Towards a Multidisciplinary Teamwork Training Series for Undergraduate Engineering Students: Development and Assessment of Two First-year Workshops

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Towards a Multi-Disciplinary Teamwork Training Series for Undergraduate Engineering Students: Development and Assessment of Two First-Year Workshops

Abstract

Teams have become the default work structure in organizations; thus, in work settings that emphasize teamwork, employees must have knowledge, skills and abilities (KSAs) to communicate and coordinate with their colleagues. Yet, teamwork skills are rarely "taught" in engineering curricula; in fact, compared to business representatives, university educators have been found to underestimate the value of teamwork KSAs. Instead, students are expected to develop teamwork and leadership skills via a sink-or-swim approach where they are assigned group work and left to perform as they can. Often, these poor teamwork experiences combined with the lack of training and opportunities for guided reflection lead to students disliking working in groups, impacting not just the cognitive but also the affective domain of learning.

In response to this identified weakness, a committee of representatives from the Faculty of Engineering and other support units at the University of Waterloo is developing a series of six workshops intended to be delivered to engineering students in all disciplines in their first three years of study. The first three workshops will provide an introduction to team-forming and building, team communication, and conflict management. The last three workshops will provide reinforcement and opportunities for application in the same areas and in multidisciplinary settings.

This paper describes the first two workshops in this series. Their design is based on the principle that teamwork skills are best learned by doing, i.e., by practicing in a context that approximates common team experiences in engineering. In the first workshop, students work in groups to construct a tower out of straws and connectors under different performance objectives and where conflict situations are intentionally created. In the second workshop, students are assigned different team roles and challenged to build a simple LEGO structure under different conditions of verbal and written communication channel effectiveness. The combined learning outcomes of the first two workshops are understanding the characteristics of effective teams, developing strategies for effective teamwork, building active listening skills, and asking effective questions.

As the workshops are developed and implemented, ongoing assessment of their effectiveness in improving students' teamwork-related KSAs is focused on the workshops' impact on (1) students' knowledge of generic teamwork competencies (or "declarative" knowledge), and, (2) transfer of that knowledge to a new performance environment. This paper reports on the results of student self-appraisal surveys/quizzes and provides an overall evaluation of the current and potential future impact of the workshop series.

The stand-alone nature of this series of workshops makes it highly adaptable not only for other engineering schools, but also for non-engineering programs that may identify the need for teamwork instruction and assessment in their curricula.

1. Introduction

Organizations worldwide have adopted teams as the default work structure; as such, identifying what makes work teams effective has become the focus of both small-group and organizational psychology research[1]. In work settings that emphasize teamwork, employees must have knowledge, skills and abilities (KSAs) that empower them to communicate and coordinate with their colleagues[2]. The ability to act as an effective team member and leader is critical for engineering graduates entering industry, business or other career paths. Accordingly, the Canadian Engineering Accreditation Board (CEAB) has designated teamwork as one of the twelve attributes engineering students must possess upon graduation[3]. Similarly, ABET has included the "ability to function on multi-disciplinary skills" in its set of professional skills[4].

In our experience as engineering educators, based on observations as well as employer and student exit surveys, the traditional academic setting cannot give sufficient experiences for reasonable team skills to develop; it cannot create sufficiently longitudinal factors that can influence team construction, assigned tasks, behaviors, and personnel issues. Moreover, teamwork skills are rarely "taught" in engineering curricula[5]; in fact, compared to business representatives, university educators have been found to underestimate the value of teamwork KSAs[6]. Instead, students are expected to develop teamwork and leadership skills via a sink-or-swim approach where they are assigned group work and left to perform as they can. The typical approach when using teaching methods such as problem-based learning (PBL)[7] is to have students learn teamwork skills by doing and then self-assessing afterwards. Typically, in these cases, external observed evidence of student learning of teamwork KSAs is weak[7]. Instead, students learn to efficiently divide work and approach group projects individually, not benefiting from the added learning that comes from group cooperation and problem solving. In addition, when faced with difficult group members or situations, they are not equipped with the necessary negotiation and conflict resolution skills to return to a functioning team. In traditional education, the profile of a typical engineering student is of one that can excel at the individual level but becomes uncomfortable with the "*unpredictable nature of interpersonal interactions*"[8]. Often, these poor teamwork experiences combined with the lack of training and opportunities for guided reflection lead students to dislike working in groups, impacting not just the cognitive, but also the affective domain of learning[9].

