Investigation on the applicability of engineering industry teamwork assessment methods for engineering education

Yi-Wei Ang & Albert Huynh

Supervisor: Professor Susan McCahan

Department of Mechanical and Industrial Engineering
University of Toronto

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Abstract

A study was conducted with students, instructors, and industry partners at the University of Toronto's Faculty of Applied Science and Engineering to understand each stakeholder's view on the evaluation of teamwork as a skill. Specifically, this study looks into if the teamwork qualities assessed in academia and the assessment methods used are authentic relative to industry expectations. The study finds that engineering academia needs to provide further opportunities for students to obtain feedback from both their peers and instructors, as honest and specific feedback is the best way for students to understand and work to improve on their weaknesses. Further, the study finds that similar to industry career development frameworks, engineering academia should develop a long-term framework to ensure that the development of teamwork skills is done throughout all four years of undergraduate education.

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1.0. Introduction

There are three key motivations for this thesis:

1. To understand what the industry's expectations are for new graduates in terms of their teamwork abilities.

2. To evaluate the effectiveness of current assessment methods in terms of their ability to prepare students for the industry's expectations of teamwork.

3. To understand if best practices in the assessment of teamwork skills can be extracted from the industry and applied to an engineering education setting.

The focus of this research will be based on the current course designs at the University of Toronto's Faculty of Applied Science and Engineering. University of Toronto Engineering students and instructors as well as several industry representatives will be the primary interview candidates for the purposes of this research.

2.0. Background

With the growing need for engineers to work in a multi-disciplinary setting, there has been an overall drive to increase engineering graduates' abilities to communicate and work in teams of various sizes. Engineering firms, university academia, and engineering accreditation bodies have all been encouraging the further development of teamwork and communication skills amongst engineering undergraduates. Even though many engineering undergraduate students were primarily drawn to their programs due to their expectations of rigorous science and mathematics, many students have since realized the importance of gaining "soft-skills" such as teamwork and communication for their future employment.

In 2008, Engineers Canada introduced a list of twelve core-engineering competencies that they expect from licensed professional engineers (*Engineers Canada*, 2012). At the same time, the Canadian Engineering Accreditation Board (CEAB), a body under Engineers Canada, introduced a set of twelve graduate attributes that mirror the core engineering competencies set forth by Engineers Canada. Institutions seeking reaccreditation were given until 2014 to demonstrate that their students comply with all of the graduate attributes (*Canadian Engineering Accreditation Board*, 2008). Many engineering institutions, including the University of Toronto, the University of British Columbia, and Queen's University, have formed task forces to reevaluate their current teaching and evaluation methods to ensure that their undergraduate programs adhere to the new CEAB requirements. The list of CEAB graduate attributes is as follows:

1. Knowledge base for engineering
2. Problem analysis
3. Investigation
4. Design
5. Use of engineering tools
6. Individual and team work
7. Communication skills
8. Professionalism
9. Impact on society and environment
10. Ethics and equity
11. Economics and project management
12. Lifelong learning

While graduate attributes "broadly define the required outcomes," institutions are expected to develop their own evaluation methods and metrics to measure their students' competencies in all twelve areas (*Ostafichuk*, 2012). Engineering programs are expected to distribute the evaluation of these competencies in the four years of a student's undergraduate education across multiple courses.

Of the list of twelve core engineering competencies, institutions often have more developed expertise in teaching and assessing some of these competencies compared to others. For instance, the competencies of *Design* and *Use of engineering tools* are often well taught and assessed in academic institutions; however, the assessment of other areas such as *Teamwork* may be less developed. As a result, many institutions have realigned their curriculum planning to address these weaknesses before their next CEAB accreditation review.

2.1. Definitions

A team is defined as "a group of individuals who see themselves and are seen by others as a social entity, which is interdependent because of the tasks performed as members of a group (*Guzzo*, 1986)." *Smith, K.*A from the University of Minnesota's Technological Leadership Institute has defined five key elements for a well-structured cooperative learning group: positive interdependence, face-to-face promotive interaction, individual accountability, teamwork skills, and group processing (*Smith*, 1995).

In the context of this investigation, teamwork considers both the process of working collaboratively in a team as well as the quality of the end deliverable that the team produces. This investigation will highlight various engineering programs at the University of Toronto's Faculty of Applied Science and Engineering. These engineering programs will be used as a point of reference for the proposed implementation of these assessment methods. The University of Toronto's engineering programs have defined three key outcomes for individual and teamwork (*Norval*, 2012). Students should demonstrate ability to:

1. Establish and monitor team organizational structure
2. Promote team effectiveness through individual action
3. Demonstrate success in a team-based project.

This paper will evaluate the various assessment methods available for teamwork in an accredited engineering institution. The assessment methods being considered will evaluate different options to assess a student's ability to:

1. Establish and use norms of practice (rules, roles, charters, agenda, etc.)
2. Apply effective teamwork techniques (communication, accountability)
3. Complete and present an end-deliverable in an engineering course as a team.

2.2. Literature Review

Existing literature will be used to understand various aspects of the teaching and assessment of teamwork in academia and in industry. Firstly, literature will be used to gain an understanding of how projects requiring teamwork are applied in technical academic programs. Secondly, literature on current evaluation methods for teamwork in academia will be assessed. Thirdly, current evaluation methods for teamwork in the industry will be showcased as a comparison. Fourthly, literature on students' perspectives on teamwork skills will be highlighted. Finally, literature will be used to identify ways to design and continuously improve engineering courses.

2.2.1. Current use of team projects in Engineering

In recent times, engineering institutions have begun to recognize the importance of introducing group design projects throughout the undergraduate engineering program. Many universities have created extensive hands-on first year engineering courses that allow students to learn the basics of engineering design. Research comparing different first-year design course methodologies illustrates that group projects involving real-world clients create the most learning about teamwork skills in comparison to a mechanical dissection or an analysis-driven textbook design method (*Bailey et al.*, 200*6*). It is also common for engineering institutions to introduce a fourth year capstone project in the undergraduate curriculum. These capstone projects are often "year-long, industry-based projects…aimed at preparing students for their professional careers (*Karunasekera & Bedse*, 2007)." Some institutions have even opened up opportunities for multidisciplinary teams of engineering students to complete a fourth year capstone project together (*Miller & Olds*, 1994).

While teaching methodologies and evaluation methods on engineering design and analysis have been well developed for first and final year courses, the same cannot be said for the

building of soft-skills such as teamwork. An evaluation by *Robert Lingard* indicated that "students seldom receive any specific training on how to function collaboratively" before they embark on group projects. As a result, many students develop "negative views about the value of teamwork" after working with dysfunctional teams (*Barkataki & Lingard*, 2011). Engineering programs often expect students to gain experience working in teams through informal settings during their undergraduate curriculum. The assumption that students will naturally gain teamwork skills without support is far from the reality. More often than not, one or two students are responsible for the bulk of a group's work (*Ko & Zou*, 2012). Research by *Swan et al.* has shown that even in fourth year Capstone courses, team members often had little experience working in a team-based environment, causing them to "retreat to a loose organization of individuals responsible for pieces of the solution (*Swan*, 1994)." Thus, literature suggests that engineering education, as a whole needs to place a stronger emphasis on developing teaching and evaluation methods for teamwork in throughout the entire engineering undergraduate curriculum.

2.2.2. Current evaluation methods for group projects in Engineering

Current engineering education practice is broad and highly variable with respect to the use of evaluation methods for group projects. Some notable base examples, however, are attribution tables, self-reflections, peer evaluations, and portfolios. The problem with these evaluation methods is that even with their pervasive implementation, both inherent and situation specific problems often exist in their reliability. For example, attribution-based assessment, one of most common classes of assessment tools in engineering academic group work, inherently tends towards self-serving biases which vary significantly across cultures and psychopathology (*Mezulis et. al,* 2004). Self-reflections, another common method, also often produce problems upon implementation, as the context of implementation is not adjusted to the needs of the project or student (*Guiffrida*, 2005). Portfolios as a tool can also lead to inauthentic and biased representations of student ability and can be seen as an additional strain by students if constructed as an "add-on" (*Arter & Spandel,* 1992).

Given that research in this field is constantly producing new variants on basic methods, it is difficult to highlight the efficacy of most modern tools. Examples of this are generally online in nature and include such tools as UCSD's anonymous peer review program, which utilizes a fixed-pie scheme to distribute ratings to teammates (Delson, 2012). In general, the literature

seems to suggest that implementation of effective team evaluation methods are highly dependent on the local environment and culture into which they are implemented.

2.2.3 Evaluation of teamwork in industry

The increasing requirement for a practicing engineer to work in a cross-disciplinary team in industry has motivated universities to encourage the development of teamwork skills in undergraduate education. This section aims to understand how practicing engineers are often evaluated in the industry and to understand if parallel methods can be backward integrated into the engineering curricula.

