STUDENT PROFICIENCY EXPECTATIONS AND SELF EVALUATION ON THE CDIO SYLLABUS TOPICS

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ABSTRACT

Students in Mechanical and Materials Engineering at Queen's University were surveyed on the CDIO Syllabus at the end of the Fall Term, half way through their final year in the program. They were asked to provide a 1 to 5 proficiency ranking on all of the 2.X through 4.X elements in the syllabus for both their own current ability and their perception of an appropriate expected proficiency level for a new graduate from an engineering program.

This data set is valuable as a snapshot of student perceptions and for comparison when the same cohort is surveyed subsequent to graduation and entry into the work force. It is particularly valuable as it covers 111 of 116 students enrolled in MECH 460, the fourth year Conceive and Design course that is a core requirement in the MME program.

The results indicate that the students are largely in accord with previously measured expectations of other students and professionals and points out the potential for including greater societal and business context as a program enhancement. The discrepancy between expectations and self assessment requires further examination.

KEYWORDS

CDIO Syllabus, Proficiencies, Self-Evaluation

INTRODUCTION

The CDIO Syllabus provides a list of knowledge, skills and attitudes that are of key importance in the practice of engineering. Combining this list with expectations for proficiency in each of the elements yields objectives for broad learning outcomes that can be applied in designing curricula for engineering programs. CDIO Standard 2 requires that stakeholders, typically through surveys of those stakeholders, validate these outcomes. In an educational setting the obvious direct stakeholders are the students (past and present), the teachers, and the future employers of the students. Although previous surveys [1] have included all three groups, there has been more focus on alumni, faculty, and industry leaders [2,3] than on current students. Student input is important first to be sure there is no disconnect between their objectives and those of the other stakeholders and second to recognize opportunities to differentiate programs and better engage students by including more emphasis on areas they find particularly important. This paper provides data on one group of current students and compares it to previous results.

METHODOLOGY

A survey based on the CDIO Syllabus was administered to a group of fourth year students nearing completion of the seventh semester in the eight semester program in Mechanical and Materials Engineering at Queen's University. All were enrolled in the capstone Conceive and Design course, and the survey was administered in class in November 2008 as part of an anonymous course evaluation. Although this required a paper survey form, it enabled a very high response rate (111 / 116).

Following Bankel et al. [1], this study used a questionnaire asking students to rank each of the second level items 2.X through 4.X from the CDIO Syllabus on the basis of a five point proficiency scale:

1. To have experienced or been exposed to
2. To be able to participate in and contribute to
3. To be able to understand and explain
4. To be skilled in the practice and implementation of
5. To be able to lead or innovate in

To provide context for each of the second level items, a list of all of the subordinate third level items (e.g. 2.1.X) was provided with each item. Item 3.3 Foreign Languages was clarified as "Using a language other than the primary language of instruction at your institution for technical communication" to allow for countries like Canada with more than one official language. Students were required to select a whole number as a response to each item by circling that number. A copy of the form is available electronically.

Students were asked first to complete a ranking for all items based on their own current level of proficiency, and then to complete an identical form for the level of proficiency that should be expected from a new engineering graduate. The forms were collected and the data tabulated in a spreadsheet for analysis and presentation.

Table 1
Student Survey Results: mean and standard deviations for student assessment of their own proficiency level and what proficiency level should be expected in a new graduate.

CDIO Syllabus Learning Objectives		Individual Assessment		Graduate Target	
		Mean	SD	Mean	SD
Personal & Professional Skills & Attributes	2.1 Engineering Reasoning	3.23	0.82	3.58	0.77
	2.2 Experimentation	2.89	0.90	3.30	0.83
	2.3 Systems Thinking	3.00	0.86	3.36	0.84
	2.4 Personal Attributes	3.65	0.80	3.65	0.77
	2.5 Professional Attributes	3.23	0.96	3.53	0.90
Communication	3.1 Teamwork	3.62	0.81	3.73	0.85
	3.2 Communication	3.40	0.77	3.72	0.79
	3.3 Foreign Languages	1.98	1.36	2.10	1.13
Operating Systems in the Enterprise and Social Context	4.1 Societal Context	2.56	0.89	3.06	0.99
	4.2 Business Context	2.60	0.88	2.99	0.93
	4.3 Conceiving	2.94	0.94	3.30	0.93
	4.4 Design Process	3.16	0.88	3.59	0.88
	4.5 Implementing	2.66	0.96	3.31	0.98