1.1 Teamwork training

Engineering programs have a number of choices with regards to the type and extent of teamwork training they can provide students at various curriculum levels. The suitability of a training activity can be evaluated on two principles: fidelity (how closely the module resembles actual working conditions that students face during their studies and upon graduation), and complexity (how difficult is the task and what level of interdependence it requires between team members). While activities that are high in fidelity and complexity may provide better learning for students, programs may find it easier to go after low-fidelity (and sometimes, low complexity) activities that are less resource-intense and easier to pilot and implement.[10]

There are several reported instances of teamwork training programs that have been successfully integrated in engineering curricula[10]. The BESTEAMS[11] project at the University of Maryland, for example, is built on three main critical domains: personal (understanding of personal strength and attributes), interpersonal (how to communicate with others), and project management

(optimizing the team process and product). Introductory, intermediate, and advanced modules are delivered to students from first year all the way to their capstone design projects. The effectiveness of the introductory modules was evaluated through a brief survey at the conclusion of each module, which asked students about their perceptions around the content and delivery of the modules[12]. École Polytechnique Montreal offers a core course to their Mechanical Engineering students (MEC1201 – Travail en équipe et leadership) with specific instruction and assessment of teamwork and leadership skills[13,14]. This course is taught in the first year of the program, and is intended to set up the future project work that students will perform. Another model has been that of creating professional skills and teamwork training programs that sit separate from the engineering curriculum. At the University of Tennessee, for example, communication, leadership and teamwork skills are taught to engineering students through a special minor that includes a series of five courses[8].

1.2 Description of workshop series

At the University of Waterloo, students have limited opportunities for acquiring formal training in working and communicating in teams. As part of the curriculum, students participate in a minimum of five four-month co-operative (co-op) work terms in industry. While on co-op, students may choose to take an elective professional development course on teamwork; however, we have found that actual student enrollment in this course has been very limited. During academic terms, students have the option of enrolling in a student leadership program[15] (that encompasses teamwork skills), but, again, only a small portion of engineering students choose to do so. For a majority of students, a limited level of teamwork instruction is achieved passively in the form of team peer evaluations, usually in capstone design courses and more rarely in other courses. Given the currently limited and fragmented opportunities to learn about why and how to work in teams, engineering students may not know: (1) why teams exist and why good teamwork is important, (2) how individuals can be effective team members, and, (3) how to structure work within the team, track progress, and deal with issues along the way.

In response to this identified weakness, a committee of representatives from various departments in the Faculty of Engineering and other teaching and support units are developing a series of six workshops that will be delivered to engineering students in their first three years of study (Figure 1). These workshops are envisioned as experiential learning activities based on team-based engineering activities. The first three workshops intend to provide an introduction to (1) team-forming and building, (2) communication, and, (3) conflict management, respectively. The last three workshops provide reinforcement and opportunities for application in the same areas and in multidisciplinary settings, as well as instruction in planning, role development, and collaborative and creative problem solving. The workshops are designed based on the principle that teamwork skills are best learned by doing[1], i.e., by practicing in a context that approximates common team experiences in engineering, while also incorporating teamwork specific reflection into the activity.

In their final year, all engineering students undertake a major team-based capstone design project; this is regarded both as an opportunity for students to practice and demonstrate the teamwork skills developed and as a final opportunity for learning and reflection in a major team-based project.

Figure 1. Planned series of six teamwork workshops by academic term

The focus of this paper is on the first *two* workshops that have been developed and implemented as of April 2016. In Section 2, we delve into the detailed description of the design of each workshop and outline important observations made in their delivery. In Section 3, we describe the approach taken to assess the effectiveness of the two workshops and review the results of pre- and post-workshop survey responses. In Section 4, we provide a general discussion of the delivery of the first two workshops and identify opportunities for improving their content, delivery, and assessment.

2. The first two workshops

In this section, we present a detailed description and evaluation of each workshop and reflect on lessons learned as we work to develop the remaining four workshops.

2.1 First workshop – Introduction to effective teams

The purpose of the first workshop was to introduce the wider Teamwork Workshop Series to first-year engineering students and to provide some basic instruction on team effectiveness. The workshop was built as an interactive session, allowing for student participation in two variations of a simulation game as well as group discussions, a background presentation on the basic theory of effective teamwork, and individual student reflection. By the end of the session students were expected to be able to use strategic questions to clarify their team's mission and goals, identify and attend to individual and team interests in order to foster team motivation, and implement strategies that encourage a supportive and positive team culture.

