2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #39538

Assessing Global Engagement Interventions to Advance Global Engineering Competence for Engineering Formation (Work in Progress)

Prof. Scott Schneider, University of Dayton

Scott J. Schneider is an Associate Professor and the ETHOS Professor for Leadership in Community at the University of Dayton. Schneider is currently focusing his research in the areas of engineering education and community engaged learning.

Dr. Corinne Mowrey, University of Dayton
Dr. Eric Janz P.E., University of Dayton
Dr. Erick S. Vasquez, University of Dayton

Erick S. Vasquez is an Associate Professor in the Department of Chemical and Materials Engineering at the University of Dayton. He received his B.Eng. in Chemical Engineering at UCA in El Salvador. He obtained his M.S. from Clemson University and his Ph.D. from Mississippi State University, both in Chemical Engineering. His laboratory research involves nanotechnology in chemical and biological processes. His educational research interests are community-based learning, open-ended laboratory experiments, teamwork, collaborative and active learning, and Transport Phenomena computational modeling.

Dr. Homero Murzi, Virginia Polytechnic Institute and State University

Dr. Homero Murzi (he/él/his) is an Associate Professor in the Department of Engineering Education at Virginia Tech. Homero is the leader of the Engineering Competencies, Learning, and Inclusive Practices for Success (ECLIPS) Lab where he leads a team focused on doing research on contemporary, culturally relevant, and inclusive pedagogical practices, emotions in engineering, competency development, and understanding the experiences of traditionally marginalized engineering students from an asset-based perspective. Homero's goal is to develop engineering education practices that value the capital that traditionally marginalized students, bring into the field, and to train graduate students and faculty members with the tool to promote effective and inclusive learning environments and mentorship practices. Homero has been recognized as a Diggs Teaching Scholar, a Graduate Academy for Teaching Excellence Fellow, a Global Perspectives Fellow, a Diversity Scholar, a Fulbright Scholar, a recipient of the NSF CAREER award, and was inducted into the Bouchet Honor Society. Homero serves as the American Society for Engineering Education (ASEE) Chair for the Commission on Diversity, Equity, and Inclusion (CDEI), the Program Chair for the ASEE Faculty Development Division, and the Vice Chair for the Research in Engineering Education Network (REEN).

Matthew A. Witenstein, University of Dayton
Jeanne Holcomb, University of Dayton

Assessing Global Engagement Interventions to Advance Global Engineering Competence for Engineering Formation (Work in Progress)

1. Introduction

The purpose of this project is to determine to what extent global engineering competence can be developed in engineering students through the use of four minimally to moderately intensive global engagement interventions. The specific global engagement interventions evaluated include the use of international engineering case studies in a quantitative analysis course, the intentional formation of multinational student design teams within a capstone design course, a Collaborative Online International Learning (COIL) research project in a fluid flow (transport phenomena) course, and an engineering short course coupled to a community engaged project. The specific research questions to be answered are:

1. To what extent can global competence be developed in engineering students through the use of the proposed global engagement interventions?
2. What are the relative strengths of each of the proposed global engagement interventions in developing global engineering competence?

This effort is motivated by the overarching goal to develop a holistic global engineering education approach to foster global competence in engineering students in order to meet the current and future needs of the engineering profession.

For this project, global competence is rooted in the institutional definition for intercultural competence at the University of Dayton (UD), which states that intercultural competence is the process of listening, learning and reflecting to develop knowledge, skills, attitudes and commitments to engage across diverse groups in open, effective and socially responsible ways. Accordingly, this project adopts the three student learning outcomes for the UD International and Intercultural Leadership Certificate which identify that students will be able to

1. Explain how issues of social justice, power and privilege are shaped in a variety of contexts.
2. Use language and knowledge of other cultures effectively and appropriately to communicate, connect and build relationships with people in other cultural communities.
3. Express respect and thoughtful engagement with people across cultures.

These outcomes focus on the development of a global mindset instead of global skillset as is more commonly found in the engineering education literature. Mindset refers to how one perceives the world, one's beliefs and motivations, whereas skillset refers to how one behaves based on their knowledge, capability, and mindset [1]. Current research has found mindset to be as important, if not more so, than skillset as a success indicator for leaders and employees [2], [3]. A global mindset can include an awareness and openness to differences, an understanding of how their actions impact local and global communities, and an interest in collaboratively addressing global issues [4]. This research project focuses specifically on developing a global engineering competence in students through the formation of a global learner mindset.