Most corporations of today have implemented extensive professional development plans for their employers that involve an annual performance appraisal. The results of these appraisals are usually an indicator of one's career growth, and often influence one's compensation and promotion schedule. Over time, different companies have adopted different performance appraisal methods. These methods include: the 360-degree appraisal, Management by Objectives (MBO), the Behaviour Anchored Rating System, and the Paired Comparison Ranking system (*Canfield*, 1997).

A 360-degree appraisal is a process where employees are evaluated and provided a performance review by their teammates and peers. Engineering firms such as the British Aerospace's Military Aircraft Division have implemented a 360-degree appraisal system to better evaluate one's ability to contribute to team's overall cause (*Bradford*, 1995). Human Resource professionals such as *Greguras et al.* believe that the multi-source nature of a 360-review provides more accurate method of measuring and evaluating one's ability to contribute to team-based work (*Greguras*, 2001). At the same time, experts have commented that a 360-degree review "can pose problems when the raters are competitors for rewards or promotions (*Lepsinger & Anntoinette*, 1997)" In a university setting, a 360-degree appraisal is most similar to a peer-evaluation in a group project. One primary difference between an academic peer-evaluation and a 360-degree appraisal is the fact that workplace compensation is often a zero-sum game – only a certain number of people are able to achieve a significant raise or a promotion (*Scholl*, 2006). For example, Microsoft, a top software-engineering firm implements both a 360-degree appraisal system and a stack-ranking system for each team. A stack ranking system gives a fixed percentage of team members great, mediocre, and bad reviews (*Allen*,

2012). These reviews in turn influence one's promotion schedule, annual bonus, and stock awards. In contrast, peer-evaluations in academic course work are often used to reduce the grade for members who have not contributed as significantly, but will not significantly increase the grade for group members who have contributed more. Thus, the implementation of a peer-review system in an academic setting may be more accurate and less contentious than the industry's implementation of the 360-degree performance appraisal.

A common alternative to the 360-degree performance appraisal is the Management By Objectives (MBO) scale. With an MBO performance appraisal system, corporate objectives are set by managers, and are "cascaded down through each management level (*Antoni*, 2005)." Employees meet with their respective supervisors to set and agree on their goals for a specific time period. After goals have been set, employees are measured based on how well they achieved their personal goals, as well as their overall contributions to the goals of their team. By aligning employees' personal goals with a team's overall goals, employees are motivated to work collaboratively with each other to drive success for their teams. An objective-based evaluation method is not often used in academia. Looking specifically at the evaluation of teamwork skills in academia, instructors rarely assess students' abilities to set personal and team objectives. Instead, "teamwork is predominantly a measure of the end product, rather than the process by which the product was achieved (*Riebe*, 2010)."

2.2.4. Student perspective on value of teamwork

The student perspective on teamwork within engineering is usually a negative one. Students often don't see the value in teamwork theory and question the methods used to promote it (*Whitman & Missingham*, 2009). In particular, the idea of feedback on teamwork within group projects is often underplayed and in some cases, missing. *Artemeva and Logie* show that if given sufficient time and resources to develop their skills, students become better evaluators and more engaged with teamwork activities (*Artemeva & Logie*, 2000), but often that time is not made available.

Due to a lack of effective training, student teams often fail to function effectively (*Barkataki & Lingard*, 2011), which subsequently causes a detriment to the learning experience (*Swan et. al.,* 1994). The focus on end deliverables over group process (*Jacobson et. al.*, 2006) is also often detrimental to the focus of students to learn teamwork characteristics as they tend

towards aspects that are rewarded in grades as described by expectancy theory (*Polczynski & Shirland*, 1977)

2.2.5. Lifecycle of teaching and assessment methods

Over time, curriculum and courses need to be modified based on pedagogical best practices and changing industry requirements. Literature shows that while many theoretical approaches to curriculum design and modifications have been explored, there "is very little written on a structured process to design curriculum (*Corbett*, 2012)." Recent research in the engineering education domain has illustrated the benefits of applying the engineering design process to the design of engineering course curriculum. The primary benefit of the engineering design process is its emphasis on refining the engineering curriculum in an iterative manner (*Corbett,* 2012).

The CEAB mandates that its member programs must continuously assess the outcomes of their programs and ensure that the results are used for the program's future development and improvement (*Canadian Engineering Accreditation Board*, 2012). Currently, many universities place a large emphasis on the design, development, and implementation of engineering programs. However, not many institutions have implemented strong feedback mechanisms to understand the key successes and failures of the curriculum they have introduced (*McGourty et al.*, 1998). By obtaining feedback from various stakeholders (instructors, students, teaching assistants, and industry partners), universities can make better decisions in the future for teaching approaches and assessment methods.

The application of continuous improvement and iterative design methods is especially important for the design of curriculum and assessment methods in less researched areas such as teamwork. Engineering institutions should ensure that a feedback loop is established for future curriculum improvement and redesign efforts.

3.0. Methodology

The primary investigation for this project is qualitative in nature. One-on-one interviews with students, course instructors, and industry professionals were conducted to better understand the effectiveness of current assessment methods, and what gaps currently exist. With approval from interview participants, the interviewers recorded each interview for further analysis. This project aims to use a commonly known engineering education conceptual framework, the *Situated Learning* Theory, as a basis for understanding results from interviews. Upon completing interviews, recordings of the interviews were codified based on the major themes that arose. A frequency analysis on the common themes provided quantitative data for the project, from which conclusions were drawn.

3.1. Grounding analysis on Situated Learning Theory

The analysis of the data points gathered was grounded on *Situated Learning Theory*, a well-known framework for research on the design of assessments. Marilla Svinicki, a leading expert in the field of engineering education highlights a few key points regarding the situated learning theory in *A Guidebook on Conceptual Frameworks for Research in Engineering Education* (*Svinicki*, 2010). Situated learning theory explains how learners often relate concepts to a specific context. In a different application context, "some of the stimuli associated with the learning" may be removed. As a result, the theory encourages "learning be done in a context as close to the eventual application context as possible." Svinicki further explains how teaching and assessing learners in an *authentic* environment provides more motivation for the learners, who can relate "what they are learning and their long range goals."

Based on the *Situated Learning Framework*, this paper aims to answer the following question – Are teamwork assessment methods used in academia today *authentic* in the context of the professional engineering industry? More specifically, this paper aims to understand: 1) if the *qualities* assessed in academia today are authentic in the context of the industry and 2) if the *assessment methods* used in academia today are authentic in the context of the assessment methods used in the industry.

3.1.1. Authenticity of qualities assessed in academia

By applying the *Situated Learning Framework*, this paper aims to understand if the qualities assessed in engineering coursework today are authentic to the qualities assessed in the real world. Three key steps will be used to gain further understanding of this topic. Firstly, the investigation will identify what the industry's expectations are for new graduates with regards to teamwork. Secondly, analysis will be done to compare students' perception of industry expectations with actual expectations from the industry. Looking into the learner's perception of industry expectations for new graduates in the area of teamwork provides insight to the learner's motivation for performing academic work related to the development of their teamwork abilities. Finally, comparing academia's perception of industry expectations in teamwork for new graduates with the actual expectations themselves will highlight results on the *authenticity* of academia's teachings in teamwork compared to real-world expectations.

3.1.2. Authenticity of assessment methods used in academia

The *Situated Learning Framework* emphasizes the importance of maintaining an authentic assessment environment to ensure that learners are able to apply the knowledge learnt to a practical application. This paper aims to understand if assessment methods used in engineering academia are reflective of methods used in the industry. If there are differences in the assessment methods used in industry compared to engineering academia, this paper will attempt to understand the impact of this difference to the underlying authenticity of the context in which the learner is being assessed.

The assessment of teamwork in academia and in industry will be evaluated from five key perspectives. Firstly, a baseline understanding of how teamwork is defined in for evaluation purposes in industry and in academia needs to be established. Secondly, a comparison will be done on the teamwork assessment methods between academia and the industry. Thirdly, the paper will understand the teamwork assessment and development frameworks used in academia and the industry. Fourthly, an analysis on the impact of the frequency of evaluation between academia and the industry will be performed. Finally, the paper will investigate the differences in the type and quality of feedback provided to the learner in academia and in industry.

By understanding the different aspects of teamwork assessment, this paper will be able to better understand the authenticity of assessment methods used in academia.

3.2. Research Participants

This section explains in further details the criteria that was used to screen and select research participants for the investigation. Participants for the research project were chosen based on their areas of expertise, and only participated on a voluntary manner. This project utilizes a *purposive sampling* technique to recruit and perform interviews. Purposive sampling is used when researchers "know the characteristics of the target population and then seeks out specific individuals who have those characteristics to include in the sample (*Hibberts et al.,* 2012) For the purposes of this investigation, a target sample size of three to five interview participants per interview group was selected to provide feedback on teamwork evaluation methods. Although this does not represent a comprehensive view of the subject matter, it serves as a starting point for further investigation and a directional indicator for future work.