2.1.1 Description

After multiple pilot offerings in the winter and spring terms of 2015, the first comprehensive roll-out of this workshop was carried out in the fall of 2015 to over 800 engineering students in their first engineering term, enrolled in 8 of the 14 engineering disciplines at the University of Waterloo. The average class size was approximately 100 students (with a minimum of 65 and maximum of 140). For each participating discipline, a suitable first-year course was targeted to host the workshop and specific time slots were arranged with the course instructors. These sessions were offered as early as week 2 and as late as week 9 in the 12-week fall semester. Almost all sessions were facilitated by a graduate Teaching Assistant that was hired and trained for this specific purpose. In many cases the course instructor and/or a Teaching Assistant from the host course also attended and supported the workshop delivery.

Materials required for the workshop were plastic bins with approximately 300 straws and 300 connectors of four or five different colors (Roylco brand) for each group, nametags showing the group assignments, and handouts for each student. In addition, presentation slides and presenter notes were prepared to ensure consistency in the delivery of sessions among different classes.

The workshop began with a hands-on activity. Students were randomly assigned into groups of five or six and given a task of building "the biggest and the best" fort as a team, using the straws and connectors they were provided. The goal was intentionally kept vague to illustrate the importance of clearly defined goals and objectives. Throughout the activity, several challenges were introduced to artificially create conflict situations within the groups. Specifically, (1) the time allocated for the build was unexpectedly reduced from 20 to 15 minutes about 10 minutes into the activity, (2) one member from each group was randomly selected and assigned to join another group, and (3) upon joining the new teams, they were to announce to their new group members that yellow connectors were defective and not supposed to be used in the structures. Finally, three randomly selected students were assigned to evaluate the structures and determine the three "highest ranking" designs based on criteria they developed independently of the builders. The total time spent on the activity, including the announcement of the winning teams was roughly 20 minutes.

After the activity, the class reconvened to debrief. Various questions were posed to facilitate a group discussion on how each group came up with a strategy, how they assigned tasks to individuals, whether/how they enabled each member to express their ideas and opinions, how the challenges affected their productivity, and how they could relate their experience in the activity to real life teamwork environments. At this point, with the assistance of a slideshow presentation, the facilitator shared some theoretical concepts on the characteristics of effective teams[16] and strategies to adopt these characteristics. In particular, the facilitator emphasized the importance of setting a clear team mission and goals, achieving team motivation through the careful balance of each team member's interests, and a team culture that promotes and encourages contribution from each team member.

Students then participated in a modified version of the fort-building activity, which was intended to be more structured and reflective of the knowledge students had just been provided. To this end, the goal of the second build was modified to "maximizing the team score, objectively measurable by a given metric". The metric to be maximized was $(n + s)(h - 4) - y$, where $n, s, h,$ and y were defined as the total number of towers, the number of square towers, the height of the tallest tower (in number of straws), and the number of yellow straws used, respectively; the complexity of the metric formula was a deliberate effort to cloud the identification of an optimal building strategy in terms of focusing on height vs. number of towers. Furthermore, several restrictions were imposed on the structures to be built, such as the definition of a tower and its minimum height. This time, no artificial challenges were introduced and teams built their structures without interruptions. Similar to the first activity, a debriefing session was held at the end to focus mainly on how an objective evaluation criterion, a clear goal, and certain restrictions contributed to team effectiveness.

At the end of the workshop, students were provided with worksheets and encouraged to reflect on what they had experienced during the workshop (and on other relevant teamwork experiences) and to identify their most prevalent strengths and weaknesses in the teamwork

context. The total length of the workshop varied from 80 to 120 minutes, depending on the time allotted by the host course.

To collect student perceptions on the workshop and assess their achieved learning, pre- and post-workshop surveys were prepared using Qualtrics software. Students were provided URL links to the surveys and given 5 minutes to complete them in class using their smartphones or other personal computing devices. Survey results are discussed at length in Section 3.

2.1.2 Observations

The implementation of the workshop in different disciplines, classrooms, and with different class sizes provided a wealth of observations, enabling the formulation of a number of recommendations for future implementations.

First, student attendance was very high (approximately 95%, on average) despite the lack of grade incentives for participation. Students were likely curious to experience a session that fell outside the regular course curriculum. This was especially true in cases where the importance of teamwork was sufficiently emphasized prior to the workshop. To that end, the role of the course instructor was essential. We observed that classes which had been given a prior introduction (via e-mail or in class) to the workshop appeared more engaged in the activities and discussions. Similarly, the presence of an instructor at the session, in general, positively affected students' active participation.

A second observation relates to classroom size. Classrooms that were too small to have 15–20 groups simultaneously build towers of straws and connectors appeared to be very challenging both from the students' and the facilitator's perspective. For an efficient implementation, the room should have enough space for students to be able to work comfortably and for the facilitator to walk around observing the group dynamics to reference later during the activity debrief. On the other hand, very large classrooms affected the quality of group discussions primarily due to difficulty of hearing and following the discussions. One way to address this problem would be to hold all sessions in a suitable pre-determined location that would satisfy the needs of both the hands-on activity and group discussions.

Third, the size of the class affected the ideal workshop length. Specifically, due to the interactive nature of the workshop, the time spent on assigning students to groups, cleaning up, and reconvening was highly dependent on the class size. Since the duration of the session was fixed, this led to the need to crop some parts of the session in some instances. According to our observations, a class size of 70–80 is ideal for this workshop.

Finally, since the kits containing straws and connectors were repeatedly used for all sessions, the quality of the materials quickly deteriorated and many of the straws broke. Although this posed an unintended challenge during the activity (i.e., work with actually defective materials), which led to some very insightful discussions, it was a frequent source of frustration for the students.

2.2 Second workshop – Introduction to effective communication in teams

The focus of the second workshop was on effective communication in teams. While it was intended to succeed the first workshop, it was designed in such a way that students could successfully complete it without the background knowledge received in the first workshop. This

enabled us to offer the delivery of the workshop to students in engineering disciplines that had not participated in the first workshop, thus increasing the pool of students on which this first implementation could be rolled out.

Like the first workshop, it was built as an interactive and hands-on session. By the end of the workshop students were expected to be able to implement effective communication strategies, assess and articulate personal strengths in communicating in a technical environment, and confidently respond to an interview question regarding their ability to communicate to technical and non-technical audiences.

2.2.1 Description

The second workshop was rolled out in the winter of 2016 to first-year engineering students in their second term of studies. The workshop was delivered to over 450 students in 7 of the 14 disciplines, 5 of which took place in their first week of classes for the term. The reason for the reduced uptake compared to the first workshop is that the other students were off campus on their first co-op work term.

The average class size was approximately 100 students (with a range of approximately 50 - 120). All sessions were co-facilitated by an engineering instructor and a member from one of the support units that frequently develops and delivers similar workshops. Additionally, three students (internally employed on co-op terms) provided logistical support during the sessions in addition to helping prepare workshop materials and providing feedback from the student perspective throughout the initial stages of workshop development.

The first activity in the session was intended to increase student motivation in the rest of the session. The facilitators discussed industry expectations and the benefits of having well-developed communication skills for engineers. Students were then provided with a sample interview question and asked to write their answer in a provided worksheet. The interview question challenged them to describe a time when they had to explain complicated technical terms to an individual without the same background knowledge and to reflect on how they ensured that individual understood. Students were then prompted to reflect on the quality and depth of their responses, an activity which helped them to begin identifying their strengths and weaknesses in communicating technical content to various audiences. It is important to note that all students were scheduled to go on a co-op term the following term and thus succeeding in upcoming interviews was a relevant and important topic to them.

In the following activity, students were randomly assigned to teams of six (based on a code on their handout) and given one of three roles, director (2), runner (2) or builder (2). The activity replicated the typical flow of information/ideas between project managers, engineers/designers, and workers working on a common project. The directors were given two isometric images of a final product, which was a LEGO structure comprised of eight unique pieces (Figure 2). The structure was to be recreated by the builders. The builder's kits included the necessary LEGO pieces as well as one or two additional pieces. The runners were the only means of relaying information between the directors and the builders. While the directors and builders could provide unlimited information and ask unlimited questions to the runners, the runners were limited to two questions at each interaction with either the builders or the directors. The runners' only means of relaying information between the builders and directors was the use of verbal and

textual written communication; the use of images or diagrams was prohibited. Further, the runners could not travel together or communicate with one another.
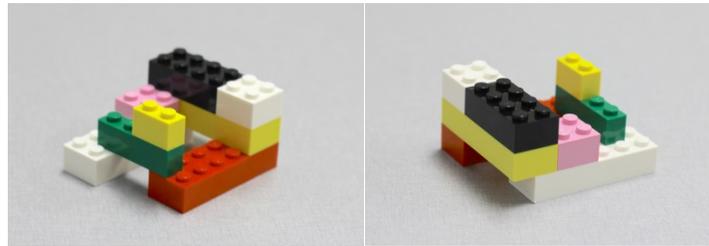

Figure 2. An example of a final product image (front and back) used in the second workshop

The activity was followed by a group reflection and discussion about the specific communication challenges the teams faced. Then, with the assistance of a slideshow presentation, the facilitators shared a recommended process for improving communication. The steps involved included asking strategic questions and knowing when to use closed vs. open questions, active listening and being aware of non-verbal cues, and summarizing and paraphrasing to check for understanding.