Global Engineering Competency (GEC) has been defined as the attributes uniquely or especially relevant for cross-national/cultural requirements in the engineering practice [5]. The global nature of the engineering profession, with expected growth in international collaborations across the spectrum of engineering functions, has led to a demand from industry for the development of GEC as a competency for future generations of engineers [5] - [10]. A number of engineering professional societies including the American Society for Engineering Education (ASEE), the

National Academy of Engineering (NAE) and the National Science Foundation (NSF) also see the development of GEC as an important part of the formation of engineers [11].

GEC has been a topic of discussion in engineering education research, although it has not been clearly defined yet [6], [12] - [16]. For our study we acknowledge GEC manifest both internally and externally in engineers. Internal manifestations center around the engineer's perspective and worldviews (mindset), which influence the external manifestations that take the form of appropriate and effective communication and behaviors (skillset).

2. Research Design

The goal of the proposed effort is to assess the impact of a variety of global engagement interventions on improving intercultural competency mindset in engineering students. It is expected that these improvements would lead to an increased global engineering skillset for engineering students.The composition of the classes targeted by each of the global engagement interventions, as described above, is shown in Table 1.

Table 1: Target populations for global engagement interventions

Global Engagement intervention	Required / Elective	Student Grade	Class Enrollment
International case study Engineering Technology	Required	Soph., Jr., & Sr.	10-15
Multi-national student teams Computer, Electrical, and Mechanical Engineering	Required	Sr.	120 - 140
COIL project Chemical Engineering	Required	Jr.	30 - 60
Engineering short course with community engaged project All Engineering Students	Elective	Soph., Jr., & Sr.	15-30

The specific elements of an intercultural competency mindset being assessed include cultural humility, global citizenship, and critical reflection. These elements are found to support the student learning outcomes identified in the Introduction section. The mapping between the engagement interventions, the student learning outcomes, and the global learner mindset elements is shown in Figure 1. The following sections describe in more detail each of the global engagement interventions being assessed through this proposed effort.

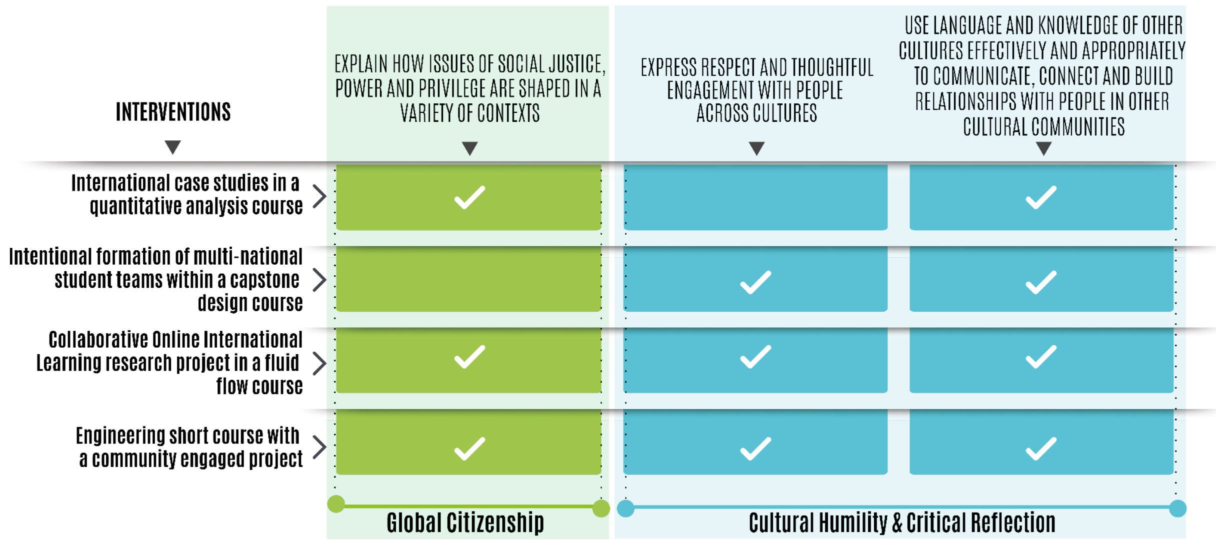

Figure 1: Mapping between interventions, student learning outcomes, and global learner mindset facets

2.1. International Case Studies

Quantitative Analysis is an undergraduate Engineering Technology class that presents an introduction to the mathematical techniques used to support decision making and managerial analysis. Content includes calculus based probability and statistics theory, decision theory, forecasting, linear programming, and queuing theory. Through this class, students are exposed to multiple decision making scenarios common to practicing engineers and the appropriate tools and approaches used to find the best solutions or answers. Though student learning outcomes for this course are specific to the technical concepts covered, the overarching goal of the class is to train and develop engineers that are capable of solving complex global problems that (generally) seek the lowest cost, the largest profit, the shortest distance, or the least amount of time. The development of critical thinking skills such as identifying problems, gathering relevant information, analyzing and interpreting data, and drawing appropriate conclusions is necessary in order to solve these problems. The development of intercultural competencies is also necessary so that future engineers are able to apply their skills successfully to real-world problems that are encountered in a global economy. To this extent, students should be able to understand how geographical location, available resources, and socio/cultural issues affect problem formulation, decision alternatives, and success of solution implementation; and effectively communicate questions, concerns and solutions to people in different cultural communities.

While standard lectures explain and illustrate the appropriate use of decision-making tools as well as the correct interpretation of their results, pedagogical approaches that make content more relevant to students' lives and the needs of society better motivates student learning and improves critical thinking [17]. Case-based instruction is one form of active learning that engages students and allows them to better relate course content to real-world problems. Studies have shown that the use of case-based instruction in engineering exposes students to the complexities of real-world problems (incomplete data, multiple sources of information, accounting for conflicting issues and contending with societal problems) and also provides the socio/cultural context that cannot be taught through standard procedure-focused lectures [18], [19]. Recent studies have shown that short-term projects can effectively increase student's GEC by helping them recognize global challenges, technological problems, and contextual influences on engineering practices [20].

In this course, students will work together to understand and define a transportation problem related to the distribution of bottled water to citizens of Turkey. As a group, students will research and discuss factors that impact the potential solution, such as Turkey's existing transportation network, and incorporate those factors into the solution procedure. To model and solve this problem, students would need to consider the characteristics of the geographical area, the resources of the local agency or government, and the behavior of the population. After solving their problem, students will submit critical reflections.

2.2. Multinational Student Design Teams

ECE/MEE431L is the first of two multidisciplinary senior design/capstone classes. Participants are computer, electrical or mechanical engineering students and are in either their late junior year or early senior year. The focus of the course is the application of engineering fundamentals to sponsored multidisciplinary team design projects. In a combination of lecture and laboratory experiences, students learn the product realization process which encompasses idea generation, proposal development, design specifications, conceptualization, and decision analysis. These types of problems do not have neat answers and stretch students to use their engineering mindset rather than techniques they have learned.

Teams have historically been assigned based on matching skills and interests. For this study, in addition to those considerations, teams will be constructed with members of different ethnicities/countries. Because of different expectations for professional communication, task delegation and management, and interpersonal skills/communication topics, this process is challenging. Simply putting team members of different backgrounds in a group does not lead to an enhanced understanding of the different cultures [21]. When not managed well, the result can be a poor experience for the participants and significant loss of a learning experience. However, managed well, it could be an excellent learning experience and result in enhanced cultural competencies. In addition to the engineering content of the class, additional modules will reinforce this content and highlight the application of it at different stages of the course. Including team formation, ideation, decision methodology and writing stages. Additionally, intentionally integrating opportunities to reflect on individual and group performance and to consider alternate perspectives will improve the student's ability to perform in teams now and after graduation.

2.3. Collaborative Online International Learning (COIL)

COIL is a pedagogical modality that uses digital technology and online communication tools to connect universities and specific courses in different world locations [22], [23]. This cost-effective approach engages students in a virtual international exchange to increase cross-cultural learning [24]. "COILing" a course involves a partnership between two faculty members in different countries willing to collaborate and engage students through instructors-developed planned teaching activities [25]. For this implementation, chemical engineering (ChE) students will work in a COIL experience to complete a five-week cross-cultural project with ChE collaborators from Universidad Nacional in Colombia.

The ChE undergraduate program offers a five-course sequence involving fluid flow concepts with two hands-on laboratory courses. CME 324 and CME 325 (Table 1) are the inaugural lecture-based courses introducing fundamental concepts of transport phenomena, including fluid flow and transport phenomena modeling. Traditionally, students make several assumptions for solving problems with equations limited to Newtonian fluids. They have little to no exposure to concepts related to non-Newtonian liquids such as slurries, food mixtures, or paints, found throughout many industrial processes [26]. At Universidad Nacional, the chemical engineering program also offers a transport phenomena course with fluid flow, heat transfer, and mass transfer principles and also provides access to transport phenomena modeling. The instructors in both countries plan to implement the 5-week activity through constant virtual interactions during the Spring semester.

The instructors will form multicultural teams based on enrollment, gender, and academic performance for the COIL implementation. Assessment of teamwork will proceed with the AAC&U teamwork value rubric [27]. First, students will discuss intercultural aspects by preparing a short introductory video with a biography and an identity element (food, music, etc.). The technical activity will proceed during weeks 2 - 3. Instructors expect that students will experience a gap in finding technical information or discussing past experiences (e.g., co-ops), which will help assess GEC. A one-page technical memorandum will be the deliverable requested by the end of week 4. Reflections and discussions will proceed during week 5. Note that students can submit the assignment in English or Spanish, which will require significant engagement from students in different countries. This COIL implementation seeks to analyze the effects of working in a second language (L2) within Chemical Engineering [28], teamwork performance and collaborations [29], and intercultural awareness in the classroom [30].

2.4. Engineering Short Course with a Community Engaged Project

Within the Ethos Center there is an engineering design and appropriate technology course that spans two consecutive semesters and includes a twelve-week immersion experience focused on technical work in a marginalized community through partnerships with long-term international NGOs. The in-class work focuses on cultural immersion preparations and developing an understanding of community engaged design principles. This course content and the associated immersive experience have a significant impact on developing the global engineering competencies of students, as found through a formal assessment process [31], [32]. However, this course, like study abroad programs, is not accessible to a large number of engineering students because of travel costs and the duration of the international immersion experience and its impact on the tightly sequenced engineering curriculums and internship/co-op positions [14].

To provide an option that is accessible to more students, the Introduction to Engineering Design and Appropriate Technology (IED&AT) short course was created as a technical elective open to all engineering students. This course was designed to introduce students to community engaged design principles within cultural contexts and to prepare them for a 10-day faculty led international community engaged project (also coordinated by the Ethos Center). The scope of both the class and travel time were kept short to better fit within the heavily constrained schedules of engineering students. This course runs during the Spring and Fall semesters with the travel component taking place during the winter or summer intersession period, respectively. In addition to the short course, the students participate in reflective practices both during and after travel for the community engaged learning project. As a short course, the classroom time is limited to 15 contact hours throughout a given semester and there is no tuition.

Helping students develop a global learner mindset is a key outcome for the IED&AT course and therefore it is purposefully planned throughout all aspects of the course. Mentoring students prior to travel is known to significantly improve their ability to develop global competencies during a travel experience [14], [33]. The course topics specifically target the global learner categories of global citizenship, cultural humility, and critical reflection. Specifically, the students start with a critical self-reflection process in order to increase their awareness and openness to other cultural contexts outside their own. They then examine their own ideological assumptions and how these beliefs impact their worldview. Finally, the students learn how community engaged design can be leveraged to make meaningful civic contributions.

2.5. Assessment Tools

Growth in the participating students' global learner mindset during the various global engagement interventions, as identified in Figure 2, is assessed using the GES tool. Additionally, the Global Engineering Competency Scale (GECS) is being used to assess improvements in key areas of each students' global engineering skillset. Combined, these research measures will provide not only an accurate picture of how each global engagement intervention impacts the formation of a global learner mindset, but also its associated ability to develop and/or improve global engineering skills.

The GES is a multi-institutional assessment tool aimed at distilling the relationship between program outcomes and student learning with respect to the global learning goals established by the AAC&U [4], [34]. The GES comprises eight scales within the areas of cultural humility, global citizenship, and critical reflection. The assessment tool uses both quantitative and qualitative questions in these scales along with their associated reliability. In total, the GES has been administered within almost 400 learning programs across 35 participating institutions between 2015 and 2019. Over 4,000 students who have completed the survey in either a pre, post, or pre and post test manner. This tool has been demonstrated to provide adequate reliability within various university programs to ensure valid results within this research program.

The Global Engineering Competency Scale (GECS) is a framework developed by Jesiek [35] that highlights required skills for engineers globally. The GECS is broken down into cognitive and behavioral categories. Questions within these categories focus on technical, teamwork and communication, business, ethics and professional practice, and leadership.

Within the context of the identified global engagement interventions, it is important to evaluate the growth in each student's global learner mindset and global engineering skillset as captured by the GES and GECS. Therefore, both the GES and GECS will be administered to students in a pre and post test manner with respect to the global learner module and global engagement intervention according to the timeline established in Figure 2. The assessment schedule for the short course with a community engaged project mirrors a method used by Davis and Knight in their assessment of the Rising Sophomore Abroad Program [36].

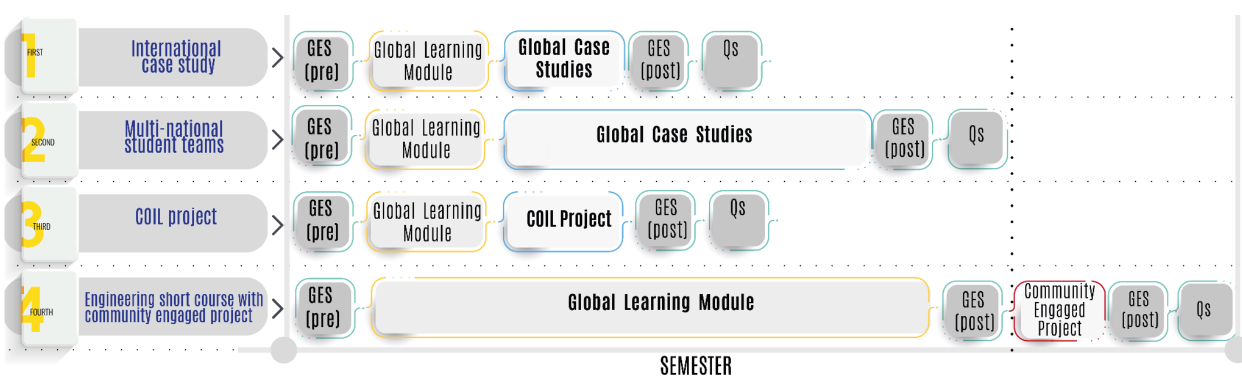

Figure 2: Assessment schedule of global engagement interventions

3.0 Next Steps

Currently, the PIs are implementing each of the four interventions and collecting data. A graduate student in the Ethos Center at the University of Dayton has been assigned to collect the GES and GECS student data for all the interventions. Over the summer term, instructors will analyze the pre- and post-survey results for each global engagement intervention administered. Data assessment will help determine a path forward to improve future efforts and summarize best practices to enhance global engineering competence interventions. The project will provide the first step towards developing a multi-tiered, holistic global engineering education process able to reach all engineering students.

4.0 Acknowledgements

This research is supported in part by the US National Science Foundation under grant PFE:RIEF [grant number 2204956].

References

[1] Medina–López–Portillo, A, "Intercultural learning assessment: The link between program duration and the development of intercultural sensitivity," *Frontiers: The interdisciplinary journal of study abroad*, vol. 10, no. 1, pp. 179-200, 2004.

[2] Deardorff, D. K, "Assessing intercultural competence," *New directions for institutional research*, vol. 2011, no. 149, pp. 65, 2011.

[3] Gupta, A. K., Govindarajan, V, "Cultivating a global mindset," *Academy of Management Executive,* vol. 16, no. 1, pp. 116-126, 2002.

[4] Association of American Colleges and Universities (AAC&U), "Global Learning VALUE Rubric," *Association of American Colleges and Universities*, 2014. Retrieved from https://www.aacu.org/value/rubrics/global

[5] Johri, A., & Jesiek, B. K. (2014). Global and international issues in engineering education. *Cambridge Handbook of Engineering Education Research*, 655-672.

[6] Parkinson, A. (2009). The rationale for developing global competence. *Online Journal for Global Engineering Education*, 4(2), 1–15.

[7] Williams, R. (2003). Education for the Profession Formerly Known as Engineering. *Chronicle of Higher Education*, *49*(20), B12-B12.

[8] Bourn, D. (2018). The global engineer. In *Understanding global skills for 21st century professions* (pp. 201-219). Palgrave Macmillan, Cham.

[9] Stevens, R., Johri, A., O'connor, K., & Olds, B. (2014). Professional engineering work. *Cambridge handbook of engineering education research*, 119-137.

[10] Bremer, D. (2008). Engineering the world. *Online Journal for Global Engineering Education*, *3*(2), 2. Available at https://digitalcommons.uri.edu/ojgee/vol3/iss2/2/

[11] Streiner, S. C., & Besterfield-Sacre, M. E. (2018). Development of the Global Engineering Programming Model: A Participatory, Mixed-Methods Approach. *Journal of International Engineering Education*, *1*(1), 3. Available at https://digitalcommons.uri.edu/jiee/vol1/iss1/3

[12] Downey, G. L., