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Evaluating a Communication Framework for Team Effectiveness in a First-Year Design and Communication Course

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Genevieve is completing her honours degree under the supervision of Dr. Thomas O'Neill at the University of Calgary looking at the influence processes in teams. She has been working with the Schulich School of Engineering for the past three years during which time her focus has been on improving team dynamics and maximizing the student experience. In addition co-developing the communication training framework that has now been applied to over 2500 students campus wide, Genevieve has personally facilitated many of the training sessions. Her goal is to continue working on developing applicable and universal tools to improve the functioning of both student and industry teams in institutions and organizations across North America.

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Nicole is completing her final year of her Masters in Industrial Organizational psychology at the University of Calgary under the supervision of Dr. Thomas O'Neill. Nicole has been working with the Schulich School of Engineering for the past two years. During this period she has been involved in several initiatives such as assessing student learning and engagement, implementing systems for peer evaluations, and leading teamwork training sessions. She is currently conducting research on team learning processes in engineering student project teams. Additionally, she has co-developed a framework for measuring and interpreting an array of team dynamics. An online assessment tool has been created based on this framework which allows teams to diagnose and improve the "health" of their team. She is passionate about her area of research and plans to continue conducting research on factors that contribute to effective teamwork.

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Tom is a Professor of Industrial/Organizational Psychology and leading expert in the areas of team dynamics, virtual teams, conflict management, personality, and assessment. He is director of the Individual and Team Performance Lab and the Virtual Team Performance, Innovation, and Collaboration Lab at the University of Calgary, which was built through a $500K Canada Foundation for Innovation Infrastructure Grant. He also holds operating grants of over $300K to conduct leading-edge research on virtual team effectiveness. Over the past 10 years Tom has worked with organizations in numerous industries including oil and gas, healthcare, technology, and venture capitals. He is currently engaged with the Schulich School of Engineering at the University of Calgary to train, develop, and cultivate soft-skill teamwork competencies in order to equip graduates with strong interpersonal and communication capabilities.

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Marjan Eggermont is the current Associate Dean (Student Affairs) and a Senior Instructor and a faculty member at the University of Calgary in the Mechanical and Manufacturing department of the Schulich School of Engineering, University of Calgary, Canada. She teaches graphical, written and oral communication in their first Engineering Design and Communication course taught to all 650 incoming engineering students. With co-editors Tom McKeag (San Francisco) and Norbert Hoeller (Toronto) she co-founded and designs ZQ, an online journal to provide a platform to showcase the nexus of science and design using case studies, news and articles (zqjournal.org). As an instructor, she was one of the recipients of The Allan Blizzard Award, a Canadian national teaching award for collaborative projects that improve student learning in 2004. In 2005, she was one of the recipients of the American Society of Mechanical Engineers Curriculum Innovation Award. She is - as PIC II chair - currently a board member of ASEE.

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Abstract

Teams are the foundational building blocks of organizations, utilized to derive increasingly innovative solutions to complex problems in order to maintain a competitive market advantage[1]. As such, the development of teamwork-based skills has been identified as a critical competency in engineering education required to prepare graduates for team-based projects in industry. While most engineering faculty have relatively effective methods in place to teach students' technical skills (e.g., design fundamentals, problem analysis, etc.), it is sometimes challenging to find suitable tools to support communication and teamwork skill development. In response to this challenge, a collaborative partnership between the Psychology and Engineering department at the University of Calgary has yielded a theoretical-based communication technique applied to the engineering curriculum in order to enhance team effectiveness.

While teams stimulate an innovative environment, the interdependence of individuals leads to an increased risk of conflict between members[2]. Teams literature has identified three types of conflict that can arise[3]: task conflict (TC), relationship conflict (RC) and process conflict (PC). Briefly, TC involves contrary perspectives and opinions about the task, RC refers to perceived interpersonal incompatibilities (i.e., personality clashes), and PC involves discordant views of roles, responsibilities, and/or task timelines. The aforementioned collaboration discovered an ideal conflict combination, or profile, linked to higher performance and positive team dynamics. Specifically, teams that engaged in task-related debates (i.e., high TC) while being unhindered by interpersonal tensions and logistical disagreements (i.e., low RC & PC) performed best. Thus, the goal of teamwork education might be advanced by encouraging this ideal conflict profile.