	4.6 Operating	2.63	1.03	3.10	0.97

RESULTS

The mean and standard deviation for each item on the survey was calculated from the tabulated data and is presented in Table 1. A copy of the spreadsheet of individual responses is available electronically.

Previous data was available for students and working professionals from three Swedish universities (Chalmers University of Technolgy, the Royal Institute of Technology (KTH), and Linköping University (LiU)) and from the Massachusetts Institute of Technology (MIT) in the USA [1]. This data was for the same proficiency scale on each of the items and is thus directly comparable to the current data.

Data sets are also available for alumni from Queen's University, Belfast [3] and from Queen's University at Kingston [2] (no affiliation), however these data sets result from a ranking of the relative importance of different items in the syllabus, rather than proficiency levels. Although these data have previously been found consistent with the data of Bankel et al. they are not directly comparable to the current data and have been omitted.

Figure 1 compares the expectations collected from Queen's students with the data previously collected for fourth year students at the other universities. Data was also collected for first year students in the previous study, however it was deemed unreliable due to the student's uncertainty on the meaning of some of the items in the syllabus. There is no data for MIT on item 3.3 Foreign Languages as it was not collected in a US environment. There is no data on item 4.3 Conceiving for the Swedish universities as the data were lost due to a software fault. The same data items are missing from the other figures.

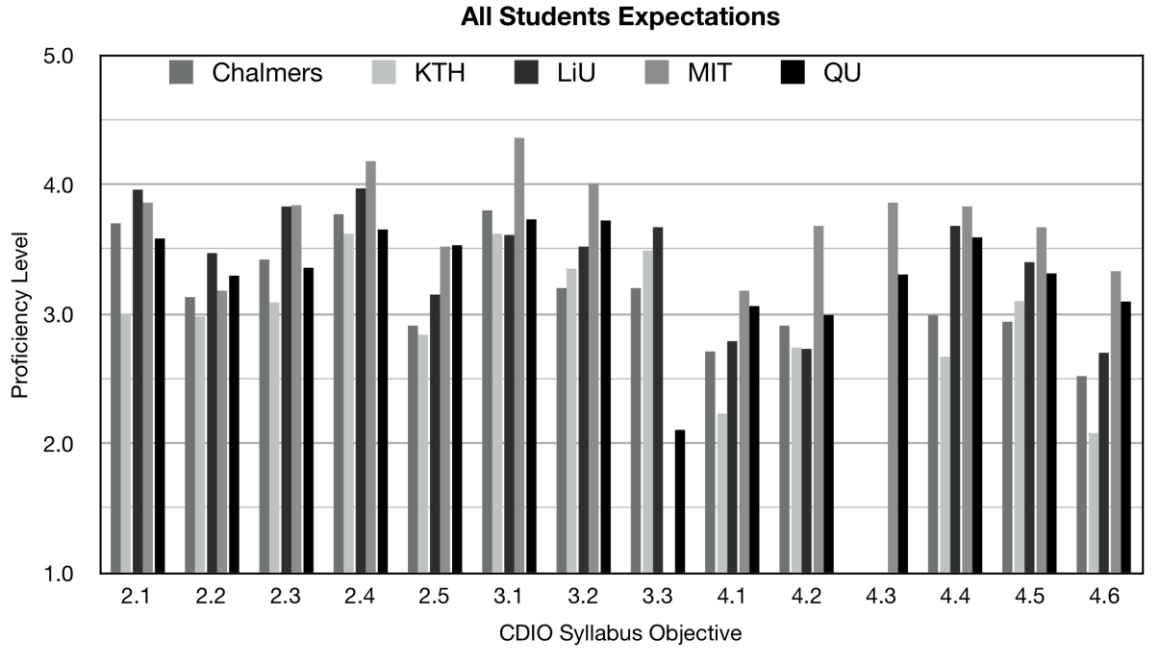

Figure 1. Comparison of fourth year student responses for expectations of proficiency for new graduates of an engineering program.