With the theory and a process to guide them, students were given 5 minutes to develop a team plan using the new strategies before completing the activity again. This time each member was given a new role and each team received a new LEGO structure comprised of ten pieces to recreate. After the activity, teams were once again given 5 minutes to reconvene and discuss their success. A group debrief then explored the second experience specifically focusing on how the strategies and time to develop a team plan affected their teamwork and individual communication skills.

Finally, the session wrapped up with an opportunity for students to reflect on their personal strengths with respect to communication. Each student revisited their initial mock interview response and was prompted to rewrite it with a more developed understanding of communication strategies and their individual strengths in mind.

In terms of materials, a total of 44 activity kits were prepared, 22 for the first activity and 22 for the second. Each kit included three unique packages that provided the necessary materials for the three different roles comprising each team: director, runner, and builder. In addition, the workshop also required the preparation of presentation slides, presenter notes, and a handout (worksheet) for each student. The handout was also used to assign team membership and roles to the students in each of the two team activities.

2.2.2 Observations

The seven sessions were closely observed by a number of representatives from the Faculty of Engineering and other support units that were directly involved in the development of the workshop. Below we summarize some important considerations (logistical and otherwise) and recommendations for future implementations.

A first observation relates to group size: while the activity was set up to be completed in teams of six, during the different sessions, team sizes varied from as few as four to as many as seven with little effect on the learning outcomes. Simple adjustments were made such that, when the team

size was smaller than six, builders and/or directors were reduced by one, and when the team had seven members, an extra director role was added.

A second observation relates to classroom space and size. The implementation of the workshop took place in a large computer lab. This gave the teams ample space to ensure the directors and builders could not see or hear one another. In addition, to ensure that teams working beside one another were not able to overhear descriptions or instructions from the teams surrounding them, two versions of the LEGO structures were created and distributed in an alternating fashion. This was less of a concern in the large computer lab; however, in a smaller, more traditional classroom space the alternating versions would likely hold greater importance.

Further, as also observed in the first workshop, the large space negatively affected the quality of group discussions. However, the availability of two co-facilitators supported by the three co-op students allowed for better interaction and discussion. Additional time was allotted to the teams to reflect amongst themselves, before sharing their thoughts with the class. The facilitators also used this time to connect with each of the teams and to prompt their reflection and further individualize learning. During the wider class discussion, the facilitators were better able to speak to specific examples they had heard and students were better prepared and more willing to contribute a response. Additionally, the three co-op students brought a microphone around to discussion contributors to ensure their responses were audible to everyone in the space.

Two important observations were also made with regards to the facilitation model employed and the level of integration of the workshop content with the larger academic context of the participants.

First, the co-facilitation of the sessions by an engineering instructor and a representative from a support unit that has extensive experience developing and facilitating such workshops proved to be valuable. This pairing allowed for the latter to clearly articulate the theory and strategies while the former provided greater context to the content. This in turn enabled the students to more directly relate the activities and strategies to their particular disciplines.

Second, the timing of the workshop within the context of term schedule has an impact. Presenting the material from a lens of professional skill building with opportunities to reflect on and refine resume writing and interviewing skills proved to be a valuable motivator for participants. When the workshop was scheduled during a time when students were about to begin applying for their first co-op placements, attendance and engagement with the material was high. In contrast, one of the seven sessions was delivered the week immediately preceding midterm exams and after co-op interviews had already started taking place. Attendance at this session was lower. In addition, students were noticeably less engaged and more distracted throughout.

3. Assessment

As the workshops are developed and implemented, a need arises for the assessment of the effectiveness of workshops in improving students' teamwork-related KSAs, including both interpersonal (conflict resolution, collaborative problem solving, communication) and self-management KSAs (goal setting, performance management, and planning and task coordination)[17]. The literature on teamwork training assessment has shown that training can

improve team effectiveness[2]. To address both stages of developing teamwork KSAs, an effective teamwork training session combines "book learning" with "experiential learning"[18]. Accordingly, teamwork training is evaluated by its impact on (1) team member's knowledge of generic teamwork competencies (or "declarative" knowledge), and, (2) transfer of that knowledge to a new performance environment[19]. The former is often measured through self-appraisal surveys and pre- and post-activity quizzes, while the latter is better measured through peer evaluations and assessment of performance of team tasks in simulated contexts[18-20].