3.2.1. Industry Professionals

Graduates from undergraduate engineering programs can be found in various industries. Results from the Engineering Society Census in 2012 of 1143 undergraduate engineering students indicate that the top eight industries that students would like to pursue a career in (in rank order) are: energy, consulting, business, information technology, public sector, healthcare, manufacturing, and oil & gas (*University of Toronto Engineering Society, 2012*). As a result, not only did this project consider teamwork in core engineering industries, it also aimed to seek input from a diverse set of industries such as consulting, business, and information technology. Industry professionals were screened based on a few key criteria. Specifically, industry professionals interviewed must have had at least ten years of professional experience, and must currently be a people-manager at their most recent role. In total, four industry representatives were used for this study including members of property management, mutual funds, information technology, and banking companies.

3.2.2. Course Instructors

Over the years, instructors of engineering courses have highlighted the importance of including group work in their courses. Most notably, students are required to perform group work in first year design courses and final year capstone courses. Interviews with course

instructors provided valuable insight about the current assessment methods used for teamwork and instructors' opinions on the effectiveness of these methods. Instructors were screened for one key criterion – they must be an instructor for an undergraduate engineering course involving a group project. Four course instructors associated with courses in four departments were interviewed.

3.2.3. Undergraduate Engineering Students

Undergraduate students in engineering programs are often expected to perform group work in their courses. For the purposes of this project, students in their first and final year of studies in various departments of engineering were interviewed. The deliberate selection of first and final year students provided an opportunity to identify any contrasting opinions about assessment methods on teamwork between students of the two years. Students from different departments were recruited to mitigate differences in teaching and evaluation between disciplines of study. In total, three first year and four final year students were used in the study.

3.3. Interview Design

The primary goal for the design of the interview questions was to ensure the consistency of questioning between all subjects. Sets of three to four primary questions were created for students, course instructors, and industry professionals respectively. The questions given across the three interview groups were designed with consistent wording and ordering. Keeping interview questions consistent across and within interview groups provides a more reliable foundation for comparative analysis within and between interview groups.

The interview questions given were designed to be open-ended in nature. *The Handbook of Survey Methodology for the Social Sciences* highlights that "open-ended question allow more flexibility, and enable the respondent to think through and provide a more detailed answer (*Gideon*, 2012)." Open-ended questions were chosen for this project to allow participants to detail their answers by drawing from their personal experience in academia or from industry. Each question was designed to provide interviewees with an appropriate scope for their answers. No time limit was provided for the answering of questions to allow for maximum output. Interview participants were also given the opportunity to provide any further thoughts and comments about the topic of discussion after the primary questions had been answered.

The following section highlights the primary questions asked to interview subjects in each interview group:

Questions for Engineering Course Instructors

1. What are the assessment methods used today in your courses for group work? Which courses do these assessments pertain to?

2. In your opinion, what are the core skills in the teamwork that the engineering industry expects from an engineering graduate?

3. Do you find the teamwork evaluation processes you use today conducive to developing those skills?

Questions for Engineering Undergraduate Students

1. What are the assessment methods you have seen used for group work? Which courses have you seen group work assessed?

2. In your opinion, what are the core skills in teamwork that the engineering industry expects from an engineering graduate?

3. Do you find the teamwork evaluation processes conducive to your learning of those core skills?

Questions for Industry Professionals

1. What assessment methods do you and/or your company have to assess your employee's ability to perform group work?
    a. Do you personally employ different assessment methods beyond that used in your company?

2. Do you find the teamwork evaluation processes conducive to developing your employee's abilities to perform group work?

3. In your opinion, what are the core skills in teamwork that the engineering industry expects from an engineering graduate?

4. Are these expectations different for long-time employees (> 2 years of employment)?

3.4. Analysis & Codifying Methodology

The research methodology used for this project is based on the *Grounded Theory* methodology, commonly used in social science research. Prior to performing interviews with research participants, it was imperative for the interviewers to not have preconceived notions about any themes that may have arisen (*Case et al, 2011*).

The *Grounded Theory* methodology highlights a three-step process for the analysis of qualitative research data. Firstly, recordings of interview participants were reviewed to identify major themes that arose. Similar incidents during the interview are grouped together and codified in a process known as *open coding*. The frequency of an occurrence of a specific theme was tabulated based on the number of times the theme arose in the interviews performed. Multiple occurrences of a theme that appear in an interview contributed to multiple counts to the frequency measurement of the theme if the context to which the theme was described was different. Secondly, the major themes identified were grouped into major categories. Finally, the conclusions were drawn based on the categorization and quantification of major themes and categories. As this investigation was grounded on the *Situated Learning Theory*, major themes and categories were derived based on key perspectives from the theory itself.

4.0. Data Gathering

The section below highlights the key categories and themes that arose during the interviews performed during this investigation. A total of fifteen interviews were conducted during a span of four weeks. Seven one-on-one interviews were performed with undergraduate students, four engineering faculty members, and four industry professionals.

4.1. Data Gathering - Authenticity of Qualities Assessed

Upon completing interviews, further analysis was done to decode the major themes that arose within and between the interviews. Major themes, frequency counts, and a representative quote can be found on *Table 1*, below.

Are the *qualities* assessed authentic in the context of the industry?			
Category: Industry expectations for new graduates			
Theme	**Description**	**Quote**	**Frequency**
Communication	Communication as a key industry expectation for new graduates	"The ability to work in a team, to know how to get along with colleagues, how to resolve conflicts, how to advance the project, to make proposals, to come to a consensus" (Academia)	Academia: 1 Industry: 0 Students: 6
Project management	Project management as a key industry expectation for new graduates	"a very clear expectation of project management—everything from managing a task list up to having a Gantt Chart of some kind, running a team meeting… and how to keep things moving along" (Academia) "You have to be able to meet those deadlines and the only way to do that is to make a clear plan and to execute them" (Student)	Academia: 2 Industry: 0 Students: 3
Adaptability	The ability for a new graduate to interact and work with colleagues outside of their discipline of study as a key industry expectation for new graduates	"Engineers are going to be able to work in teams both with other engineers, and most often, with engineers not from the same academic tradition or background as the graduate, but also people from the outside of engineering" (Academia) "Ability to view a situation from multiple perspectives to allow you to work more effectively with people who have different perspectives" (Academia) "Being able to learn quickly is something that I also noticed was expected of me just because the job I was working was not quite Chemical Engineering but they expected me to learn what I needed to know to do the job" (Student)	Academia: 3 Industry: 2 Students: 5

Ability to give meaningful feedback	Ability to give meaningful feedback as a key industry expectation for new graduates	"Ability to take and give effective feedback rather than non-feedback" (Academia)	Academia: 1 Industry: 2 Students: 0
Humility (ability to receive feedback)	Ability to receive and internalize feedback as a key industry expectation for new graduates	"People need to be able to give others a chance to talk."… "I have run into situations where the feedback I've gotten about an individual has been that this person thinks that they know it all and they are right, if there's a disagreement, then the other person is wrong" (Industry) "the biggest one is humility… it's not about getting a star on your hand or getting recognition from me personally" (Industry)	Academia: 2 Industry: 2 Students: 0
Being organized	Being organized as a key industry expectation for new graduates	"The individual be organized – an efficient type of organized" (Industry)	Academia: 1 Industry: 1 Students: 1
Problem analysis	Ability to accurately and quickly analyze a problem as a key industry expectation for new graduates.	"I would expect a certain level of organization, certain level of being able to help diagnose various processes, such as being able to simplify it" (Industry)	Academia: 0 Industry: 1 Students: 1
Decisiveness	Ability to make quick decisions as a key industry expectation for new graduates	"The ability to make fast but well thought through decisions" (Student)	Academia: 0 Industry: 0 Students: 1
Ability to evaluate other's skills	Ability to understand others' strengths and weaknesses as a key industry expectation	"We would expect them to be able to navigate an organization effectively – there are times where you need help from people, and there are times where people need help from" (Academia)	Academia: 0 Industry: 2 Students: 1
Ability to motivate	Ability to motivate and drive others towards making progress in a team effort	"If you've got that EI or EQ, the combination of the two could drive a group dynamic to go to a higher level" (Industry) "You need to perform this task and now you have to go out and find the people that you need to bring in that are going to help you and then you need to get them engaged" (Industry)	Academia: 0 Industry: 2 Students: 0

Table 1: Key themes on the authenticity of the teamwork qualities assessed in engineering education

Four primary observations can be found from *Table 1*:

4.1.1. Adaptability as an important skill for new graduate

Students, academia, and industry professionals all agree on the importance of *adaptability* as a core skill that engineering graduates need to possess. Adaptability in the context of a professional skill set refers to an employee's ability to work in different environments with other colleagues who may be from a different training or background. Industry professionals have the expectation for new graduates to be able to navigate an organization in order to bring in colleagues of differing expertise to assist and collaborate with their projects. Students who have completed internships during their academic career make similar observations, commenting on the need for them to go above and beyond their area of specialty to complete tasks given to them. Instructors in academia also have a clear understanding of this requirement. Instructors we have interviewed emphasized the importance that students be able to view situations from multiple perspectives to ensure all stakeholders within a company are satisfied.

