

InVEST: Equipping Engineering Students with Professional Competencies and Interpersonal Skills

Anuli Ndubuisi, Ph.D. Candidate
Ontario Institute for Studies in Education,
University of Toronto
Toronto, Canada
Anuli.Ndubuisi@mail.utoronto.ca

Elham Marzi, Ph.D.
Institute for Studies Transdisciplinary
Engineering Education and Practice,
University of Toronto
Toronto, Canada
Elham.Marzi@utoronto.ca

Abstract— Work in Progress: Over the past year engineering education has experienced radical changes. The demand for innovative and accessible methods to deliver top caliber engineering education has been high, while educators have faced numerous limitations in integrating experiential learning methods into virtual classrooms [1][2]. To facilitate a scalable global educational program that fosters inclusivity, diversity, and supports development of lifelong learning and professional skills the International Virtual Engineering Student Teams (InVEST) project developed an Intercultural Competency Modules (ICM) program utilizing the Knowledge Community and Inquiry (KCI) pedagogical model [3] to support students' development of these 21st century competencies within a global virtual team (GVT) projects context. The ICM program provided intercultural, virtual-team, decision making, and conflict resolution-based content for student participants from various countries, institutions, and disciplines, collaborating in the InVEST virtual projects. Pre-and post-data were collected from students and evaluated using a content analysis method to determine the impact of the modules on their learning, progress, and performance within their virtual teams. Five themes emerged from the coding and synthesis of the collected data namely: (1) intercultural awareness and understanding, (2) diversity appreciation, (3) project planning and coordination, (4) intercultural communication, and (5) social cohesion, trust, and commitment. Findings from the three offerings of the ICMs demonstrated improved intercultural, virtual-collaboration, and discipline-based skills.

Keywords - Global virtual teams, Engineering Education, Global Competence, Intercultural Competence, Collaborative Learning, Learning Communities, Experiential Learning, Focus Group

I. INTRODUCTION

Globalization and technological advancements have led to the significant growth of remote and virtual teams in the workforce, with engineering educators recognizing the need to equip students with professional competencies and transferable skills needed to competently work across geographic and cultural boundaries [4]. While many higher education institutions have integrated professional and global competence elements into their global engineering education programs, the growth of these international experience programs have been adversely impacted by safety issues, political instability, culture shock, travel restrictions, as well as to scalability, access, diversity, and inclusion concerns [5][6][7]. Recently, engineering education has experienced radical changes with many institutions transitioning to virtual teaching and learning

amidst the COVID 19 health crisis for both domestic and international students [8]. These trends have led to a high demand for innovative and accessible methods to deliver top caliber global engineering education that can help future engineers to collaborate with diverse peers in preparation for the 21st century workforce. However, some educators have recognized that diversity and intercultural competence can't be effectively taught in isolation in the classroom [9][10], while others faced numerous limitations integrating intercultural competence learning into the virtual classroom [1][2]. This led them to recommend a more experiential learning approach such as the use of virtual team projects to help students develop these global engineering competencies.

II. INVEST INITIATIVE

In response to the global engineering education challenge, the International Virtual Engineering Student Teams (InVEST) initiative established international research partnerships between University of Toronto Engineering Faculty members and counterparts at various institutions around the world. These partnerships allowed for the two or more faculty members and their students to collaborate on technical research projects. The multi-disciplinary engineering students are placed in global virtual teams under the guidance of their co-supervising faculty. InVEST also supported students learning through Intercultural competency modules (ICM) offered at the front end of their projects. The InVEST initiative began in early 2019, pre-dating the Covid-19-era, positioning it well for expansion. InVEST aims to provide equitable and inclusive access to international educational experiences and collaborative research opportunities to undergraduate and masters students [7]. The InVEST initiative's core purpose is to equip students with competencies to successfully transfer their knowledge and skills to the workplace. InVEST provides in-course and credit-based opportunities for students to work in virtual teams with counterparts in other globally distributed institutions on multidisciplinary engineering projects over a period of 4-12 months.

III. METHOD: GLOBAL VIRTUAL TEAM PROJECTS

The three Intercultural Competency Modules (ICM) offerings were delivered to 11 virtual project teams involving 41 engineering students from 15 universities and 1 firm. Each global virtual team project comprised an average of 3 - 5 Masters or undergraduate students and their supervisors from various collaborating institutions. ICM participants were multi-

disciplinary engineering students that self-selected to participate in the program from a wide range of countries as shown in Figure 1 below. Each institution would advertise the virtual research project opportunities to their students and successful applicants would be enrolled in ‘for-credit’ undergraduate capstone or graduate course by their respective faculty supervisors. Project topics included process piping systems, transmission line performance, food manufacturing clusters, cassava biogas production, and palm waste utilization.

3 Study Iterations	
Number of Students	41
Number of Virtual Teams	13
# of Universities Represented by Students	11
Location of Industry Partner(s)	Canada
Location of University Partners	Singapore, Canada, The Caribbean, Nigeria, Brazil, Germany and South Africa
Engineering Disciplines	Mechanical and Industrial, Civil and Transportation, Chemical, Electrical, Biocomputational, Biomedical, Electrical, and Computer
Geographic Location of Students	Singapore, The Caribbean, Canada, Zambia, Nepal, China, Germany, The United States, Rwanda, Nigeria, Burkina Faso, Tanzania, Poland, Brazil, and United Arab Emirates

Figure 1 Participants Profile for the three ICM instances

A. Theoretical Perspectives

The ICM curriculum’s development (e.g., learner experience, materials, and interactions) was guided by four theoretical perspectives as follows: 1) social constructivism [11] was utilized for a collaborative student-centered learning; 2) Kolb’s [12] experiential learning model supported students’ learning from actions and reflections in their virtual team projects; 3) the Community of Inquiry (COI) framework [13] was applied to create an effective online educational experience; and 4) the Knowledge Community and Inquiry (KCI) instructional model [3] facilitated a learning community approach to students’ global competence development.

B. Intercultural Competency Modules (ICM)

The ICM curriculum was consisted of 4 - 5 hybrid online modules that were delivered through cycles of asynchronous online learning and synchronous video sessions (Figure 2). The learning objectives for the three ICM instances were the same (Figure 3). The engineering students worked together in a KCI-based ICM curriculum to share their ideas, worldview, and experiences with each other, thereby creating a community knowledgebase that became a primary resource for curriculum and their projects’ collaborative activities. Each instance utilized five learning approaches to support the engineering students’ global competence development as shown in Figure 4.

Study Iterations	1 st	2 nd	3 rd
Learning Modules			
1. Project Scenario and Technology Training	✓	✓	✓
2. Virtual Teamwork and Collaboration	✓	✓	✓
3. Intercultural Communication	✓	✓	✓
4. Engineering Intercultural Scenarios	x	✓	✓
5. Engineering Application Project	✓	✓	✓

Figure 2 ICM Learning Modules for the 3 instances

ICM Learning Objectives	
1	Learn to collaborate and communicate effectively with virtual team members
2	Demonstrate group behavior inclusive of concepts such as conflict, power, leadership, ethics, and decision making and analyze the impact within an organizational setting.
3	Create a group report reviewing intercultural differences and designing a roadmap for collaboration
4	Apply course concepts to self, teammates, cases, and course activities and evaluate impact and effectiveness
5	Utilize course concepts to investigate issues while collaborating as a team to formulate solutions and produce a cohesive project report and presentation.

Figure 3 ICM Learning Objectives for the 3 instances

Learning Approaches	
Social Learning	Students’ community building was promoted using ice-breaker activities, group work and virtual team exercises.
Active Learning	Active learning strategies were utilized to increase student engagement with the intercultural learning content and virtual interactions with peers.
Inquiry Learning	Guided inquiry discussions facilitated student’s knowledge construction and peer learning within and across virtual project teams.
Scenario-based Learning	Scenario based learning activities simulated students’ generation of multiple perspectives in a real-world engineering context.
Experiential Learning	Action-based exercises facilitated students’ application of their renewed intercultural knowledge and reflection of experiences in their virtual teams.

Figure 4 The ICM’s Five Learning Approaches

C. Data Source

This case study focuses on three ICM instances delivered at the University of Toronto from Winter 2020 to Winter 2021. The three instances were delivered using the same KCI-based curriculum, followed similar topic sequence, and learning materials, included the same focus group discussion questions and surveys for assessing learner experiences, and were engaged by the same instructors. A mixed method approach was utilized for data collection comprising pre- and post-test surveys, focus group discussion notes, group activity responses, research team observation notes and student's online artifacts. Then a content analysis method was used to categorize, code, and analyze the collected data across the three ICM instances to identify themes in students' learning, experiences, and perceptions of the program.

IV. FINDINGS AND DISCUSSION

A. Pre-Survey of Students' Prior Knowledge and Orientation

At the start of each ICM instance, the students completed a pre-test survey covering background information and open-ended questions to gain insights about their previous knowledge, experiences, and cultural awareness such as: 1) what is your English language level? 2) how many times have you travelled outside your home country? 3) have you participated in an online multicultural team with international members? Figure 5 provides an overview of student respondents' prior experiences for the three instances.

Theme	Focus	1 st ICM	2 nd ICM	3 rd ICM
% Respondent		45%	76%	100%
International Exposure	Travelled outside their home country at least once	64%	60%	100%
Previous Virtual International Team Experience	Participated in an online multicultural team with international members	22%	7%	15%
English Language Proficiency	English language level rated \geq "Intermediate"	78%	85%	100%

Figure 5 Students' Prior Experiences and Cultural Orientation

Their responses showed that while many students' travel history indicated some international exposure (>60%), very few had previous experiences with virtual international teams (<25%). In addition, while many of the students had rated their English language proficiency as "Intermediate" or above, a few had expressed some concerns about their ability to communicate with team members. Furthermore, while many students across the three ICM instances considered communication, planning and coordination as key conditions for effective virtual collaboration, and some identified technologies, none recognized the value of intercultural communication (Figure 6).

Hence, prior to the program, most of the engineering students in the three ICM offerings did not appreciate the significance of intercultural competence in a global virtual team environment.

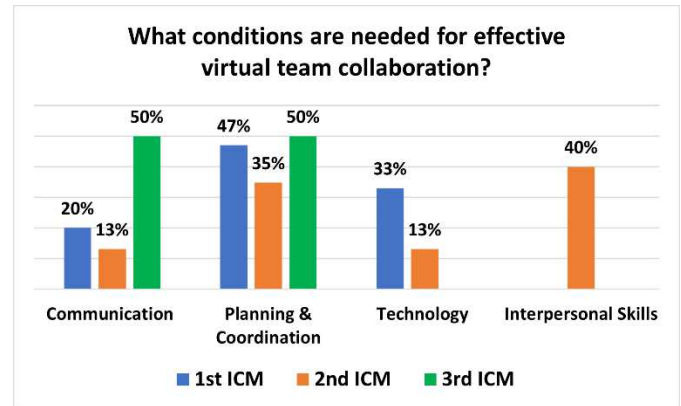


Figure 6 Students' Response to a Pre-Test Question on Virtual Team Collaboration

B. Post-Survey of Students' Learning Experiences

At the end of the ICM, students completed an exit survey on their learning experiences where they answered the question: what was your experience with this session? Their response across the three instances showed that they were highly satisfied with the program (Figure 7), with a 95% mean rating on their learning experiences (either "excellent" or "very good") and an average of 97% saying they would recommend the sessions to others.

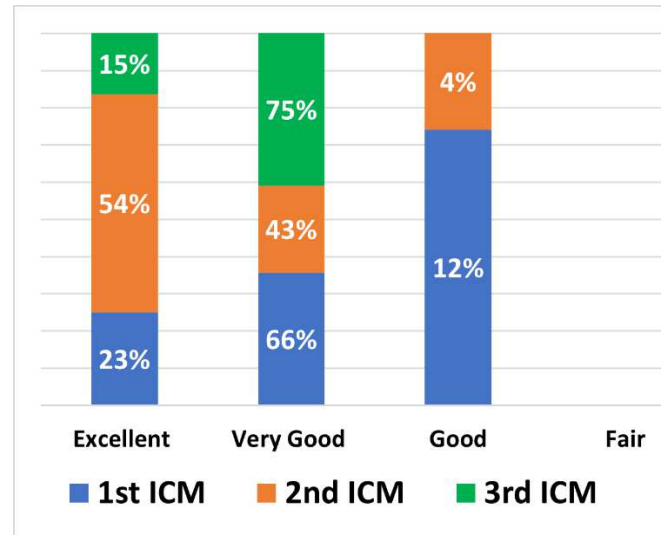


Figure 7 Students' Feedback on the ICM program

C. Focus Group Discussion of Students' Learning and Experiences

Furthermore, at the end of each the ICM instance students participated in focus group discussions to provide feedback on their intercultural learning and virtual teamwork experiences. Discussion Prompts included: 1) what are the cultural similarities and differences in your team? 2) How are the members interacting with each other? 3) are there any cultural

considerations in the design or implementation of your project?
4) how do members encourage and support each other on their individual tasks? Following the synthesis of students' responses across the three ICM sessions, five distinct themes emerged: (1) intercultural awareness and understanding, (2) diversity appreciation, (3) project planning and coordination, (4) intercultural communication, and (5) social cohesion, trust, and commitment.

1) Intercultural Awareness and Understanding

Students' responses showed that they recognized similarities in cultural values of team members like "shared university culture, peer-aged", "common language" and "all engineers in training". They also appreciated the cultures of the target communities where their project is situated. For instance, a student indicated that one of the team's intent was "to be respectful of cultural heritage regarding palm processing" as they worked on their engineering projects. Several approaches were recounted, for promoting intercultural experiences within their virtual teams such as "showcasing more cultural heritage to colleagues", participating in "more team socials", increasing "frequency of games and ice breakers", and continuing to "allow for free expression of ideas".

2) Diversity Appreciation

Student's feedback indicated that they appreciated differences in cultural values of peers such as living across "different time zone", realizing that "weekends aren't the same across the world" and having different communication styles such as an "open communication" or "direct communication" style. They students also valued the diversity of team members such as "we have a good cultural representation in the time. we respond to solving problem differently". Hence, "respecting everyone's world view" and accommodating differences of ideas was important to the students as they worked together (e.g., "compromising, so that work is still completed while being respectful to your teammates").

3) Project Planning and Coordination

The students used information communication technologies (ICT) to conduct "weekly meetings and discuss the project and – tasks" with team members and supervisors. ICTs were also used to provide "progress reports", "share ideas and research findings", "give feedback on work done" and for "answering questions that other team mates have". The team meetings also enabled students to escalate issues "if it cannot be resolved, to experienced individuals – Prof X". However, some students observed that managing a team of about 10 students in a virtual project setting presented some challenges, (e.g., "Large group size makes it difficult to track progress & have efficient meetings"). Consequently, the students split their team into "smaller groups / sub-teams" and encouraged "constant communication with members" to address this dilemma.

4) Intercultural Communication and Sensitivities

Students' responses indicated that they recognized and appreciated that effective communication across cultures and geography was essential for collaboration in virtual teams. Generally, they were "friendly and tolerant" and made efforts to minimize misunderstandings by "recognizing differences & asking for clarification" and striving to "communicate clearly".

Some students recognized the value of having diverse voices in the decision-making process by promoting agency (e.g., "ensuring that everyone has a chance to voice their opinion"), and by making culturally responsible decisions (e.g., "we first wanted to make electricity but due to the community needs we decided to make gas for cooking").

5) Social Cohesion, Trust, and Commitment

Some student teams made efforts to create a sense of community (e.g., "trying to get to know team members personally") and engage in social interactions "discuss on issues outside our project. we talk and show areas of our environment to team members to enhance our intercultural experience". These virtual interactions helped students to earn the swift trust of their peers as depicted by one student, "we all view each other as trustworthy", build social cohesion in the team that supported their virtual team collaboration (e.g., "each of us is active on the group chats, answering any questions our teammates may have as soon as possible") and remain committed to the project team goals: "when someone has a busier schedule, the team helps by taking on a larger role for that time period, which is usually worked out later".

V. CONCLUSION

In conclusion, this study demonstrated that learning within a global virtual team setting is a successful strategy for introducing international experiences and global perspectives into the curriculum while preparing students for the 21st century workplace. The study is significant as it shows that combining global virtual team projects with ICMs can be used to support students to listen, respect and learn from diverse peers within virtual groups. In addition, educators can utilize this approach to promote collaborative and inclusive learning amongst diverse team members across geographic, cultural, and ethnic boundaries. Future studies will seek to explore opportunities for engineering students to work together with non-engineering peers within virtual team project settings.

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ABOUT THE AUTHORS

Anuli Ndubuisi is the Research and Program Manager of the International Virtual Engineering Student Teams (InVEST) initiative and a researcher with Encore Lab at the Ontario Institute for Studies in Education (OISE), both at the University of Toronto. She is also a doctoral student in the collaborative specialization in engineering education program. Anuli is highly interested in the effective use of computer supported collaborative learning to enhance inclusive team learning experiences.

Elham Marzi Ph.D. is the Director of the Engineering Business Minor Program and Principal Investigator for InVEST under the Dean's Strategic Fund. She is a Teaching Stream faculty member in the Institute for Studies in Transdisciplinary Engineering Education & Practice at the University of Toronto. She teaches in the Engineering Business Program in areas inclusive of Organizational Behavior, Human Resource Management, Strategy, and Negotiations. She is highly interested in developing innovative teaching techniques and strategies that can contribute to the students learning and experiences both inside and beyond the classroom.