Figure 2 compares the expectations of Queen's students with the data previously collected for working professionals by the other universities, typically alumni, faculty and industrial contacts. Only aggregate data is presented here, however the previous study separated the

responses into faculty, industry, and alumni at 5 and 15 years post graduation, noting general consensus across groups.

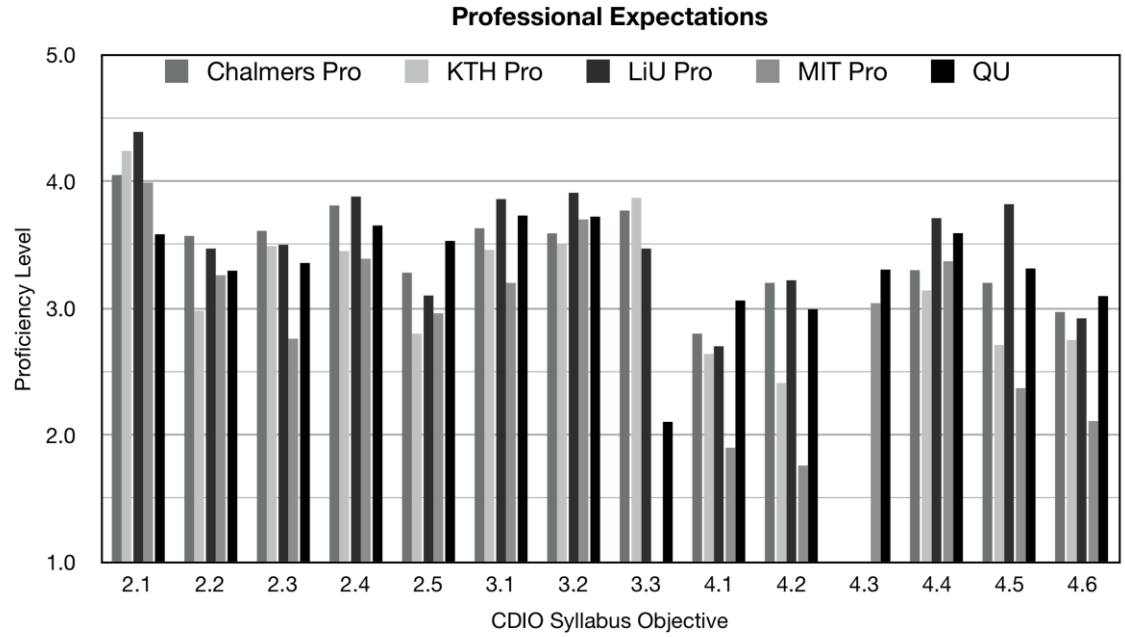

Figure 2. Comparison of working professional and Queen's fourth year student responses for expectations of proficiency for new graduates of an engineering program.

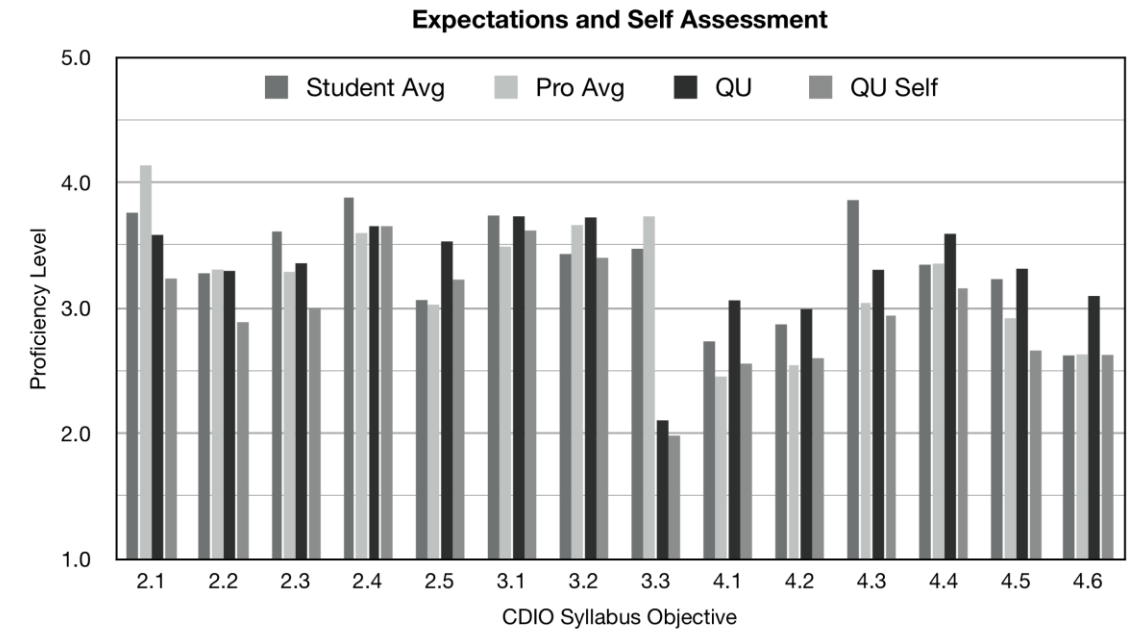

Figure 3. Comparison of expectations of students and professionals with expectations of Queen's students and Self Assessments of Queen's students.

Figure 3 Compares the averages of the expectations of students and working professionals with the current data for the expectations of Queen's students and for the students' self assessment of their own individual levels of proficiency on the various syllabus items.

Bankel et al. [1] did not provide standard deviations for their data set, so a direct comparison of significance cannot be made. It is however, possible to use the confidence in the means of the current data set as an indicator. With 111 samples, a typical mean of 2.97, and standard deviation of 0.92; a T test requires a difference of 0.25 between means for significance at 95% confidence. Thus differences of less than a quarter of a point should probably be ignored. In addition, the small sample sizes for fourth year students from KTH (8) and MIT (6) make comparisons problematic.

DISCUSSION

The first clear feature of all of this data is the degree to which all stake holders share similar opinions on the levels of proficiency expected in the various areas. This has been noted before [1,2,3] and validates the general direction of the CDIO initiative and syllabus. There are, however, some noteworthy differences on some items.

On item 2.1, Engineering Reasoning, the Queen's students are in close agreement with the other students and both are more than half a point below the professionals. This is especially troubling as it indicates many students accept level 3 (understand and explain) rather than expecting level 4 (skilled practice) in this fundamental skill.

On item 2.5, Professional Attributes, and 4.3 through 4.6 (C, D, I, and O) the Queen's students show generally higher expectations. That may be due to their experience of our program post CDIO adoption, which have added emphasis on professional practice issues within design project courses and feature the words Conceive, Design, Implement, and Operate throughout the program.

On item 3.3, there should be no surprise that in Canada, an officially bilingual country, there is some importance placed on communication in another language. Queen's is an English speaking university, so even unilingual students can expect a reasonable degree of success in an international environment where English is the common language. Thus, it is not unexpected that they place less emphasis on this item than both the students and professionals in a Swedish context. That the MIT survey did not include item 3.3 suggests the limited importance placed on other languages within the US curricula and professional environment.

On item 4.1, Societal Context, there was a notably higher ranking in the Queen's data, probably indicative of the general societal trend to more emphasis on social and environmental issues. It is also noteworthy that students in the previous survey ranked this item more than half a point above the professionals.

There is significant variation on item 4.2, Business Context, especially among the different groups of professionals, as note by Bankel et al. [1]. There is a clear indication that students expect to develop proficiency at working within a business context while some industrial respondents might prefer they get that context within their own corporate structure, particularly in the US aerospace industry from which most of the MIT responses were drawn.

