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STUDENT PERCEPTION OF NON-TECHNICAL COMPETENCIES DEVELOPED THROUGH A TYPICAL CONSTRUCTION MANAGEMENT COURSE

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Abstract: To respond to the need for educating well-rounded engineers, a group of international researchers have formed the Conceive-Design-Implement-Operate (CDIO) initiative for engineering education. The goal of the CDIO initiative is to provide post-secondary engineering educational institutions with a framework for their undergraduate programs that incorporates 104 technical, personal, professional and interpersonal competencies that are desired of a well-rounded engineering graduate. The intention is that through various courses in a program, engineering students should gain proficiency in CDIO competencies. This study explores which areas of the CDIO syllabus are addressed in a typical Construction/Project Management course offered in an accredited Canadian Civil Engineering undergraduate program. This paper focuses on the perception of students as one of the stakeholders in post-secondary education. A questionnaire was developed based on the CDIO list of engineering competencies. Students taking a Construction/Project Management course were asked to identify the competencies that, to their perception, are addressed in the course. They were also asked to self-assess their proficiency level on each competency. The questionnaire was administered twice, once at the beginning, and once at the end of the course. Descriptive statistics are used to portray student perceptions on which competencies were captured by the course. Inferential statistical techniques such as McNemar's test and paired samples t-tests were used to study the difference between the perceptions at the beginning and the end of the course. While students' self-assessed proficiency increased for over half of. the competencies, it was observed that students do not have an accurate understanding of their proficiency level and the competencies addressed by the course. The nature of changes in student perceptions of their proficiencies in CDIO competencies, as well as the potential impact of Construction/Project Management courses in developing engineering competencies in a Civil Engineering program will be further discussed in the paper.

1 INTRODUCTION

Rapid advances in scientific and technical knowledge since the 1950's have shifted engineering education from engineering practice towards engineering science (Dym et al. 2005, Nair 1997). Thus, graduates from engineering programs are reportedly deemed to have strong technical skills, but do not posses the non-technical skills desired for practice (Bowman and Farr 2000, Banios 1991, Liebman 1989, Bakos 1997). In response to the disconnect between education and practice, a group of international researchers and educators formed the worldwide Conceive-Design-Implement-Operate (CDIO) Initiative. The goal of the initiative is to provide post-secondary engineering educational institutions with a framework for their undergraduate programs that addresses the disconnect (Crawley et al. 2011). With input from practitioners,

alumni, and educators, a syllabus was developed that addressed the desired attributes of an engineering graduate.

In civil engineering education, courses typically focus on imparting knowledge and developing technical skills. Project and construction management courses are one of the few courses offered in the civil engineering curriculum to address the non-technical skills desired in practice, which highlights the value of these courses in civil engineering education. This study aims to understand the extent to which a typical project/construction management course contributes to the development of non-technical skills through student perceptions of the competencies addressed by the course, and their self-assessed proficiency levels for those competencies. While the instructor's intention for the course is clear, student perceptions are important to consider. Studies have found that when student perceptions are not aligned with reality, it can result in lower levels of engagement and have negative impacts on performance (Bordia et al. 2008). As such, student perceptions will also be compared to the instructor's intention for the course to gauge how aware students are of the course intention and their expected proficiency levels. The results of this study will provide insights into the types of changes the instructor could implement to assist students in developing the competencies expected by industry.

2 METHODOLOGY

To achieve an understanding of student perceptions of the course and their self-assessed proficiency, a survey was administered electronically, once at the beginning (pre) and once at the end (post) of the semester. The same survey was used to record the instructor's intention for the course and expected proficiency levels of students by the end of the course. Ethics approval was granted for this project by the University of Calgary Conjoint Faculties Research Ethics Board.

2.1 Course Content

The course in this study is a typical Project/Construction Management course. Material covered in the course includes the construction project lifecycle from preliminary estimating, to bidding and tendering, managing the construction site, and closing. In-class exercises are expanded upon in assignments that include creating a project estimate, and optimizing site layouts. A group project required students to conduct a site visit, define the problem, engage stakeholders, define a solution, perform a cost estimate, produce a technical report, and present their project in front of the class. The class was composed of 86 students in their third or fourth year of undergraduate civil engineering studies.