Reaching this ideal profile may lie in a communication framework known as constructive controversy[4] (CC). CC requires an openness to new perspectives, challenging of assumptions, and identification of optimal courses of action[5]. Adapting this theoretical foundation, we created an easy to remember acronym, SUIT, which was the basis for a 90-minute training session administered to students. SUIT stands for Share, Understand, Integrate and Team decision. Specifically, teams are taught to share all unique information; understand information through critical questioning; integrate concepts to create innovative solutions; and agree on a team decision to implement a plan. The SUIT training session included an informational overview, followed by a structured role play, a decision making exercise, and team charters.

We report on the results of a study evaluating the effectiveness of CC-based training in two cohorts of a first-year design and communication course. Contrasting 195 untrained (n=577 individuals) and 177 trained (n=566 individuals) teams found an approximately 20% increase in the number of teams categorizing themselves into the ideal conflict profile. Additionally, trained teams reported significantly lower competitive conflict management, higher perceived innovation efficacy, and higher collective team cohesion, strongly supporting the inclusion of the SUIT technique in the first-year curriculum to improve team functioning. Taken together, this evidence-based technique offers a valuable pedagogic foundation that can prepare students for the team-based work prevalent in organizations and holds potential as a universal application to various levels in engineering education.

Introduction
As teams become the building blocks of modern organizations, the need to develop teamwork-based competencies in engineering graduates has been brought to the forefront of both education and research. Specifically, recent changes to accreditation mandates by Canadian professional engineering bodies have identified the need for teamwork skill development in new graduates to better prepare them for team-based work in industry[6]. Furthermore, American accreditation bodies recognize that engineering curriculums should "include communication and collaboration with other design or construction team members," in order to develop communication and teamwork skills in graduates[7]. While engineering departments and faculty have established methods to develop students' technical skills (e.g., design fundamentals, problem analysis, etc.), it can be challenging to find suitable tools to support communication and teamwork skill development. In response to this challenge, a collaborative partnership between the Individual and Team Performance Lab in the department of Psychology and the Schulich School of Engineering at the University of Calgary has developed a theoretical-based communication technique. This technique was applied to the first-year curriculum in order to build teamwork skills and enhance the team experience.

Team conflict
Teams are frequently utilized in organizations to create innovative solutions to complex problems in order to maintain an advantage in today's increasingly competitive market[1]. Although teamwork can promote innovation through the integration of unique ideas, Social Interdependence Theory posits that the increased interdependence of individuals, working together to achieve a common goal, increases the risk of conflict between members[8]. The literature has identified three types of conflict that can arise in teams[3]: task conflict (TC), relationship conflict (RC), and process conflict (PC). TC involves contrary ideas and perspectives specific to a task, RC refers to interpersonal incompatibilities perceived between members (i.e., personality clashes or annoyances), and PC involves conflicting views of member roles, responsibilities, and task scheduling.

Traditionally, these three aforementioned conflict types are considered individually with regard to team outcomes such as performance (i.e., separation perspective). Within this separation perspective, the three conflict types relate in different ways to team performance. Specifically, RC and PC are moderately and consistently detrimental to team outcomes such as performance[9, 10, 11]. In contrast, the impact of TC on team performance is less clear. While past meta-analyses have found a negative effect[9], more recent analyses have reported TC as being positively (or at least neutrally) related to team performance[10, 11].

Despite the need for a foundational theory of individual conflict types occurring within a team, it is unlikely that these interactions are occurring in isolation from one another. In response, a complex view of conflict types has emerged in the literature[12]. This complexity perspective proposes that team outcomes (e.g., performance) are actually a function of the collective, dependent and simultaneous occurrence of all types of conflict occurring within a team at any given time. This idea is in direct opposition to the outdated maxim that all conflict is bad and should be skillfully avoided. In fact, it suggests that teams can benefit from task conflicts, which can inspire innovation through the integration of unique perspectives, if people-related conflict (i.e., RC and PC) can be avoided[13].

The complexity perspective draws support from the general theory of information processing, which suggests that a threat, such as that perceived in people-related conflict (i.e., RC and PC), will increase individual cognitive load. Research has found that this additional strain exhausts cognitive resources that could be directed towards the understanding and critical inquiry of different perspectives[14], which in turn inhibits creativity and triggers rigid thinking[15]. As a result, teams bogged down by RC or PC may be limiting their innovation and subsequent team performance on a task[9]. Thus, teams should actively seek to minimize disputes related to coordination and relationships, which divert valuable cognitive resources, and focus their time and energy on discussion about the task.
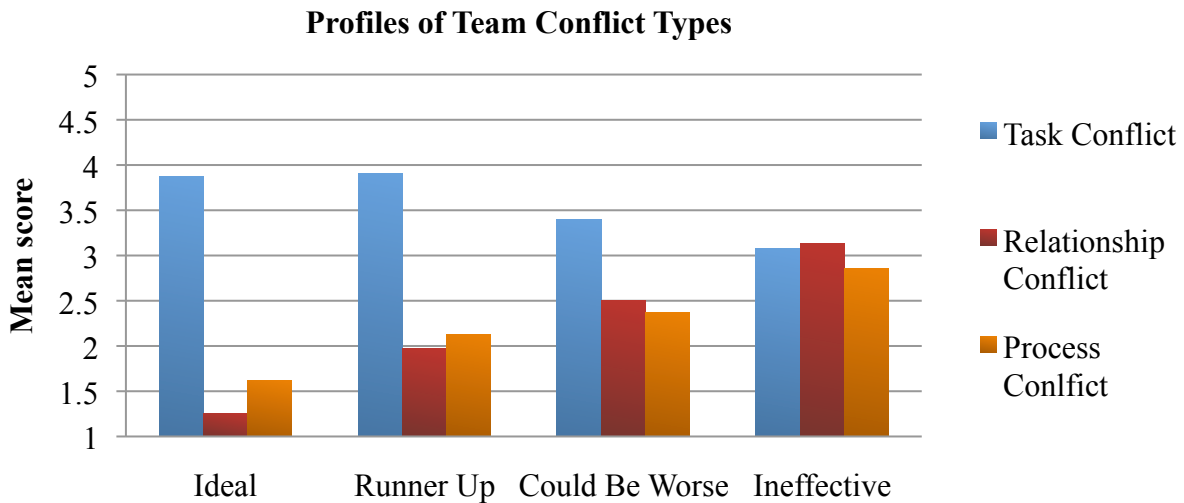
Team conflict profiles
While this ideal pattern of TC, RC, and PC has found little support in the literature, it is likely due to the lack of experimental research clearly testing the complexity perspective. Accordingly, the aforementioned inter-department collaboration revealed evidence for the existence of stable, complex conflict profile structures. Specifically, four team conflict profiles were identified through latent profile analysis, which were defined by distinct patterns of TC, RC and PC (see Figure 1). Accordingly, the four emerging profiles were labeled for ease of reference as the 'ideal', the 'runner up', the 'could be worse', and the 'ineffective'. While the profiles that emerged from a latent profile analysis are referenced, the complex statistical methods by which they were confirmed is not the focus of this paper and will not be reported. However, validation of these structures was found in engineering student team samples from two large, separate Canadian universities[16] and further investigation revealed that the conflict profiles had functional implications for team dynamics (e.g., performance). Specifically, teams in the 'ideal' conflict profile (i.e., high TC, and low RC & PC) performed best. The level of performance decreased step-wise in the three subsequent profiles (i.e., runner up, could be worse, and ineffective, respectively). The discovery of an ideal conflict profile aligns with what would be predicted by the complexity and information processing theory previously described. Thus, targeting and encouraging the most effective conflict profile in student project teams might hold a key to reaching the goals of teamwork education in engineering.

Communication framework
In order to progress towards the ideal team conflict profile, the aforementioned research collaboration investigated a communication framework known as constructive controversy (CC), utilized successfully with managers in the decision-making literature[4, 5, 17]. CC requires openness to new ideas; critical analysis of perspectives and assumptions; and action plan creation. Specifically, Tjosvold[18, 5] offered four stages of CC: (a) Develop and Express: individuals present their personal view to the team, and, in so doing, enhance their own understanding of their ideas; (b) Question and Understand: once confronted with opposing views, uncertainty and curiosity result, which leads to a search for clarifying information about others' perspectives; (c) Integrate and Create: various elements of different viewpoints are incorporated into a new understanding of the problem; and (d) Agree and Implement: action plans are agreed upon and assigned. As might be expected, groups scoring high on CC are viewed as more innovative[19] and tend to make higher quality decisions[18]. Aligning with the previous theories, CC emphasizes leveraging a team's combined knowledge and mental processing potential through productive,

task-focused discussion. Thus, the CC framework appeared highly consistent with the ideal conflict profile mentioned above and a potential avenue to explore in team training education.

Figure 1.

Profiles of Team Conflict Types

Note. Identified latent team conflict profile structures as defined by distinct patterns of task, relationship and process conflict confirmed in both the trained and untrained cohorts.

Given these theoretical foundations, we sought to explore the theory of constructive controversy as a communication framework for team training aimed at improving the conflict profiles of student teams. In general, we believed the training cohort would express a higher number of teams in the ideal conflict profile. Additionally, we envisioned that the trained cohort would experience better team dynamics and increased quality of the team experience as a result of this shift in their conflict profile.