In both 4.1 and 4.2 the student data from this survey and the previous one indicates a desire on the part of students to see their studies in a larger context, even though professionals see less of a requirement for developing that context while students are still in university. This represents an opportunity for programs to attract more students, particularly female students,

by further emphasizing the context of an engineering education as improving the state of the world, both economically and socially.

One troubling result of the survey is that students assessment of their own level of proficiency falls consistently below their expectations for a graduating student. The only exceptions are items 2.4, Personal Attributes, and 3.3, Foreign Languages. There are several possible explanations. It may be a matter of modesty, although the result on 2.4 suggests otherwise. It may be that these students were surveyed less than 7/8 of the way through their program and expect to develop further proficiencies before graduation. It may be that students are not reaching their full expectations within our program, or some combination of all three. This issue requires further examination, especially in light of the continuing financial pressure on engineering programs within Ontario, and globally.

REFERENCES

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Biographical Information

Rick Sellens is an Associate Professor in the Department of Mechanical and Materials Engineering at Queen's University. His research background is in Fluid Mechanics and more recently in Biomechanics and he has been actively involved in facilities development to support active learning, including the recently completed Integrated Learning Centre at Queen's

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On this page please **circle one whole number** beside each of the topics representing what you think is: **Your own current level of proficiency** Keep in mind that the levels 1 to 5 represent the range of proficiency levels one would expect to find in working professionals. Thus, it would be unusual for even highly skilled practitioners with long experience to have more than a few fives.		**Circle one level of proficiency for each topic**				
		1. To have experienced or been exposed to	**2. To be able to participate in and contribute to**	**3. To be able to understand and explain**	**4. To be skilled in the practice or implementation of**	**5. To be able to lead or innovate in**
Personal and Professional Skills and Attributes	**2.1 ENGINEERING REASONING AND PROBLEM SOLVING** *Problem Identification and Formulation* *Modeling* *Estimation and Qualitative Analysis* *Analysis With Uncertainty* *Solution and Recommendation*	**1**	**2**	**3**	**4**	**5**
	2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY *Hypothesis Formulation* *Survey of Print and Electronic Literature* *Experimental Inquiry* *Hypothesis Test, and Defense*	**1**	**2**	**3**	**4**	**5**
	2.3 SYSTEM THINKING *Thinking Holistically* *Emergence and Interactions in Systems* *Prioritization and Focus* *Trade-offs and Balance in Resolution*	**1**	**2**	**3**	**4**	**5**
	2.4 PERSONAL SKILLS AND ATTRIBUTES *Initiative and Willingness to Take Risks* *Perseverance and Flexibility* *Creative Thinking* *Critical Thinking* *Awareness of One's Personal Knowledge, Skills and Attitudes* *Curiosity and Lifelong Learning* *Time and Resource Management*	**1**	**2**	**3**	**4**	**5**
	2.5 PROFESSIONAL SKILLS AND ATTITUDES *Professional Ethics, Integrity, Responsibility and Accountability* *Professional Behavior* *Proactively Planning for One's Career* *Staying Current on World of Engineer*	**1**	**2**	**3**	**4**	**5**
Communication	**3.1 TEAMWORK** *Forming Effective Teams* *Team Operation* *Team Growth and Evolution* *Leadership* *Technical Teaming*	**1**	**2**	**3**	**4**	**5**
	3.2 COMMUNICATIONS *Communications Strategy* *Communications Structure* *Written Communication* *Electronic/Multimedia Communication* *Graphical Communication* *Oral Presentation and Inter-Personal Communications*	**1**	**2**	**3**	**4**	**5**
	3.2 COMMUNICATION IN A FOREIGN LANGUAGE *Using a language other than the primary language of instruction at your institution for technical communication*	**1**	**2**	**3**	**4**	**5**