4.1.2. Students believe in the importance of communication as a skill

During the interviews, most students mentioned the importance of the ability to communicate effectively. Students viewed communication as an enabler for them to accomplish tasks in a work setting. Students interviewed saw the importance of being able to communicate technical information with various levels of depth to both engineering and non-engineering audiences. Students identified the importance of public speaking and team leadership as two important skills that they believe industry expects of them. In contrast, industry professionals and engineering instructors interviewed made no specific mention of communication as a skill they expect from new graduates.

4.1.3. Industry expects humility from new graduates

A point brought up by multiple industry professionals that was distinctly absent from the students interviewed was the importance of remaining humble in the workforce. While industry managers recognize that the new graduates that they hire are often young, bright individuals, they also feel that many new graduates are over-confident and are unwilling to consider other points of view. Similarly, an engineering instructor interviewed highlighted a common scenario he has observed, that often times "one member of the team feels they've done exceptionally well,

and their team members don't necessarily agree." As a whole, industry professionals and engineering instructors believe that new graduates need to remain humble, improve their listening skills, and be able to internalize feedback given to them by their peers and their superiors.

4.1.4. Academia and Students place emphasis on Project Management skills

Both students and engineering instructors believe in the importance of project management as a key skillset required by the industry. An engineering instructor interviewed placed an emphasis on skills such as running efficient meetings, the usage of project management tools (i.e. Gantt Charts), and effective role distribution. Similarly, students believe that they will be required to perform project management tasks such as following-up with colleagues on their tasks when managing a project. In contrast, most industry professionals interviewed made no specific mention of Project Management as a key skill expected from new graduates.

4.2 Data Gathering – Authenticity of Evaluation Methods

Aside from establishing codes for the qualities that the interviewed segments believed were important to teamwork, themes were also identified around the types of evaluation methods employed by academia and the industry. *Table 2* summarizes the information for this branch of the study.

Are the *assessment methods* used authentic in the context of the industry?			
Category: How is a team defined for evaluation purposes?			
Theme	**Description**	**Quote**	**Frequency**
Holistic view of evaluating teamwork	No explicit definition for team work or set rubrics for qualitative evaluation; part of a greater whole	"Yes, we are evaluating those skills. The problem is that we're doing it at such a holistic level that the students can't use that as a learning factor" (Academia) "these more qualitative attributes of students, people are reluctant to be presented with a statement on a rubric that says 'the students have exhibited teamwork' that tries to qualify what we mean by teamwork" (Academia) "I don't isolate the traits [teamwork], I look at it more holistically, it's an element of an overall picture" (Industry)	Academia: 3 Industry: 2 Students:
Quantifiable view	Focus is on the quantifiable indicators of an individual's contribution	"If a team is doing something, and there are 30 people on there, how are managers supposed to evaluate individual performance? So we must know who actually contributed what idea." (Industry)	Academia: Industry: 2 Students: 4
Difficulty in **quantifying** teamwork as a skill	No metrics or indicators to measure teamwork even when a description or definition exists	"people are reluctant to be presented with a statement on a rubric that says 'the students have exhibited teamwork' that tries to qualify what we mean by teamwork." (Academia) "Because of such complexity, it's very difficult to narrow it down to concrete indicators" (Academia)	Academia: 3 Industry:0 Students:0
Lack of consistency in quantification methods	Every person has their own view on what looks like "good teamwork"	"We have to be concerned about whether or not, if we don't put the structure in there, whether or not two different clients or two different instructors are assessing two completely different things" (Academia) "difficult for many engineering professors to accept that they aren't likely going to be able to do that reliably between supervisors across students in different projects with different clients" (Academia)	Academia: 1 Industry: 0 Students: 2
Category: Assessment methods used today (Peer Evaluation, Self Evaluation, External Review)			
Theme	**Description**	**Quote**	**Frequency**
PE: Point/Scale-Based 360 Review	Input from a combination of lower, equal, and higher seniority members using rating scales.	"management usually asks employees to identify who they'd like to receive feedback from… it's up to the manager to add people, remove people, or whatever the manager decides to do. It's a bunch of multiple choice type questions (ratings), and also free-form text" (Industry) "Each of your group members evaluated you on several categories through a sheet, written down,	Academia: 0 Industry: 1 Students: 2

		and your score was the average against all these categories" (Student)	
PE: Point Distribution	A set number of points is available for peers to distribute to their teammates in a number of areas based on perceived level of input	"Here's 30 points, distribute them amongst your team members on how they've contributed to the project" (Academia)	Academia: 1 Industry: 0 Students: 0
PE: Attribution Tables	Names written alongside sections completed by each person	"Most other projects if it's a report based project, it will be like write your name next to the section that you completed and you'll get a mark based on what you wrote." (Student)	Academia: 3 Industry: 0 Students: 5
SE: Project Assessment	Self-description of project contributions peer-reviewed by 2 colleagues	"Employees are asked to do at least 2 project assessments a year… the employees have to fill out a form that says this was a project I was on, this is what the objective of the project was, this was what my role was, and this what I did. Here are two people who can vouch for what I've did." (Industry)	Academia: 0 Industry: 1 Students: 0
SE: Reflection	Personal reflection on strengths and weaknesses	"Society in general focuses too much on weaknesses. Instead of saying "you're bad at this and we've got to make you better at it", well "what are you good at and how do I give you more of it"?" (Industry)	Academia: 0 Industry: 2 Students: 0
TP: Internal Observation	Occasional observation from an individual within the organization + annual review	"We have project managers who are in the room with the TAs in the tutorial room. They meet weekly with the students, doing a status report. They are responsible for giving an **individual grade** to the student… it's 10% of a student's grade" (Academia) " A formally scheduled performance review should be just "we talk on a regular basis so now this is just to reconfirm some of the things that we're doing"." (Industry)	Academia: 5 Industry: 4 Students: 3
TP: External Review	Observation from an individual external to the organization	"team work is assessed by…the industry client by way of a rubric…the rubric is based on the graduate attributes process" (Academia)	Academia: 1 Industry: 0 Students: 0

Category: Assessment frameworks

Theme	Description	Quote	Frequency
Long term	A development framework exists to guide evaluation and growth for an individual over several years and positions within an organization	"It's a monthly review that takes place with individuals and then formally from [the company] there is an expectation that twice a year we sit down with folks and turn around and take a look at their overall performance" (Industry) "[A career framework] guides employees through career related things from training, to mentoring, and about how to progress up the organization" (Industry)	Academia: 0 Industry: 3 Students: 0

Category: Frequency of evaluation

Theme	Description	Quote	Frequency

Project Based	Evaluation performed based on project milestones	"We're doing a number of group projects right now and we're coming to the end so I know we're going to have a peer evaluation" (Student)	Academia: 2 Industry: 0 Students: 2
Time Based	Evaluation performed on regular or irregular time intervals (e.g. weekly, annually, impromptu)	"It's a monthly review that takes place with individuals and then formally from [the company] there is an expectation that twice a year we sit down with folks and turn around and take a look at their overall performance" (Industry)	Academia: 3 Industry: 5 Students: 1
Situation Based	Evaluation performed based on particular circumstances	"Within our upper years we haven't really had much team evaluation at the end. It's kind of been a "if you're working well then continue", "if you're not working well you raise the issue to your instructor" (Student) "I do not wait for the 360 degree feedback process to kick off in a normal cycle if I feel that there's an individual who's ready for an award or a promotion, or needs some help." (Industry)	Academia: 1 Industry: 2 Students: 3
Category: Quality of Feedback			
Theme	**Description**	**Quote**	**Frequency**
Honesty & transparency	Contributors of feedback were completely honest about their sentiments and held nothing back	"The thing that we fight to maintain is an absence of politics within this team, which is open honesty and that everybody knows where everybody stands and nothing is hidden and nobody goes home with something in their chest pocket that's bothering them, that is what I think the key to it is. No	Academia: 0 Industry: 3 Students: 1

		behind the back chatter, transparent honesty and integrity.“ (Industry) “Teammates are usually fairly nice to each other unless somebody is really doing a bad job. If you’re doing not so good of a job sometimes it passes by without you noticing; they might just forget it” (Student)	
Face-to-face feedback	Feedback was delivered orally	“it is more conversation, spending time with them and understanding to make sure that their bucket’s full at the end of the day” (Industry) “That doesn’t happen very often that you get one-on-one interview to be graded” (Student)	Academia: 2 Industry: 4 Students: 5
Self-initiated feedback cycle	Feedback was peer-initiated in the absence of a formal feedback structure	“If someone is not doing as good of a job as we think they can do then sometimes people just voice their opinion and then people usually just work on that” (Student)	Academia: 0 Industry: 0 Students: 4
Specificity	Feedback was specific and actionable	“The TA’s don’t do that much when they comment, they kind of just say “your team dynamic isn’t as good as it should be” or “it’s great” or whatever, I haven’t read anything, I haven’t read any feedback from the form we filled out this term” (Student)	Academia: 1 Industry: 1 Students: 5

Table 2: Key themes on the authenticity of the teamwork evaluation methods assessed in engineering education

Six primary observations can be found from *Table 2*:

4.2.1. Holistic vs. Quantifiable views on teamwork depend on type of work

Both industry and academia agree that there is difficulty in defining and assessing teamwork, however all segments of industry seem to bypass this by either using holistic process-based evaluation or quantifiable deliverable-based evaluation. Particularly, the two industry participants working in revenue generating segments focused specifically on quantifiable outputs

of their employees whereas the two industry participants working in development and design segments focused on a holistic view of soft-skill evaluation through the process of working.

4.2.2. Industry assessment methods more heavily focus on self-reflection

Throughout the interviews, multiple industry representatives made mention of the need for employees to self-evaluate to identify strengths and weaknesses for the benefit of being able to work more effectively. Although one member of academia expressed the importance of self-reflection for the growth of students, the point was made that there was much room for improvement in this area with regards to how academia should perform evaluations.

4.2.3. Frameworks exist only for industry assessment methods

The idea of individual assessments fitting into a long-term developmental framework was mentioned by several members of industry during the interviews. Monthly and annual reviews, project assessments, self-reflection exercises, and casual meetings all fit together within a broader context for an employee's individual skills and career development through the company. No mention of any such framework was made by students or academia.

4.2.4. Industry emphasizes high-frequency of evaluation

Although project-based evaluation seems to be used more within academia, it is not ever mentioned by industry representatives. By contrast, industry focuses on constant communication in the form of impromptu meetings and discussions as well as regular feedback independent of project milestones. One industry interviewee also pointed out that feedback is given in situations where the employee is performing well and not just when there are issues to be addressed as it is in academia according to the student responses.

4.2.5. Academia lacks regular face-to-face feedback

The subject of lack of face-to-face feedback opportunities in courses was brought up several times by student participants. In particular, several students who had worked in summer or full-year internships made mention that this was common practice in industry but was absent in academia. Comments made by industry participants confirmed that almost all evaluations, even when written, were followed up by face-to-face interaction.

4.2.6. Academia lacks culture of specific and completely honest feedback

Two industry representatives emphasized the importance of honest and actionable feedback for the purpose of employee development and team dynamics improvement. One of these representatives specifically made the point to say that newer employees often provide vague comments and are less honest about the negative points of their peers. Mention of this came up again by one of the student participants revealing that "teammates are usually fairly nice to each other" and in being so are less likely to want to provide points for improvement in fear of hurting the feelings of their peers.

5.0. Discussion

The section below aims to provide insights for the data collected in *Table 1* and *Table 2*. Two key areas will be assessed in this section. Firstly, the analysis will aim to understand if the qualities assessed in engineering academia are *authentic* to industry expectations. Secondly, the analysis will understand if the evaluation methods used in academia today are *authentic* compared to those used in the industry.

5.1. Evaluation of the authenticity of qualities assessed

By comparing student motivation and academia intentions for group work in academia to industry expectations of new graduates, conclusions can be drawn about the overall *authenticity* of the qualities currently taught and assessed by engineering academia.

During the interviews with undergraduate engineering students, students were asked what they felt were the key skills in teamwork that they needed to possess when entering the workforce. Literature in *Situated Learning Theory* mentions that when teachings and assessments are authentic to the real world "they are more motivating for students, who can now see the connections between what they are learning and their long range goals (*Svinicki 2010*)." As such, the answers that the students provide on this question provide a basis of understanding the underlying motivation for students to develop their teamwork skills. Students identified three primary skills in teamwork that they believe industry expects from them: communication, adaptability, and project management. While the industry agrees with adaptability as a core skill set in teamwork, less emphasis was placed on the importance of communication and project management. Students interviewed failed to mention the industry expectation of humility and ability to provide high quality feedback.

One-on-one interviews with engineering instructors were also carried out to better understand current assessment methods used today and what instructors believe are the industry's expectations in teamwork for engineering graduates. Engineering instructors play an integral role in determining the format and assessment methods used in engineering coursework. As a result, course instructors are in the best position to affect the *authenticity* of the qualities assessed during coursework. This section also aims to understand if the engineering academia and the engineering industry have an aligned understanding in the qualities in teamwork that they expect new graduates to possess upon completing group coursework in their undergraduates

studies. Upon analyzing and codifying interviews done by engineering instructors, it can be seen that engineering instructors believe that project management, one's ability to adapt in various situations, one's ability to provide quality feedback, and one's ability to receive and internalize feedback are four key skills in teamwork that the engineering industry expects from new graduates. As a whole, the four skill sets that the engineering academia prioritizes aligns with the industry's view on skills expected from engineering graduates.

The section below highlights the key themes that arose during interviews with students, engineering course instructors, and industry professionals. The section below will highlight how these themes relate to the authenticity of qualities assessed by engineering academia today.

5.1.1. Adaptability

Students across all years of engineering have identified the importance of being adaptable as a key teamwork skill for the industry. Specifically, students believe that a new graduate's ability to learn quickly, offer and seek help during projects, and ability to work in cross-functional teams are important skills that industry expects from them. Similarly, the engineering faculty believes that it is imperative for students to be able to work in various environments and with industry professionals from different backgrounds.

The first aspect of being adaptable is a new graduate's ability to learn new skills quickly to contribute to the team they are part of. Engineering graduates are often well versed in the technical theories in their area of study. However, the engineering industry often requires engineers to apply skills from different disciplines to reach an end solution. As an example, a fourth year Chemical Engineering student who completed her engineering internship year mentioned that "being able to learn quickly" was expected of her during her internship, as she was asked to do tasks that were not necessarily rooted in Chemical Engineering. This example highlights that unless new graduates are able to grasp new technical concepts quickly, it would be difficult for them to making meaningful contributions to their team. Furthermore, not only are new graduates expected to grasp new technical concepts quickly, they are also expected to adapt quickly to their team's culture. This point is well articulated by a seasoned engineering manager, who believes that it's "the ones who are new to the organization that need to do more to fit in and be part of the team." Being able to assimilate into a team's culture will allow new graduates to work more cohesively and productively with their team. The examples shown highlight the need

for new graduates who are entering the workforce to adapt by learning new technical skills quickly and adapting to a team's culture as soon as possible.

Another key aspect of being adaptable in a team setting is one's ability to proactively offer help to others and ask for help from colleagues. New graduates who are transitioning into the workforce are not expected to know all of the inner workings of the industry or the company they are working for. A banking manager interviewed mentioned that for new students who have just entered the company, "there's an expectation that they're learning the culture, learning the work environment, so from an output or contribution point of view, it won't be as large." As a result, the industry expects that new engineering graduates be able to know when to ask for help in order for them to perform their expected roles. Over time, engineering graduates will gain expertise in certain areas of their work. At that point, industry managers also expect them "to be cooperative and give help" to those who need it. The statements from students are consistent from those mentioned by the industry. A first year engineering student highlighted that "being able to step up when you have to or if it's your area of expertise" is a key expectation of teamwork from the industry. It can be seen that students understand the industry expectation for them to contribute to tasks that they can perform well at, and know when to ask for help to bolster areas that they are weaker at.

The final aspect of being adaptable in the work environment is one's ability to work in cross-functional teams. Current researchers in organizational behavior believe that traditional "highly centralized vertical hierarchies will essentially be a thing of the past as organizations move to flexible decentralized forms of organizing based on horizontal work processes (Armstrong & Daft, 2009)." Due to this paradigm shift on organizational structures, new graduates who are moving into the workforce can be expected to work closely with colleagues who don't necessarily have an engineering background. Interviews performed with students showed that students are well aware of the rising need to work with non-engineers in the workforce. A fourth year Industrial Engineering student interviewed believes that engineers have to "work with work with people who are not with engineering backgrounds." The student further explains the importance of being able to "incorporate [engineering] knowledge into a more general project." The statement highlighted by the student is an indicator that engineering students understand that when placed in a cross-functional setting, they need to be able to adapt their communication and knowledge into forms that colleagues from other backgrounds can

understand. Engineering course instructors agree on various degrees that it is important for engineers who are entering the workforce to be able to work closely with colleagues from other disciplines. A course instructor responsible for a fourth year capstone course mentioned that engineers need to work "in teams both with other engineers, and most often, with engineers not from the same academic tradition or background as the graduate, but also people from the outside of engineering." To a slightly varying degree, another course instructor mentions that new graduates in engineering will most likely be responsible for "their unit of a project with some interaction with other members" in their team. It can be seen that engineering students, instructors, and industry professionals are well aligned to adapt to the requirement for engineers to work in a cross-functional team in the industry.