2.2 Survey Tool and Administration

A survey based on CDIO Syllabus v2.0 (Crawley et al. 2011) was created. The four sections of the syllabus are: Section 1. *Disciplinary Knowledge and Reasoning*, Section 2. *Personal and Professional Skills and Attributes,* Section 3. *Interpersonal Skills: Teamwork and Communication,* and Section 4. *Conceiving, Designing, Implementing, and Operating Systems in the Enterprise and Societal Context*. Section 1 of the syllabus addresses the technical knowledge in civil engineering, whereas sections 2, 3, and 4 represent the non-technical skills (such as teamwork, communication, innovation, etc.) that are desired of engineering graduates in practice. Figure 1 lists the competencies identified by the instructor as being addressed by the course. These competencies are drawn from sections 2, 3, and 4. Section 1 competencies are excluded because it represents the technical knowledge in civil engineering, whereas this study focuses on the non-technical competencies represented by the other three sections. Instructions included in the survey tool asked students to:

1. Identify competencies they think will be/were addressed by the course.
2. Self-assess their proficiency for each competency on a scale of 1 to 5, irrespective of whether they think it will be addressed in the course or not. The scale used is shown in Figure 1.

3 SURVEY RESULTS AND ANALYSIS

Data analysis is presented by the three CDIO syllabus sections being considered. For each section, students self-assessed competency proficiency level at the beginning (pre) and end (post) of the semester will be compared. Their proficiency level will also be compared to the instructor's expectation of proficiency which they should have achieved at the end of the course.

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 or implementation of
5 To be able to lead or innovate in

SECTION 2
PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES
ANALYTICAL REASONING AND PROBLEM SOLVING
2.1.1 Problem Identification and Formulation
2.1.2 Modeling
2.1.3 Estimation and Qualitative Analysis
2.1.4 Analysis with Uncertainty
2.1.5 Solution and Recommendation
EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY
2.2.1 Hypothesis Formulation
2.2.2 Survey of Print and Electronic Literature
2.2.3 Experimental Inquiry
2.2.4 Hypothesis, Test, and Defense
SYSTEM THINKING
2.3.1 Thinking Holistically
2.3.2 Emergence and Interactions in Systems
2.3.3 Prioritization and Focus
2.3.4 Trade-offs, Judgement and Balance in Resolution
ATTITUDES, THOUGHT AND LEARNING
2.4.1 Initiative and the Willingness to Make Decisions in the Face of Uncertainty
2.4.2 Perseverance, resourcefulness, flexibility, responsibility, and will and urgency to deliver
2.4.3 Creative thinking
2.4.4 Critical thinking
2.4.5 Self-awareness, Meta-cognition and Knowledge Integration
2.4.6 Lifelong Learning and Educating Others
2.4.7 Time and Resource Management

SECTION 3
INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION
TEAMWORK
3.1.1 Forming Effective Teams
3.1.2 Team Operation
3.1.4 Team Leadership
COMMUNICATIONS
3.2.5 Graphical Communication
3.2.6 Oral Presentation
COMMUNICATIONS IN A FOREIGN LANGUAGE
3.3.1 Communications in English

SECTION 4
CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – INNOVATION
ENTERPRISE AND BUSINESS CONTEXT
4.2.5 Engineering Project Finance and Economics
DESIGNING
4.4.3 Utilization of Knowledge in Design
OPERATING
4.6.1 Designing and Optimizing Sustainable and Safe Operations
LEADING ENGINEERING ENDEAVORS
4.7.1 Thinking Creatively and Imagining Possibilities
4.7.2 Defining the Solution
4.7.3 Creating New Solution Concepts
4.7.6 Exercising Project/Solution Judgement
4.7.7 Innovation – the conception, design and introduction of new goods and services

Figure 1: CDIO competencies identified by the instructor as being addressed by the course

3.1 Participant Demographics

Eighty-six (86) students were enrolled in the course. Depending on the competency being considered, the number of valid cases in the analyses was reduced to a minimum of seventy students.
Of the 86 students enrolled:

1. Sixty-two (72%) were in their fourth year of studies and 24 (28%) were in their third year of studies
2. Fifty-seven (66%) were male, 26 (30%) were female, and three (4%) did not respond

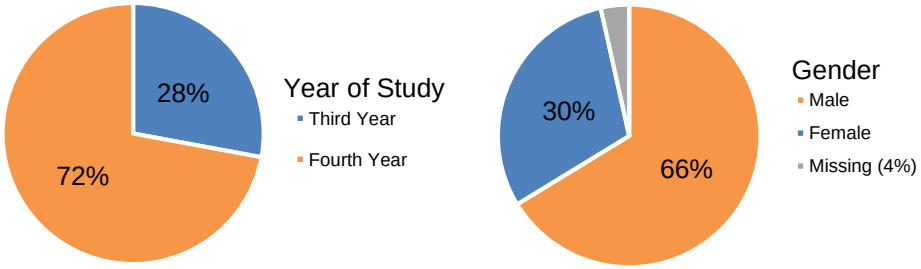

Figure 2: Student demographics by year of study and gender

3.2 Section 2 – Personal and Professional Skills and Attributes

3.2.1 Competencies Addressed by CM Course

In the *Personal and Professional Skills and Attributes* area, the instructor identified 20 out of the 27 competencies as being addressed in the course. These 20 competencies are shown below in Figure 3. At the beginning of the semester half of the students identified seven (7) competencies, and three quarters of the students identified two (2) competencies as being addressed by the course. At the end of the semester half of the students identified eight (8) competencies and three quarters of the students identified three (3) competencies as being addressed by the course.

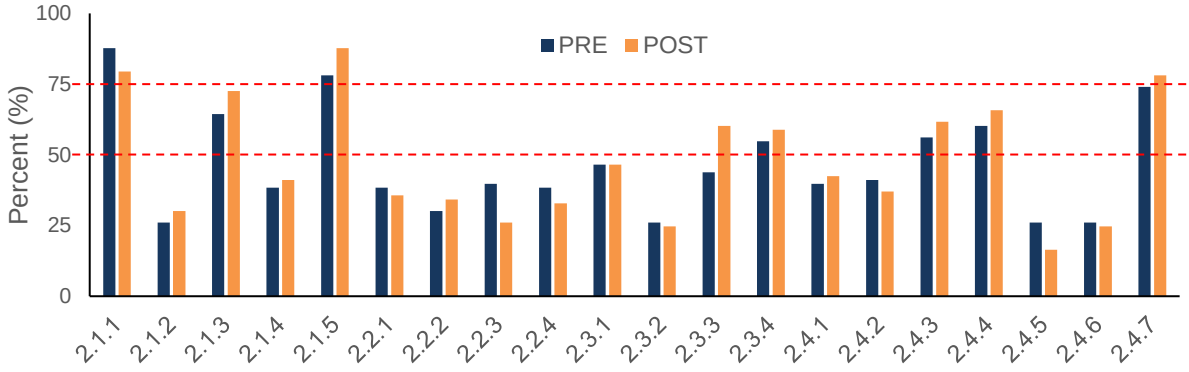

Figure 3: CDIO competencies (Section 2) addressed by the course

Student perceptions of the competencies addressed by the course changed from the beginning to the end of the semester for all competencies except 2.3.1 *Thinking Holistically*. Eight (8) out of the 20 competencies decreased and 11 competencies increased. McNemar's test identifies statistically significant changes for paired dichotomous data (Adedokun and Burgess, 2011). The results of McNemar's test (Table 1) indicates that competency 2.3.3 *Prioritization and Focus* increased the most, from 43.8% to 60.3% of the class, significant at $p<0.05$.

Table 1: Statistically significant changes in Section 2 competencies

Competency	Pre (%)	Post (%)	Change (%)	X^2 statistic	*p*
2.3.3 Prioritization and Focus	43.8	60.3	16.5	4.654	0.029

It is possible that the group project may have contributed to students selecting 2.1.1 *Problem Identification and Formulation* and 2.1.5 *Solution and Recommendation* because these two competencies were required to complete the project. The statistically significant increase in 2.3.3 *Prioritization and Focus* may also be related to the group project. Course material such as cost estimating may have contributed to students selecting 2.1.3 *Estimation and Qualitative Analysis*, and material such as site logistics, project funding, and cash flow may have contributed to students selecting 2.4.7 *Time and Resource Management*.