The planned assessment of the teamwork training series as a whole includes a combination of self and peer appraisal to be applied at different times, including assessment of: (1) knowledge gained immediately at the time of workshop delivery, (2) student attitude and perception later in the term of delivery, and, (3) behavioural changes in the major capstone project at the end of the program. The latter is particularly important as it provides evidence that the students can transfer their knowledge and skills to a different application, i.e., that deep learning has been achieved.

In the context of the first two workshops, we assessed (1) whether students had objectively improved their declarative knowledge of teamwork concepts, and (2) whether they perceived the workshops to be effective in improving their teamwork skills. Assessment was achieved through anonymous surveys that were conducted immediately before and after each workshop.

3.1 Assessment of the first workshop

Surveys were completed online during the workshop on the students' personal devices. The pre-workshop survey questions were designed to assess the students' existing perception of their teamwork skills and their initial knowledge of the specific teamwork paradigms discussed in the workshop. The post-workshop survey was intended to capture the students' immediate reaction to the workshop, as well as their suggestions for improvement. In addition, three of the questions tested the same 'knowledge' questions that were tested in the pre-workshop survey, in order to assess whether any knowledge gains had been made as a result of the workshop.

3.1.1 Assessment of knowledge of teamwork concepts

Three knowledge questions were asked in identical format in the pre- and post-workshop surveys. All three questions were presented in multiple-choice form. The questions were:

1. According to Tuckman, there are five stages to team development. Which of the following is their correct order?
2. An effective team has a clear mission and goals. This is best achieved in the following way:
3. The "Yes, and …" method can create a positive team culture by…

The usefulness of the results was mixed. Student answers to the first question clearly indicated learning in terms of specific knowledge of the five stages of teamwork development, as defined by Tuckman[21]. The percentage of students that identified the correct sequence of stages (forming, storming, norming, performing, adjourning) increased from 34% in the pre-workshop survey to 75% in the post-workshop survey. In addition, the percentage of students that stated that they did not know the stages decreased from 39% to 6%. The results of the second question were less encouraging; in particular, there appeared to be a (insignificant) *decrease* in the percentage of students that chose the right option "*All team members come together and define a*

common goal" (58% to 49%). This result is tentatively attributed to some overlap/ambiguity in the available response options. Similarly, student responses to the third question were almost identical before and after the workshop, with 89% of students responding correctly in both cases. The question was intended to measure student awareness of a specific idea generation strategy ("Yes, and …") introduced in the workshop; however, unlike the first question, it did not provide an option for not being aware of the strategy. In addition, it appears that the wrong answers were not significant distractors. These questions will be revised when the workshop is delivered again with next year's cohort.

3.1.2 Student self-assessment of teamwork skills and perceptions of workshop effectiveness

A second set of questions measured student assessment of both their own teamwork skills as well as the overall effectiveness of the workshop in improving those skills. Students were generally confident in their awareness of their own teamwork skills before the workshop and also generally found the workshop to be of value. Although *before* the workshop, 87% strongly agreed or agreed with the statement "*I am aware of my strengths and weakness in working effectively in team environments*", after the workshop, a majority (64%) strongly agreed or agreed with the statement "*After having participated in the 1A Teamwork Ideas Clinic, I am **more** aware of my strengths and weaknesses in working effectively in team environments*" (emphasis in original). Students also recognized the relevance of the workshops to engineering practice, with 73% agreeing or strongly agreeing with the statement "*I think the workshop contributed to my professional development as an engineer*". There was also general agreement that the workshop was useful in developing teamwork skills, with 63% of students responding "*Yes*" to the statement "*The workshop helped me develop my teamwork skills*" (25% "*Unsure*" and 12% "*No*").

Some of the questions were intended to measure the students' immediate reaction to the workshop. A majority (85%) of the students found the workshop useful and stated that they would be willing to participate in a similar workshop (focusing on different aspects of teamwork) in the future. The students who disagreed provided the simplicity of tasks and challenges as a reason. Furthermore, several students indicated that they would benefit more from such a workshop if the activities were directly relatable to their fields of study. While simplicity and commonality (to all engineering disciplines) were the intended features of the first workshop, student feedback clearly indicated that the students preferred more complicated tasks/challenges that were tailor-made to their disciplines.