It is known that over time, companies evolve their organizational and management styles based on an ever-changing workforce culture. With this evolution, engineering graduates who are in the workforce need to ensure that they are adaptable to the changing requirements given to them. Engineers need to be able to learn new skills quickly, proactively seek for and offer help, as well as work in all levels of technical depth depending on the background of their colleagues. Adaptability is a quality that students, industry professionals, and engineering academia prioritize as a highly important teamwork skill to possess. As most students understand the importance of adaptability in the industry setting, they will more motivated to develop this skill set in teamwork settings in academia. Due to the high level of relevance adaptability has in a real world setting, engineering academia's emphasis on this skill is highly *authentic* and has a significant level of transferability to an industry setting.

5.1.2. Communication

The most frequent teamwork skill that students felt the industry expects them to know upon entering the workforce is one's ability to communicate effectively. Students believe that it is important to be able to present in front of a large crowd, communicate technical information concisely, and be able to communicate with team members to ensure that their team is making progress. In contrast, both engineering academia and industry professionals interviewed made no specific mention to communication as a key skill in teamwork that they expect from new graduates. However, by further analyzing the context to which students feel that communication

skills are important, one can see that the engineering industry does place some importance in one's ability to communicate in a specific context.

For instance, industry professionals interviewed emphasized the importance of their employees' ability to identify stakeholders and partners for a project, and for employees' to be able to motivate these stakeholders towards the project's success. A manager commented that as young engineers mature in an organization, he expects that they will "be able to marshal the right people to get the project going." While the term *communication* was not used specifically in this context, it can be seen that to be able to drive the relevant stakeholders forward in a project, engineers need to be able to communicate convincingly. Furthermore, the industry also has an expectation that engineers possess a high level of analytical skills that will allow them to drive a team forward. For example, a manager mentioned that she expects that a new graduate in engineering to possess a high level of "questioning and probing… to turn around and get the group to go to a higher level." While many engineering graduates are highly analytical in nature, being able to analyze problems and articulate their insights, questions, and concerns to their team requires them to possess professional levels of communication abilities.

While engineering instructors did not mention the trait of *communication* specifically as an industry expected skill for teamwork, they placed a large emphasis on certain assessment methods that requires students to demonstrate effective, constructive, and professional levels of communication. As an example, first year engineering students are required to submit multiple deliverables throughout the year, including both written and oral reports. Dedicated communications instructors are also assigned to grade students' abilities to communicate technical knowledge in a professional manner. In other words, engineering coursework provides an opportunity for students to develop their communication skills by requiring students to demonstrate high levels of communication in all of their deliverables.

In conclusion, one student's comment on the importance of communication adequately summarizes the importance of the skill with regards to the industry's expectations of new graduates – "if you can't communicate with others, then you can't get anything accomplished." While the engineering industry does not specify communication as a primary skill in teamwork they expect from new graduates, it is evident that without adequate levels of communication, other expectations such as adaptability and their ability to provide high-quality feedback will be affected. The engineering industry expects students to be able to communicate both horizontally

and vertically in an organization to drive initiatives forward and enhance collaboration between their colleagues. As engineering instructors place students in realistic situations where they have to deliver technical content in both written and oral form to various audiences, the communication skill taught in industry is *authentic* to the industry's needs.

5.1.3. Project Management

Engineering students also identified the need to be able to perform project management tasks as a skill in teamwork that industry expects from them. Project Management refers to tasks such as scheduling and role-allocation that allows for a successful final deliverable in a group setting. Similarly, engineering instructors have also placed an emphasis on Project Management, highlighting it as a key teaching concept for first year engineering students. In contrast to the students' emphasis on Project Management, none of the industry professionals interviewed specifically mention project management as a skill that they expect to see from a new graduate in engineering who's entering the workforce.

In undergraduate coursework, most team projects are self-managed by students. Due to the relatively horizontal structure of student project teams, all team members need to be aware of the progress that other team members have made in order to ensure the final deliverable is of high quality and is submitted on time. A fourth year Materials Science Engineering student drew on her experience with course based group-work and emphasized the need to have "someone follow-up with each group member all the time and make sure that everything is being done on time." As a result, many students have applied elements of project management skills that were taught in various courses. For example, in the first year engineering design course, engineering academia requires that students to develop Gantt charts to train students to manage and distribute work appropriately within a group to meet both internal and external deadlines. Furthermore, the first year design course also requires students to submit a project status report to a project manager on a weekly basis to simulate an entry level engineer's responsibility to report to a manager in a work environment. As a whole, engineering academia places and emphasis a student's ability to perform project management tasks that will help drive their team's progress forward.

In contrast to an academic group-work setting, new graduates in the field of engineering are mainly responsible for their individual contributions. Usually, either engineering managers or

designated project managers are responsible for tasks related to the overall planning and management of the project. For instance, a manager within the finance industry commented, "with some engineers, they have been more successful as an individual contributor as opposed to an important component in an overall team." Engineering employees who are primarily individual contributors may find that they use project management skills learnt in academia less frequently upon entering the industry.

While project management may not be a skill set that the industry expects from an engineering graduate immediately upon graduation, engineering graduates may see the need for such a skill set upon further growth in an organization. Furthermore, having an understanding of where an individual component to a project plays in a larger setting will allow engineers to better prioritize their work depending on their team's dependencies on them. Due to the lack of immediate need of project management skills for new graduates who are entering the engineering industry, it can be said that the emphasis on project management by engineering academia is *not authentic* to its immediate application in the industry.

5.1.4 Humility

Industry professionals interviewed believe that the most important skill that new graduates in engineering should possess is their ability to remain humble and be able to receive and internalize feedback provided to them. When performing group work, one's ability to keep an open mind and participate in meaningful dialogue with parties with opposing views ensures that teams operate functionally. While humility was a core skill set in teamwork that was highly valued by industry professionals and engineering instructors interviewed, the skill was not mentioned by any of the students interviewed during the interviews. In extension, while engineering instructors strive to provide feedback opportunities to students, they feel that there is an overall lack of opportunities for students to internalize the feedback given to them.

Seasoned industry managers believe that new graduates in engineering need to strive to remain humble when working with other team members. When asked what the most important skill in teamwork the industry expects from new graduates was, a technical executive at a property management firm mentioned that "the biggest one is humility… teamwork is people on the team helping each other, working for each other, it's not about getting a star on your hand or getting recognition from me personally." The industry expects new graduates to not possess an egotistical mindset and instead, focus more on the team's success. Similarly, a senior level

manager from the software industry mentions that new graduates "need to be able to give others a chance to talk … I have run into situations where the feedback I've gotten about an individual has been that this person thinks that they know it all and they are right, if there's a disagreement, then the other person is wrong." New graduates who are entering the industry should keep in mind that there are often multiple perspectives to an issue. Instead of driving their own personal agendas, new graduates need to keep an open mind to alternative solutions that could be more beneficial for the team.

A subset of being humble is one's ability to openly receive and internalize feedback from peers and superiors. Similar to the engineering industry, engineering instructors believe that a new graduate's ability to receive and internalize feedback is an important skill to possess when they transition into industry. In highly structured courses such as the first year engineering design course, instructors have established feedback systems to allow both peers and project managers to provide feedback to students. However, current engineering instructors also recognize that current coursework does not provide ample opportunities for students to use to internalize the feedback given to them. An instructor for a fourth year capstone course mentioned that "we don't do enough self evaluation with the students…the students need to do a self evaluation as to their progress, their weaknesses, how they're going to improve, and we don't do that as much as we should." Ideally, students who receive feedback from their peers or course instructors should be given opportunities to reflect on their weaknesses, and be given time and opportunities to strengthen those areas in the long term.

The ability for students to receive and internalize feedback is a gap that engineering that leads to the lack of *authenticity* in the quality of humility compared to the industry. A key consideration for future development in coursework design and assessment method for group work should provide opportunities for students to provide feedback to each other. Students should also be given self-reflection opportunities to internalize the feedback given to them and improve their performance throughout the course.

5.1.5. Ability to provide feedback

The ability to provide highly concise and constructive feedback is a skill that both engineering academia and industry professionals value as an important teamwork skill. Being able to provide constructive feedback allows other individuals in the team to understand and

further improve on their key weaknesses. Furthermore, a culture of constructive honesty allows for teammates to develop a strong level of trust for each other. In other words, the ability to provide feedback is an essential skill for the long-term development of a team's abilities and productivity.