Method
The control cohort consisted of 577 first year-engineering majors (70% male) in a mandatory design and communication course (ENGG 200) with a mean age of 19.17 (*SD* = .46). Team members were organized into 195 engineering design teams. In comparison, the training sample consisted of 566 first year-engineering majors (73% male) arranged into 177 teams with a mean age of 18.78 (*SD* = 2.10) in the following cohort of the same course.

In both cohorts, teams were required to complete four engineering design projects over the course of a 13-week semester, with 80% of the course grades reserved for team-based assignments. All aspects of the course were identical with the exception of minor changes to the actual content of the team projects. Specifically, projects for the control group (and corresponding weighting for course grades) included a sailboat (10%), a racecar (20%), a biomimetic design (20%), and a video game (30%). In contrast, the training group projects included a musical instrument (10%), a structure (10%), bridge (25%), and racecar (40%). Both cohorts were required to sketch, construct, present and test their designs in the laboratory.

Adapting the theoretical foundation of CC, we created a simple and clever acronym, SUIT, which was the basis for a 90-minute training session administered to students. SUIT stands for Share, Understand, Integrate and Team decision. Specifically, teams are taught to share all unique knowledge, understand information through critical questioning, integrate concepts to create innovative solutions, and agree on a team decision to implement a plan following the four stages proposed by Tjosvold[5]. The complete SUIT training session included an informational overview of team conflict, followed by a structured role play outlining each stage, a decision making exercise (i.e., arctic survival task), and team contracts aligned with each step of SUIT (e.g., teams would write down three ways they would engage in "Sharing"). While the control cohort did not receive the training, surveys were administered to both groups measuring conflict states, conflict processes, innovation beliefs and cohesion exactly two weeks prior to the last day of classes (11 weeks into the teams' lifecycle).

Measures
In order to explore the latent conflict profiles, we adopted RC, PC and TC scales reported by Behfar, Mannix, Peterson, and Trochim[20]. However, we adapted the TC scale so that items referred to specific stages of the engineering student design process: identifying the problem definition, considering design concepts, deciding on prototype specifics, and preparing team presentations. For example, "To what extent are different opinions, viewpoints, and perspectives resolved before settling on your team's problem definitions?" We used a five-point scale with options ranging from *a very small amount* to *a lot* for all of the TC, RC, and PC items. A detailed list of these measures is found in Appendix A.

Indirect measures of team performance and quality of experience were measured on three team dynamic outcomes. First, competitive conflict management (CM) involves a combative approach to goal achievement whereby individuals treat conflict as a struggle with a single victor. This approach manages conflict through individuals' self-interest and does not take into consideration possible shared solutions that would be needed for innovative integration of ideas. Competitive CM was measured with five items[21], and an example item is "Team members want others to make concessions but do not want to make concessions themselves." Second, a four-item scale of cohesion[22] was collected to measure the extent to which members get along, remain united and enjoy working together. An example item from this scale is, "We enjoy spending time together." Responses for both competitive CM and cohesion were provided on a seven-point response scale, ranging from *strongly disagree* to *strongly agree*. Third, team efficacy for innovation is the belief about the team's ability to innovate. This construct was developed in the current research with engineering students specifically in mind. The five item scale included items such as: "How confident are you that your team can develop new techniques?" and "How confident are you that your team can invent new things?" ($\alpha = .93$, ICC[1] = .29). Responses were provided on an eight-point scale ranging from 0 (*no confidence*) to 7 (*complete confidence*). A detailed list of these measures is found in Appendix B.

Results
Analysis of the distribution of teams falling into each conflict profile are reported in Table 1. For the training condition, the distribution of the teams shifted with less teams falling into the "could be worse" (-14.55%) and "ineffective" (-6.52%) and more teams being categorized in the "runner-up" (+4.87%) and "ideal" (+16.2%) conflict profiles. Independent t-tests were conducted

to compare team outcomes revealing significant differences in all variables of interest. Specifically, the training cohort had increased team efficacy for innovation and cohesion with lower levels of competitive CM (t(370) = 6.85, 7.46, and 7.55, respectively). All reported t-tests were significant at p< .001 (see Table 2).

Table 1

Distribution (%) of Team Conflict Profiles

Conflict Profile	Control	Training	Change
1. Ideal	42.56	58.76	+ 16.2
2. Runner Up	25.64	30.51	+ 4.87
3. Could Be Worse	23.59	9.04	- 14.55
4. Ineffective	8.21	1.69	- 6.52

Note. Percentage distribution of the teams in the four conflict profiles from the control sample and training sample.

