associate degree curriculum for the academic year 2012–13. For instance, in order to further strengthen the learning outcomes of “Understanding of subject knowledge,” our program team decided to double the credits on mathematics and physics subjects. Secondly, laboratory sessions/seminars were included to all engineering subjects in order to consolidate students’ ability to apply learnt theories and concepts. Besides, teaching method/style may be changed by offering sufficient support for completing challenging questions/assignments, pointing out students’ legitimate arguments from their answers before criticism, etc. to enhance students’ self-perceived competences.

For further studies, it would be useful for the program team to gather direct measurement evidences, such as academic performances of certain assessment tasks that are designed to measure specific program learning outcomes, in order to examine the convergence of self-reported and objective performances. Finally, it is meaningful for the research team to conduct in-depth interviews with graduates to help specifically identify the fine-grained curriculum and instructional aspects that students find effective and conducive to their learning and development of the program intended learning outcomes [6].

REFERENCES