Many firms in the engineering industry have implemented feedback mechanisms that include both upward, peer, and downward feedback. For new graduates, the ability to provide quality feedback to their peers and their supervisors are important elements for a team's overall success. A senior software executive interviewed mentioned that his company's performance evaluation process works extremely well to develop his team's teamwork abilities. Specifically, he specifies that "it's very important for people that are providing feedback provide honest, constructive feedback… if they don't do that, then the entire process is a waste." The software executive also mentions that compared to junior employees, higher-level executives who "have learnt how important this feedback is" tend to be honest and open with the feedback. New graduates who are transitioning into the workforce need to ensure that they invest time and effort into providing useful feedback to their teammates to ensure the overall success of teamwork development programs. In another interview with an executive of a property management company, the executive mentioned that his company strives for a culture that has "an absence of politics within this team, which is open honesty and that everybody knows where everybody stands, and nothing's hidden, and nobody goes home with something in their chest pocket that's bothering them." For new graduates, their ability to provide constructive feedback to both their peers and their superiors will encourage a culture of open honesty that is key to a team's cohesiveness and success.

While engineering instructors have attempted to provide more feedback opportunities for student groups, students feel like many of these initiatives are insufficient. Engineering instructors today have many tools at their disposal to provide students with opportunities to provide feedback to each other. For instance, recent developments in online tools have continued to make it easier for students to provide anonymous feedback to each other during the course. While engineering students have been exposed to various tools and opportunities to provide feedback to each other, some students feel like these initiatives have not been overly effective. For instance, a fourth year Mechanical Engineering student interviewed compared the opportunities for feedback from her industry work-term to her coursework, and felt that

engineering academia lacked opportunities to provide and receive quality face-to-face feedback. Specifically, she mentions that when she was evaluated during her work-term, she was given an opportunity to have an open discussion with her manager who gave "justification behind the score they are giving you or feedback they are giving you." In contrast, she believes that the academia's method of "stress[ing] that these peer evaluations will be confidential" is not as effective, as it does not provide opportunities for further discussions or questions regarding the feedback. Similarly, a first year student commented constructive and useful feedback is hardly given, as teams have been "fairly nice to each other unless somebody is really doing a bad job." In other words, students in engineering believe that there are current gaps exist in opportunities to provide high quality feedback to their peers. The lack of these opportunities makes it difficult for engineering students to develop their abilities to provide feedback to both peers and superiors, a skill expected by the engineering industry.

In conclusion, many of the performance appraisal and feedback mechanisms in the industry operate under the assumption that employees are able to provide honest and constructive feedback to their peers. While there has been development in the engineering education space to provide tools for students to provide feedback to each other, students believe that they lack opportunities to provide open, honest, and in-person feedback to their teammates. Thus, the engineering curriculum's application of peer feedback is *not authentic* in comparison to the industry's expectations.

5.1.6. Summary

The analysis completed above highlighted five key skills that either students, industry professionals, or students felt were important skills for new graduates to possess when the enter the workforce. The skills investigated were – adaptability, communication, project management, humility (ability to receive and internalize feedback), and ability to provide quality feedback to other teammates.

The analysis performed shows that engineering academia's emphasis on adaptability and communication is *authentic* to industry needs. New graduates who are entering the workforce today are often expected to be able to work in cross-functional teams. Unlike traditional team structures, cross-functional teams may be composed of engineers from differing disciplines and other teammates who do not have an engineering background. As a result, there is an ever-

increasing need for students to be able to communicate at all levels of technical detail. A new graduate's ability to communicate will also empower them with the ability to drive and motivate their team towards the success of their project.

While the skills of adaptability and communication are highly useful skills in the engineering industry, academia's heavy emphasis on project management may not be as *authentic* to the industry's expectations. In the engineering industry, it is common for teams to have a dedicated engineering manager or project manager who is responsible for managing costs, schedules, and resources for a project. As a result, while students in engineering have been taught many key skills in project management, these skills may not be highly necessary for engineers who are just entering the industry. However, there may be long term benefits of imparting project management skills to students. As engineers continue refining their technical and management skill sets, they may be promoted to positions that require them to demonstrate their abilities to perform project management tasks for their team.

To increase the *authenticity* of qualities in teamwork assessed in engineering coursework, engineering academia need to increase the number of opportunities that students have to provide and internalize feedback. Industry professionals believe that many engineering students need to learn to remain humble and be able to internalize feedback and opinions provided to them by their superiors and their peers. New graduates who actively reflect on their weaknesses will be able to better develop their skill sets to adapt to increasing industry expectations. Not only are new graduates required to actively reflect and internalize feedback given to them, they are also expected to provide high-quality constructive feedback to their teammates. Most performance appraisal and development assessment methods in industry require employees to seek upward, downward, and peer input. As a result, new graduates may be expected to provide input on how their peers and their superiors are doing. Being able to provide insightful and quality feedback will contribute to the overall success of the team's performance. While engineering course instructors recognize the importance of feedback and reflection opportunities for students, there have been insufficient opportunities for students to engage in feedback activities. In the future, engineering course instructors should identify further opportunities to allow undergraduate teams to provide and receive feedback from their peers and their instructors. Providing students with open and honest peer evaluation activities will allow teams to develop a higher level of trust and effectiveness in the long term.

5.2. Evaluation of the authenticity of assessment methods

By comparing and contrasting the evaluation methods and principles used by industry and academia with supporting evidence from students who have experienced aspects of both, we can evaluate the authenticity of the assessment of teamwork within the educational context.

Just as *Situated Learning Theory* emphasizes the use of realistic environments for assessment, the idea of the assessment itself should be authentic to provide the most effective learning outcomes (*Svinicki 2010*). Although evaluation across different segments of industry varies a great deal, certain core principles can be drawn from the interviews within the sample to be applied with discretion to the academic setting, better simulating expectations of new graduates entering the workforce.

Amongst the core themes to be pulled from the industry perspective is a large focus on feedback and its various aspects. Particularly that clear, meaningful feedback is vital to improvement and that it should be delivered in high frequency and in complete honesty. Additionally, the idea of self-assessment of strengths and weaknesses as a foundation for a long-term development framework is a key industrial contrast to the modular course-based nature of academic study. Finally, the disparity of grades-based academic evaluation over qualitative performance review in industry plays an important role in the challenges of how convergence of these two systems may be attempted.

The following section will explore each of these aspects of the industry/academia relationship with respect to assessment methodologies and attempt to bring to light ways in which these relationships can be made more cohesive.

5.2.1 Feedback Mechanisms

As mentioned in section 5.1.5, the ability to provide meaningful feedback is invaluable. Not only does this create a culture of maximum continuous improvement, but it also helps to develop a mindset of support over stress. It is this culture of constantly asking and providing feedback that is emphasized and appreciated in the industry-based interviews and seems to be missing from the academic sector, particularly from the student perspective. The idea that providing completely honest feedback will hurt other people's feelings or result in negative team dynamics seems to be pervasive within the student segment. One fourth-year mechanical engineering student mentioned that the reason that peer evaluations are likely done anonymously

in school is “just by the nature of having to work with someone in another team”. Of course, this situation is also true of industry work, but the fact that the culture of accepting that feedback is a norm means that this problem does not arise nearly as often.

Aside from being able to provide honest feedback during evaluation, it’s also been mentioned that face-to-face feedback is sorely lacking within the educational setting. Even within industry, when a written evaluation such as a 360 review (refer to *Table 2*) is used, that information is followed up with a face-to-face meeting with somebody to allow for clarification and discussion. The nature of face-to-face interaction provides room for double-loop feedback, whereby the evaluated individual can ask the evaluator points for improvement or justification behind the feedback provided. This allows the individual to contextualize the information in a way that is meaningful to them such that they can translate the ideas into actionable improvements. Face-to-face conversation was also mentioned to increase retention of feedback as one student mentioned that “if it was just written, [she] wouldn’t say it’s necessarily stuck with [her]. Maybe [she has] seen it but [she doesn’t] necessarily remember”.

The last point on feedback, which has yet to be mentioned, is the focus on continuous and constant feedback within industry. Given the project-based nature of all team or group work within school, evaluation in academia seems to be grounded within project milestones. Even worse, this method seems to be focused primarily on feedback only after the completion of the end deliverable. The use of evaluation post-project works against encouraging skills development as there is no longer anything for the students to gain out of the project assessment itself, nor will those particular comments fit coherently into the next group project that they take on, given the modular nature of course work. From a situation-based feedback perspective, academia focuses on use of feedback for corrective means. One course instructor emphasized that it was important to primarily “help students communicate professionally when a team hasn’t performed”. Contrasting this is the notion of a software executive who initiates a feedback process if he “feels[s] that there’s an individual who’s ready for an award or a promotion, or needs some help”. Within industry, both negative and positive situations are used as catalysts for feedback and growth, ultimately allowing for more opportunities to give and receive feedback.