3.2.2 Competency Proficiency Level

In the *Personal and Professional Skills and Attributes* area, average student self-rated scores are all above 2. According to the survey scale, this corresponds to students "being able to participate in and contribute to" for each competency. As illustrated in Figure 4, ten (10) of the 20 competencies increased, and ten (10) decreased. A paired samples *t*-test indicates if there is a statistically significant change in mean scores for paired data. The paired samples *t*-test indicates that 2.1.2 *Modeling* increased from a mean score of 2.48

to 2.75, significant at $p<0.05$, and 2.1.3 *Estimation and Qualitative Analysis* increased from a mean score of 3.16 to 3.44, significant at $p<0.05$.
The group project and site layout exercise may have contributed to the increase in 2.1.2 *Modeling*, whereas the cost estimating material may have contributed to the increase in 2.1.3 *Estimation and Qualitative Analysis*.

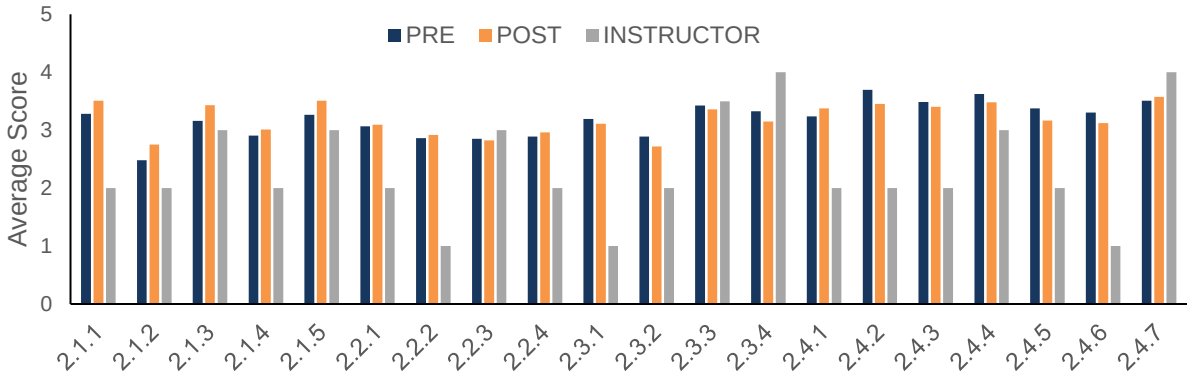

Figure 4: CDIO competencies (Section 2) proficiency levels

Table 2: Statistically significant changes in Section 2 proficiency levels

Competency	Pre	Post	Change	*t*-statistic	*p*
2.1.2 Modelling	2.48	2.75	0.27	-2.043	0.045
2.1.3 Estimation and Qualitative Analysis	3.16	3.44	0.28	-2.365	0.021

Comparing average post student self-rated scores to the instructor's expectation of scores reveals a large difference. Students rated themselves higher than the instructor's expectation in 16 of 20 competencies. The high scoring could be due to the competencies being developed in other courses/extracurricular activities or an inaccurate assessment of their proficiency. Differences of at least one point between the student and instructor were found for the following competencies:

- 2.1.1 Problem Identification and Formulation
- 2.1.4 Analysis with Uncertainty
- 2.2.1 Hypothesis Formulation
- 2.2.2 Survey of Print and Electronic Literature
- 2.3.1 Thinking Holistically
- 2.4.1 Initiative and Willingness to Make Decisions in the Face of Uncertainty
- 2.4.2 Perseverance, resourcefulness, flexibility, responsibility, and will and urgency to deliver
- 2.4.3 Creative Thinking
- 2.4.5 Self-awareness, Meta-cognition and Knowledge Integration
- 2.4.6 Lifelong Learning and Educating Others

For these competencies, student's average proficiency levels are at 3 or higher, indicating that students believe they can understand and explain these competencies. The four competencies in which the students rated themselves lower than the instructor's expectations are 2.2.3 *Experimental Inquiry*, 2.3.3 *Prioritization and Focus*, 2.3.4 *Trade-offs, Judgement and Balance in Resolution*, and 2.4.7 *Time and Resource Management*. However, none of these competencies have a difference of at least one point between student and instructor scores. A possible explanation for why students rated themselves lower than the instructor on these competencies is that they are more complex and require time and practice to develop to a high proficiency level.

3.3 Section 3 – Interpersonal Skills: Teamwork and Communication

3.3.1 Competencies Addressed by CM Course

In the *Interpersonal Skills: Teamwork and Communication* area, the instructor identified six (6) out of the 18 competencies as being addressed in the course. These six (6) competencies are shown below in Figure 5. At the beginning of the semester half of the students identified five (5) competencies and three quarters identified three (3) competencies as being addressed by the course. At the end of the semester half of the students identified all six (6) competencies and three quarters identified two (2) competencies as being addressed by the course.

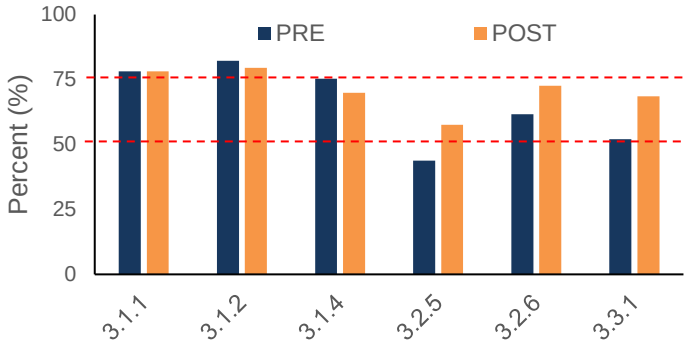

Figure 5: CDIO competencies (Section 3) addressed by the course

Student perceptions of the competencies addressed by the course changed from the beginning to the end of the semester for all competencies except 3.1.1 *Forming Effective Teams*. Two (2) out of the six (6) competencies decreased and three (3) competencies increased. McNemar's test for significance indicates that competency 3.3.1 *Communications in English* increased the most, from 52.1% to 68.5% of the class, significant at $p<0.05$.

Table 3: Statistically significant changes in Section 3 competencies

Competency	Pre (%)	Post (%)	Change (%)	X^2 statistic	*p*
3.3.1 Communications in English	52.1	68.5	16.4	4.654	0.029

The group project introduced at the beginning of the semester may have led to students selecting competencies relating to teamwork (3.1.1, 3.1.2, and 3.1.4). Project deliverables at the end of the semester, such as the report and presentation, may have contributed to the increase in competencies relating to graphical and oral presentation (3.2.5 and 3.2.6) and to the statistically significant increase in 3.3.1 *Communications in English*. A greater proportion of students identified competencies in this syllabus area compared to the *Personal and Professional Skills and Attributes* area. A potential explanation for this could be that students were able to directly relate these competencies to the group project which involved teamwork and communication.

3.3.2 Competency Proficiency Level

In the *Interpersonal Skills: Teamwork and Communication* area, average student self-assessment scores are all above 3. According to the survey scale, this corresponds to students being "able to understand and explain" the competency. As illustrated in Figure 6, three (3) of the six (6) competencies increased, and three (3) decreased. A paired samples *t*-test indicates that competency 3.2.6 *Oral Presentation* increased from a mean score of 2.99 to 3.30, significant at $p<0.05$. The group project may have contributed to the increase in proficiency level of 3.2.6 *Oral Presentation* because this competency was required for the presentation component of the project.

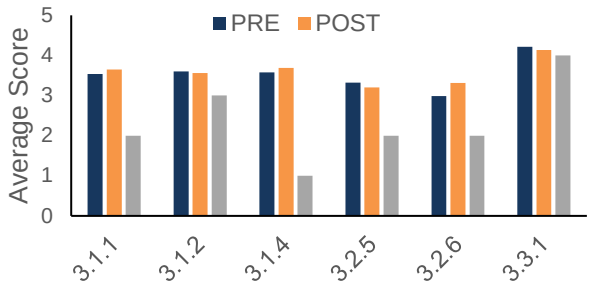

Figure 6: CDIO competencies (Section 3) proficiency levels

Table 4: Statistically significant changes in Section 3 proficiency levels

Competency	Pre	Post	Change	*t*-statistic	*p*
3.2.6 Oral Presentation	2.48	2.75	0.27	-2.221	0.029

Comparing average post student self-rated scores to the instructor's expectation of scores reveals a large difference. Students rated themselves higher than the instructor's expectation in all competencies. Differences of at least one point between the student and instructor were found for the following competencies:

3.1.1 Forming Effective Teams
3.1.4 Team Leadership
3.2.5 Graphical Communication
3.2.6 Oral Communication

For these competencies, student's average proficiency levels are at 3 or higher, indicating that students believe they can understand and explain these competencies. The competency with the least difference is 3.3.1 *Communications in English*, with a level of 4 corresponding to the students being skilled in the practice of this competency.

3.4 Section 4 – CDIO Systems in the Enterprise, Societal and Environmental Context

3.4.1 Competencies Addressed by CM Course

In the *CDIO Systems* area, the instructor identified eight (8) out of the 53 competencies as being addressed in the course. These eight (8) competencies are shown below in Figure 7. At the beginning of the semester half of the students identified four (4) competencies but no competencies were identified by over three quarters of the students as being addressed by the course. At the end of the semester half of the students identified four (4) competencies and three quarters of the students identified one (1) competency as being addressed by the course.

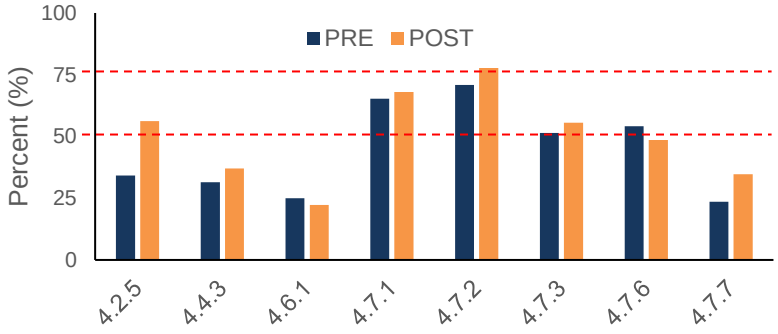

Figure 7: CDIO competencies (Section 4) addressed by the course

Student perceptions of the competencies addressed by the course changed from the beginning to the end of the semester for all competencies. Two (2) out of the eight (8) competencies decreased and six (6) competencies increased. McNemar's test (Table 5) for significance indicates that competency 4.2.5 *Engineering Project Finance and Economics* increased the most, from 34.2% to 56.2% of the class, significant at $p<0.05$.

Table 5: Statistically significant changes in Section 4 competencies

Competency	Pre (%)	Post (%)	Change (%)	X^2 statistic	*p*
4.2.5 Engineering Project Finance and Economics	34.2	56.2	22.0	5.921	0.014

The group project may have contributed to students selecting 4.7.2 *Defining the Solution* because this competency was required to complete the project. Course material such as project funding and cash flow may have contributed to students selecting 4.2.5 *Engineering Project Finance and Economics*. A lower proportion of students identified competencies in this syllabus area compared to the *Interpersonal Skills: Teamwork and Communication* area. A potential explanation could be that the meaning of competencies in this syllabus are more complex and difficult for students to relate to course content and assignments.

3.4.2 Competency Proficiency Level

In the *CDIO Systems* area, average student self-rated scores are all above 2. According to the survey scale, this corresponds to students "being able to participate in and contribute to" for each competency. As illustrated in Figure 8, six (6) of the eight (8) competencies increased, and two (2) decreased. A paired samples *t*-test indicates that 4.7.2 *Defining the Solution* increased from a mean score of 3.28 to 3.54, significant at $p<0.05$. The group project may have contributed to the increase in proficiency level of 4.7.2 *Defining the Solution* because this competency was a required process in the project.

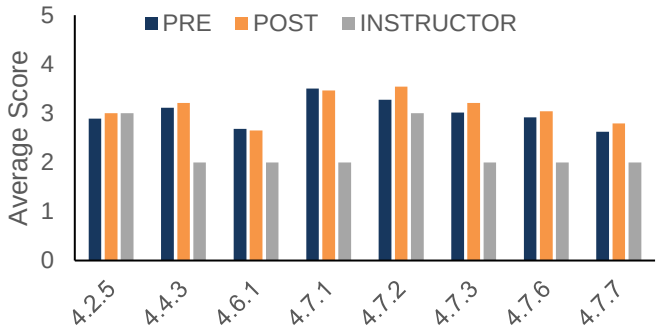

Figure 8. CDIO competencies (Section 4) proficiency levels

Table 6: Statistically significant changes in Section 4 proficiency levels

Competency	Pre	Post	Change	*t*-statistic	*p*
4.7.2 Defining the Solution	3.28	3.54	0.26	-2.031	0.046

Comparing average post student self-rated scores to the instructor's expectation of scores shows greater alignment for this syllabus area than the other two. Students rated themselves higher than the instructor's expectation in seven of eight competencies. The higher scoring could be due to the competencies being developed in other courses/extracurricular activities or an inaccurate assessment of their proficiency. Differences of at least one point between the student and instructor were found for the following competencies:

- 4.4.3 Utilization of Knowledge in Design
- 4.7.1 Thinking Creatively and Imagining Possibilities
- 4.7.3 Creating New Solution Concepts
- 4.7.6 Exercising Project/Solution Judgement

For these competencies, student's average proficiency levels are at 3 or higher, indicating that students believe they can understand and explain these competencies. The competency with the least difference is 4.2.5 *Engineering Project Finance and Economics*, with a level of 3 corresponding to the students being able to understand and explain this competency.

4 CONCLUSION

4.1 Summary and Discussion

The instructor identified a total of 34 competencies identified as being addressed by the course. At the beginning of the semester, half of the students identified 16 competencies and three quarters of students identified five (5) competences as being addressed by the course. At the end of the semester, half of the students identified 18 competencies and three quarters of students identified six (6) competences as being addressed by the course. Over the semester, average student perceptions changed with statistical significance towards the instructor's intent for three competencies: 2.3.3 *Prioritization and Focus*, 3.3.1 *Communications in English*, and 4.2.5 *Engineering Project Finance and Economics*. While student perceptions changed to better match the instructor's intention at the end of the semester, less than half of the students identified 16 of the 34 competencies. This indicates that students are not entirely aware of the competencies that the course is intended address. It is interesting to note that students were able to correctly identify competencies that relate directly to course content such as assignments, group projects and lecture topics. More complex competencies that are not explicitly addressed by the course content were not identified by as many students.

Self-rated proficiency levels were compared at the beginning and end of the semester for the same 34 competencies. From the beginning of the semester to the end of the semester 19 competencies increased and 15 decreased in proficiency levels. Only competencies that increased were statistically significant: 2.1.2 *Modelling*, 2.1.3 *Estimation and Qualitative Analysis*, 3.2.6 *Oral Presentation*, and 4.7.2 *Defining the Solution.* These changes could be partly explained by the contribution of the course; however, these scores are also impacted by other factors during the semester. Student post self-rated proficiency levels were also compared to the instructor's expectation at the end of the course. Students rated themselves higher than the professor on 30 out of 34 competencies. Of these 30 competencies, 18 competencies had a difference greater that one (1) point between the students and instructor. Of the four (4) competencies that students rated themselves lower than the instructor's expectation all had a difference of less than one (1) point. This indicates that either students have developed these competencies previously or that they are not aware of their true proficiency level and the difference between each interval in the self-evaluation scale.

4.2 Recommendations

Instructors can benefit from these results by being able to identify how aware students are of the course intent and the competencies they are meant to develop, as well their perception of their proficiency level for each competency. The results of this study indicate that students require more guidance and explanation of competencies and the different proficiency levels or that different methods of assessment may be required to properly capture student perceptions. This can be done by modifying course content and communication of the material to better address competencies that deviate too much from the instructor's intent. The end goal of these modifications is to improve student learning and development of the competencies identified by industry as being underdeveloped in engineering graduates. Further expansion of this study includes continued measurement for each new generation of students and enhancing the survey tool to collect demographic information such as internship experience.

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