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Operating Systems in the Enterprise and Social Context	**4.1 EXTERNAL AND SOCIETAL CONTEXT** *Roles and Responsibility of Engineers* *The Impact of Engineering on Society* *Society's Regulation of Engineering* *The Historical and Cultural Context* *Contemporary Issues and Values* *Developing a Global Perspective*	**1**	**2**	**3**	**4**	**5**
	4.2 ENTERPRISE AND BUSINESS CONTEXT *Appreciating Different Enterprise Cultures* *Enterprise Strategy, Goals, and Planning* *Technical Entrepreneurship* *Working Successfully in Organizations*	**1**	**2**	**3**	**4**	**5**
	4.3 CONCEIVING AND ENGINEERING SYSTEMS *Setting System Goals and Requirements* *Defining Function, Concept and Architecture* *Modeling of System and Insuring Goals Can Be Met* *Development Project Management*	**1**	**2**	**3**	**4**	**5**
	4.4 DESIGNING *The Design Process* *The Design Process Phasing and Approaches* *Utilization of Knowledge in Design* *Disciplinary Design* *Multidisciplinary Design* *Multi-Objective Design (DFX)*	**1**	**2**	**3**	**4**	**5**
	4.5 IMPLEMENTING *Designing the Implementation Process* *Hardware Manufacturing Process* *Software Implementing Process* *Hardware Software Integration* *Test, Verification, Validation, and Certification* *Implementation Management*	**1**	**2**	**3**	**4**	**5**
	4.6 OPERATING *Designing and Optimizing Operations* *Training and Operations* *Supporting the System Lifecycle* *System Improvement and Evolution* *Disposal and Life-End Issues* *Operations Management*	**1**	**2**	**3**	**4**	**5**

On this page please **circle one whole number** beside each of the topics representing what you think is: **The level of proficiency a new engineering graduate should have** Keep in mind that the levels 1 to 5 represent the range of proficiency levels one would expect to find in working professionals. Thus, it would be unusual for even highly skilled practitioners with long experience to have more than a few fives.		**Circle one level of proficiency for each topic**				
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	SD	Average	m No.	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu
INDIVIDUAL ASSESMENT																																	
Personal & Professional Skills & Attributes	**0.82**	**3.23**	**2.1**	3	3	4	3	3	4	3	4	3	4	4	2	3	4	3	3	3	4	4	3	3	4	4	2	4	2	3	4	2	4
	0.90	**2.89**	**2.2**	4	2	1	4	3	3	3	2	3	3	5	2	3	3	1	3	3	3	3	4	3	4	4	1	4	3	2	4	3	3
	0.86	**3.00**	**2.3**	3	4	3	3	2	4	3	4	3	4	3	3	2	3	4	4	3	3	3	3	3	4	2	2	3	2	4	4	3	3
	0.80	**3.65**	**2.4**	4	3	5	4	3	4	4	3	4	5	4	3	4	4	5	3	3	4	4	3	4	5	3	3	5	2	3	5	3	4
	0.96	**3.23**	**2.5**	3	3	3	4	1	4	4	4	2	4	4	3	3	3	3	4	4	3	2	4	4	4	3	3	5	3	3	3	4	3
Communcation	**0.81**	**3.62**	**3.1**	4	3	4	5	4	4	4	3	3	3	4	2	3	3	4	4	3	4	2	4	4	5	4	2	4	3	2	4	4	5
	0.77	**3.40**	**3.2**	4	3	4	4	2	4	4	4	3	4	3	2	2	2	4	3	2	3	4	4	4	4	3	2	5	3	2	3	4	4
	1.36	**1.98**	**3.3**	1	4	5	1	1	4	1	1	1	1	3	1	1	1	1	1	1	5	1	5	4	1	1	1	1	1	1	2	1	1
Operating Systems in the Enterprise and Social Context	**0.89**	**2.56**	**4.1**	4	3	4	3	1	1	2	3	2	2	3	2	2	1	3	2	2	2	4	3	4	4	5	3	3	3	2	2	2	3
	0.88	**2.60**	**4.2**	3	1	3	3	1	1	2	2	3	2	4	2	4	1	4	3	1	3	4	3	3	4	3	3	3	1	3	2	2	2
	0.94	**2.94**	**4.3**	3	3	3	4	0	3	3	3	3	4	4	3	3	2	3	3	2	3	4	3	3	3	5	2	4	2	3	3	2	4
	0.88	**3.16**	**4.4**	3	3	3	4	2	4	3	4	4	5	5	3	3	2	5	3	1	3	3	4	3	4	3	2	3	4	2	4	3	3
	0.96	**2.66**	**4.5**	3	2	4	3	2	3	3	2	3	3	4	3	3	2	3	2	1	3	2	4	3	3	4	1	3	3	2	4	1	3
	1.03	**2.63**	**4.6**	4	2	4	3	4	3	2	2	3	4	4	3	3	1	4	3	1	4	4	3	3	4	3	1	4	1	2	3	1	4
EW GRADUATE EXPECTATIO																																	
Personal & Professional Skills & Attributes	**0.77**	**3.58**	**2.1**	3	4	3	3	2	4	5	3	4	4	5	4	3	3	4	4	4	4	4	3	5	3	4	3	4	3	3	4	3	4
	0.83	**3.30**	**2.6**	3	4	3	3	2	2	5	2	3	4	4	4	3	3	5	4	3	4	5	3	5	4	4	3	4	3	2	3	3	3
	0.84	**3.36**	**2.7**	3	3	2	3	2	3	5	3	3	4	4	4	2	2	4	4	3	4	4	4	5	3	3	3	4	3	3	3	2	3
	0.77	**3.65**	**2.8**	3	4	3	3	4	4	4	4	4	4	5	4	4	3	4	3	4	3	4	3	5	4	2	3	4	4	4	4	3	3
	0.90	**3.53**	**2.9**	3	4	3	3	4	4	4	4	3	4	5	3	2	3	5	4	4	3	3	4	5	4	3	3	4	4	3	3	2	3
Communcation	**0.85**	**3.73**	**3.1**	3	4	3	3	4	4	4	3	3	4	4	3	3	3	5	4	4	4	5	4	5	4	4	3	4	4	3	4	2	4
	0.79	**3.72**	**3.2**	3	4	3	3	4	4	4	4	3	4	5	4	2	2	4	4	4	3	4	4	5	4	3	3	4	3	4	4	3	4
	1.13	**2.10**	**3.3**	3	4	2	3	3	1	2	1	2	2	4	2	1	1	1	3	3	4	1	4	3	2	3	3	1	1	1	3	3	1
Operating Systems in the Enterprise and Social Context	**0.99**	**3.06**	**4.1**	3	3	3	3	3	1	4	3	4	3	4	3	4	1	4	2	3	4	4	3	4	4	2	3	4	3	3	4	2	3
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	0.93	**3.30**	**4.3**	3	3	4	3	3	2	5	3	3	4	5	5	3	3	5	3	3	3	3	3	5	3	4	3	4	3	3	4	3	4
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	0.97	**3.10**	**4.6**	3	3	4	3	3	2	4	2	3	3	4	4	3	3	4	4	3	4	2	4	5	3	3	3	4	3	2	4	1	4

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DIO Syllabus Learning Objective		Individual Assessmen		Graduate Target	
		Mean	SD	Mean	SD
Personal & Professional Skills & Attributes	2.1 Engineering Reasoning	3.23	0.82	3.58	0.77
	2.2 Experimentation	2.89	0.90	3.30	0.83
	2.3 Systems Thinking	3.00	0.86	3.36	0.84
	2.4 Personal Attributes	3.65	0.80	3.65	0.77
	2.5 Professional Attributes	3.23	0.96	3.53	0.90
Communicati on	3.1 Teamwork	3.62	0.81	3.73	0.85
	3.2 Communication	3.40	0.77	3.72	0.79
	3.3 Foreign Languages	1.98	1.36	2.10	1.13
Operating Systems in the Enterprise and Social Context	4.1 Societal Context	2.56	0.89	3.06	0.99
	4.2 Business Context	2.60	0.88	2.99	0.93
	4.3 Conceiving	2.94	0.94	3.30	0.93
	4.4 Design Process	3.16	0.88	3.59	0.88
	4.5 Implementing	2.66	0.96	3.31	0.98
	4.6 Operating	2.63	1.03	3.10	0.97