The use of honest, face-to-face, and constant feedback not only helps to improve feedback quality by allowing for specific, actionable outcomes to come to the surface on a frequent basis, but the combination of these three also helps to create a culture of continuous

improvement where employees are not as afraid to speak up and to take criticism for the purpose of growth. Within academia, an onus lies on course instructors to instill this mindset into the student body by creating more opportunities for non-grades based qualitative assessment and by discussing and showcasing the merits of transparent feedback with students.

5.2.2. Self-Reflection for Framework Development

Within academia, most of the evaluation methods employed seems to prioritize peer or third-party evaluation over self-reflection. Although all are important, "the students need to do a self-evaluation as to their progress, their weaknesses, how they're going to improve, and we don't do that as much as we should" as remarked by one course instructor. Within industry, the use of self-reflection allows for employees to best establish their fit and role within any working team and allows team dynamics to be mitigated more easily.

Reflection, however, is often not an effective or well-received form of evaluation amongst students as it often leads to inauthenticity in responses and lack of learning through forced responses (*Guiffrida* 2011). This is linked to the grade-based focus behind academic self-reflection with the absence of emphasis on long-term benefits for the individual. The problem is also rooted in the post-project nature of most self-reflection opportunities within school, similar to how feedback in general is often provided as mentioned in 5.2.1. This second problem ties closely to prevalence of long-term developmental frameworks within industry.

Almost all of the industry interviewees made reference to long-term evaluation frameworks for the purpose of highlighting areas for improvement and to bring context to future feedback. Companies across these industries value the development of their employees within the organization, as doing so will ultimately help their teams to succeed in meeting company objectives. To make this development easier, frameworks in which all forms of evaluation from annual reviews to performance outcomes are centralized to allow for a more complete, continually growing picture of an employee's strengths and weaknesses. One high-rise developer executive commented that the company even had "psychometric profiles of different people. So in the performance review [they]'ll typically look at their strengths profile, [they]'ll look at their psychometric profile and [they]'ll see [if they are] in alignment with what they naturally do well."

Due to the fact that courses within university are often modular and communication between different course instructors and departments is minimal, no such long-term framework exists for students to track their personal growth over several years, projects, and roles. Implementation of such a framework would increase the efficacy of self-reflection and all forms of feedback, even those of the post-project variety as continuity could be established for future growth. The establishment of such a framework would also allow students to more easily see how different projects and evaluators may view teamwork development differently, a point that will be brought up again in section 5.2.3.

5.2.3. Holistic and Quantitative views on teamwork assessment

Although bridging between academia and industry with respect to feedback, self-reflection, and developmental frameworks is relatively simple, the nature of academia as metric-centric grade-based work establishes a fundamental difference with how many segments of industry operate. The focus on the need to quantify evaluation for the sake of fairness creates inherent *inauthenticity* in academic assessments. Both academic and industrial interviewees confessed to the vague nature of teamwork and admitted difficulties in establishing consistent definitions (and subsequently metrics) for the subject. One professor stated industry clients often "know good teamwork when [they] see it." This also creates issues for students navigating different companies as new graduates as different organizations will have different expectations for teamwork, especially in comparison to academia.

Looking more closely at this disparity, however, reveals that although the overarching problem of definition still exists, different industries have employed different methods to working around a formal definition to create their own indicators and methods for assessing teamwork. The particular difference to be noted is that revenue generating groups concentrate more on individual (quantitative) contributions to project outcomes while design or development based groups focus more on individual (qualitative) contributions to team dynamics throughout the process of working on a project. Within academia, we also see that both methods are utilized, but somewhat inconsistently. As shown in *Table 2*, the use of attribution tables for assessment is pervasive in academia whereby it doesn't exist in any capacity within the industrial interview segment. The fact that very few (if any) undergraduate engineering projects actually generate measurable outcomes or revenue also suggests that the use of tools like attribution tables and point distribution are not valuable forms of evaluation, especially in the absence of descriptive

feedback. A fourth year chemical engineering student stated that "an attribution doesn't really make me communicate better", highlighting again the disconnect between not only the evaluation methods used in academia and industry, but the inconsistency in targets as characterized by the different teamwork qualities addressed in section 5.1. The use of divisive assessment methods also deters from helping to develop qualities associated with the process of teamwork. "I feel like our engineering 4 years, the only team things you do is literally "you have to do this, you have the deliverable and then you do it"; there's not really a team sense, like especially during 4th year even though every single course, 5 courses, which have team projects, we didn't really work as a team, we each had our individual parts and then all did it on our own and put it together, there was no working together," said one fourth year materials science student.

Given the nature of engineering group work in academia, it would be more authentic to emphasize the techniques of constant feedback with relation to the teamwork process over a heavy focus on individual contributions to the end deliverable while focusing on the use of long-term frameworks to allow students to navigate how different evaluators may bring out or highlight different strengths and weaknesses across different projects. Though not completely addressing the need for accountability and clear definition in academic practice, the integration of these methods can help to close the gap.

5.2.4. Summary

The nature of assessment across different organizations is highly variable, finding common ground only in the most general definitions of peer evaluation methods. However, within the breadth of different methods available to use, several key themes across select design-based and revenue-based industries provide a focal point to bring academic evaluation methods more in line with working reality.

Feedback quality, frequency, and structure are cornerstones of successful industry development tools while the combination of self-reflection and tailored assessment for different project types can help to increase authenticity of the student group work experience.

6.0. Future Work

This section highlights the next steps and future opportunities to extend and implement the results from this thesis. In the short term, it is recommended that engineering instructors instill a culture of open and honest feedback to courses that currently teach teamwork skills. In the long run, engineering academia should work with industry partners to develop a long-term framework for team skills development to ensure that qualities and assessment methods used in academia are authentic to industry expectations. Finally, further research should be done to identify and validate various implementation options to extend the work completed in this project.

6.1. Short Term

Short-term opportunities refer to opportunities that engineering academia can explore and embark on in the next academic year. These opportunities are relatively low-risk and allow engineering academics to perform pilot tests of different implementation methods.

One of the primary findings of this thesis is the focus on the culture of feedback within engineering courses. Currently, many first and final year students are involved in semester or yearlong design courses. Engineering instructors should find opportunities to educate and instill a culture of feedback in these courses. Specifically, students in certain courses should be exposed to various avenues to provide frequent and honest feedback to each other. These students should be exposed to how a culture of continuous feedback that is honest and constructive leads to an overall increase in team synergy and productivity. Engineering instructors should also participate in contributing to a higher frequency and quality of feedback from themselves and their teaching assistants. Additionally, they should ensure that student and teaching-assistant feedback is obtained to verify that changes implemented have led to a more positive learning teaching and learning experience.

Further, the current engineering curriculum places the most emphasis on team skill development coursework in the first and fourth years. Engineering departments should identify design courses in second and third year where team-skill development education can be instilled. Identifying these courses will allow departments to have courses in all four years of the undergraduate program that they can incorporate in a long-term teamwork development framework.

6.2. Long Term

Long-term initiatives refer to opportunities that are greater than one academic year in span. The majority of the work in teamwork skills course development should be done in the long run to ensure that initiatives are well thought out before they are implemented throughout the faculty.

Moving forward, engineering course instructors should ensure that teamwork activities used in academia contributes positively to skills that are highly useful in the industry. During the interviews performed for this research, some industry professionals have commented on how *inauthentic* team based work is academia is. Course instructors in various departments should establish partnerships with industry professionals to ensure that proposed curricula are useful for developing skill sets that the industry expects from engineering graduates. Particularly, course instructors should engage with engineering and human resource managers, who have the most familiarity with industry requirements and career development frameworks.

A key finding from this thesis is the importance of applying a long-term teamwork skills development framework in academia. A long-term framework provides an opportunity for students to continuously develop their skill sets in teamwork, instead of having their learning end abruptly upon a course's completion. Furthermore, a long-term framework allows for engineering curriculum designers can ensure that various aspects of team skills development are covered in different courses during undergraduate studies. When designing a long-term teamwork development framework for engineering departments, departmental instructors should work with industry professionals to ensure that best practices in industry career development frameworks are integrated within academia. Instructors should also make appropriate use of self-reflection tools to help establish parameters for individual student frameworks.

Finally, further work should be done to pilot and validate any curriculum changes that will be implemented. As recommended by the Canadian Engineering Accreditation Board and many engineering education researchers, instructors should ensure that continuous improvement techniques are implemented to curriculum design. It is likely that upon initial implementation, course instructors will need to modify their teaching and assessment methods based on feedback by other instructors, students, and industry professionals.

7.0. References

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