3.2 Assessment of the second workshop

As in the case of the first workshop, a survey was administered to the students before and after the second workshop. For the most part, students were given the same questions in both surveys in order to assess how their knowledge and perception changed during the activity. In addition, the post-workshop survey included a few more questions that sought to capture student perceptions of the effectiveness of the workshop.

3.2.1 Assessment of knowledge of communication concepts

Three multiple-choice questions were used to assess student gains (if any) in the knowledge of concepts that were directly "taught" in the workshop. The three questions challenged students to

correctly identify an open-ended question, identify the best approach to learn more about the audience, and indicate how summarizing and paraphrasing help when communicating with someone, respectively. A summary of student performance on questions 1–3 is given in Table 1 below. There was a noticeable increase in the number of students who could answer the questions correctly after the session.

Table 1. Aggregate data for six sessions of the second workshop.

| Question # | Number of students (out of total) that answered correctly | |
	Pre-workshop	Post-workshop
1	361/471 (77%)	277/330 (84%)
2	250/470 (53%)	251/334 (75%)
3	400/469 (85%)	294/329 (89%)

The data in Table 1 shows that the total number of respondents was approximately 30% higher in the pre-survey compared to the post-survey. One possible explanation is that the students who were disengaged in the workshop simply did not fill in the post-survey. One could argue that the drop in respondents artificially inflated the percentage of correct responses in the post-survey. Therefore, we conducted a more detailed analysis, focusing on the data from the session (of six total) that had the smallest participation drop-off from pre- to post-survey (Table 2).

Table 2. Data for session with smallest drop in number of respondents.

Question #	Correct – pre-workshop	Correct – post-workshop
1	78/95 = 82%	65/76 = 86%
2	60/95 = 63%	67/77 = 87%
3	75/95 = 79%	70/76 = 92%

While this session saw a drop of 18% in the number of respondents from pre- to post- survey, it still showed gains in the number of correct respondents in all three questions.

3.2.2 Self-assessment of communication skills and perceptions of workshop effectiveness

A second set of questions measured student self-assessment of their teamwork and communication skills. The questions presented Likert-scale responses for students to select from. Of particular interest are student responses to two questions. The first asked students to rate their level of agreement or disagreement with the statement "I enjoy working in teams". The second asked them to rate their level of confidence in using four different communication skills.

When comparing pre- and post-workshop responses for the six sessions for which we have survey data, the percentage of students that agreed or strongly agreed with the statement "*I enjoy working in teams*" increased from 66% ($n = 466$) to 77% ($n = 327$). Further, in response to the second question, students reported an increase in their level of confidence ("*confident*" or "*somewhat confident*") in the skills of tailoring their message to the audience (69% to 78%), asking strategic questions (68% to 81%), and paraphrasing and summarizing (73% to 84%). The confidence in the skill of active listening remained virtually unchanged (89% to 87%).

A third (and final) set of questions prompted students to share their immediate reaction to the workshop's effectiveness. Overall, student feedback was positive. In particular, 71% of students ($n = 337$) agreed or strongly agreed that the clinic contributed to their professional development as engineers, with 88% ($n = 335$) stating that they would recommend the workshop to first-year students the following year. Students also provided constructive feedback by both identifying areas of weakness and suggesting improvements. In particular, 32 students expressed that the length of the workshop was not sufficient and suggested that it be increased to include more content and/or more build phases. Several students wished they could have experienced all three roles present in the activity, instead of just two. Some students were also very concerned that some of their classmates may not have been following the rules and wished that the facilitators "policed" the activity better. Reading between the lines, this could point at a high level of student engagement in the activity.

A small minority (seven students) stated that they had already developed similar skills in the past. Students are entering the program with differing backgrounds, and so creating an activity in which all students learn an equal amount is a challenge. Nevertheless, even students that possess the teamwork skills that the workshops intend to provide can benefit from the opportunity to reflect on prior learning. In addition, they can enhance the learning context of others in the class through their engagement and participation in the activity. Anecdotally, the facilitators of this workshop noticed that all groups were actively engaged throughout the sessions.

4. Discussion

Reflecting back on the two activities that were rolled out so far, we identify some important common observations and lessons learned.

First, student motivation and engagement in the workshops was increased when the professor in charge of the host course prefaced the activity with the importance of the skills the session addressed. It is possible that in cases in which the professor introduced the workshop's purpose to the class in advance of the sessions, students had an opportunity to consider their potential relevance ahead of their delivery. In addition, students generally hold their professors as sources of valuable knowledge and experience related to their development as engineers, thus making professors' 'endorsement' of the sessions important. Prior research has demonstrated the importance of student interest in enhancing their engagement and attitude towards learning[22]. The sessions have yet to be fully integrated into a course (or around course activities) and may therefore be perceived by students, at least to some degree, as external to the course curriculum. If the sessions became fully integrated into or around existing course activities, students may see more value in the activities as relevant skill development opportunities.