Table 2

Team Outcome Measures

Outcomes	Control		Training		T-Tests	
	Mean	SD	Mean	SD	t-value	p-value
1. Innovation	5.06	0.90	5.64	0.71	6.85	0.0001
2. Cohesion	4.93	0.85	5.56	0.77	7.46	0.0001
3. Competitive CM	3.48	0.92	2.77	0.89	7.55	0.0001

Note. T-test comparison of mean and standard deviation of control and training cohort outcomes.

Discussion

In the current research, we explored and evaluated the effectiveness of CC-based training in two cohorts of a mandatory first-year design and communication course. Using a complex perspective of team conflict, we found over 20% more of the trained teams shifted into one of the two more effective team conflict profiles, with over 16% more in the most effective profile, supporting inclusion in future courses. The aforementioned benefits of this conflict profile are further bolstered by the results of the team outcome measures. Specifically, teams trained with

the SUIT framework reported significantly lower competitive conflict management[23], which correlates negatively with team performance at $\rho = -.21$. Additionally, teams perceived significantly higher levels of innovation efficacy, meaning they believed they could create more innovative solutions to the problems they were presented in lab. Furthermore, the significant increase in team cohesion reveals the improvement in team relationships that were formed during the team experience. While team cohesion reflects the enjoyment of a teamwork experience, meta-analyses have also demonstrated that it is positively related to team performance[24, 25]. Collectively, the results shown above highlight the effect of the SUIT training framework whereby all team dynamic variables were influenced in the desired direction.

Despite the positive trends highlighted above, the quasi-experimental nature of the study brings attention to the potential for significant differences between the cohorts used in the study. This potential limitation called for highly comparable samples and procedures to maintain high internal validity. Accordingly, we adhered to stringent procedures in regards to the data collection of the surveys and saw no differences that would call for alarm in the demographics collected for each cohort. For these reasons, we believe the samples were relatively equivalent for comparison purposes. Nonetheless, further research is needed to validate the changes seen in the trained group in order to completely attribute the positive shift to the SUIT framework. Additionally, future research should consider the effects of the training on objective performance measures such as team project grades.

Taken together, this evidence-based technique offers a valuable pedagogic foundation that can prepare students for the team-based work prevalent in organizations. Following the shift towards the use of applying behavioral science research to education[26], it is simply not enough to place students into teams and expect them to learn how to work together without guidance[27]. Giving students basic tools to communicate with various organizational levels, professionals and cultural backgrounds in the first-year curriculum will be key to developing successful graduates. While the above study focuses on first year engineering students, the versatility and broad scope of the SUIT communication framework allows for universal application to all levels of engineering education to develop individuals throughout their degree.

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APPENDIX A

Measures of Task Conflict, Relationship Conflict, and Process Conflict

Task Conflict
1. To what extent are different opinions, viewpoints, and perspectives discussed while settling on your team's *problem definitions?*
2. To what extent are different opinions, viewpoints, and perspectives discussed while settling on your team's *design concepts?*
3. To what extent are different opinions, viewpoints, and perspectives discussed while settling on your team's *prototype specifics?*
4. To what extent are different opinions, viewpoints, and perspectives discussed while settling on your team's *team presentations?*

Relationship Conflict
1. How much friction is there among members of your team?
2. How much are personality conflicts evident in your team?
3. How much tension is there among team members?
4. How much emotional conflict is there among team members?

Process Conflict
1. How frequently do your team members disagree about the optimal amount of time to spend on different parts of teamwork?
2. How frequently do your team members disagree about the optimal amount of time to spend in meetings?
3. How often do members of your team disagree about who should do what?

APPENDIX B

Indirect Measures of Team Performance

Self-Efficacy for Innovation
1. How confident are you that your team can develop new techniques?
2. How confident are you that your team can invent new things?
3. How confident are you that your team can be innovative?
4. How confident are you that your team can create new methods?
5. How confident are you in your team's ability to design new devices?

Cohesion
1. We enjoy spending time together.
2. Team members do **not** like each other.
3. Our team would like to hang out outside of our work.
4. Relationships in our team are harmonious.

Competitive Conflict Management (CM)
1. Team members demand that others agree to their position.
2. Team members want others to make concessions but do not want to make concessions themselves.
3. Team members treat conflict as a win-lose contest.
4. Team members state their position strongly to get their way.