Second, the workshops highlighted the importance of activities that approximate team experiences in engineering and which are perceived as appropriately complex. While our game-based activities in both workshops may have replicated some aspects of team experiences in engineering, several students expressed that the activities/games were 'too childish,' not complex enough for their level of experience and understanding of the skills they aimed to develop, or not sufficiently based on engineering concepts. Further investigation of the efficacy of game-based activities with engineering students could be valuable. Measuring the effectiveness of these game-based activities would also contribute to the larger engineering educational literature, as there is currently limited empirical evidence on this topic[23]. However, care must be taken to

ensure that learning teamwork skills does not become overshadowed by the engineering task itself.

Third, the workshops also highlighted the need to design activities that are directly relatable to the students' specific engineering disciplines. While the complexities of teamwork are likely relevant and common to all disciplines, engineering students at the University of Waterloo do not share a common first-year engineering curriculum and are thus more likely to strongly identify with their discipline early on in their first year of studies. Thus, the examples and activities used in the workshops need to be contextualized appropriately in order for students to comprehend how the skills will be relevant and applicable in each discipline. In the case of the LEGO activity in the second workshop, a common context was established, yet, it was difficult for some students to make the connection between the activity and the skills being practiced and their implications or relevance in industry contexts. This was likely an outcome of the lack of significant prior work experience in industry for these students. We may find the results to be different when we offer this workshop again in the spring of 2016 to a different set of students who will be returning from their first co-op experience; they may be better prepared to connect the content/skills to real world experiences and situations.

As we look ahead to developing and delivering the next four workshops in the series as well as re-offering the first two workshops to the next cohort of students, we identify several opportunities for improvement and challenges along the way. The consideration of other approaches to the pedagogical design of the activities embedded within the workshops could be considered, for example taking a more integrative approach or using problem-based learning[7] to improve student inquiry. A more integrative approach can better embed the workshop content and activities into the existing curriculum of host courses and add value to discipline-specific content that is already delivered in them. Further, an integrative approach incorporates the professor of the host course more naturally into the delivery of the workshop content itself, which has been observed to increase student motivation and engagement with the workshop content.

While integrating the workshops with existing activities within a course is desirable, there are several complexities that must be considered before adopting this approach. First, maintaining the current workshop structure, which includes instruction on teamwork theory and the delivery of the pre- and post- quizzes, necessitates the identification of suitable workshop facilitators, content hosts, and timing of delivery around the existing course activity. There is the additional challenge of identifying courses/activities within each of the programs that will allow for both a differentiated experience among disciplines and for the transfer of a shared knowledgebase of teamwork concepts and the development of equally relevant and transferable skills. A third challenge is gaining the buy-in from professors of targeted host courses that are willing to integrate the workshop content into their curricula. In this regard, careful assessment of workshop effectiveness in improving student teamwork KSA skills may significantly lessen this challenge.

5. Conclusions

As engineering programs in Canada move towards outcome-based assessment, the need for instruction on and assessment of student teamwork skills has become clear. The planned series of six teamwork workshops provides programs across the faculty with a common instructional tool

to achieve this, relying on collaboration between engineering departments and other support groups to create sessions that are relevant to a diverse student body. The stand-alone nature of the series of workshops makes it also highly adaptable not only for other engineering schools, but also for non-engineering programs that may identify the need for teamwork instruction and assessment in their curricula.

In this paper, we have presented a detailed description of the first two workshops in the series that have been developed and delivered so far, and shared our observations and recommendations for future implementation. Detailed assessment using pre- and post-workshop surveys have provided encouraging evidence that the workshops were well received by the students and that they can improve students' declarative knowledge of teamwork concepts. It is expected that the fine tuning of current surveys as well as the development of assessment tools for future workshops will contribute to the continuous improvement of the whole series of workshops as well as demonstrate their overall effectiveness in improving students' teamwork KSAs. In addition, assessment of students' teamwork KSA can be used by the faculty and programs to assess the 'teamwork' graduate attribute for accreditation purposes. Finally, outcomes of the assessment can also help secure more buy-in from departments and individual instructors, thus enabling a smoother integration of the workshops in the engineering programs' curricula.

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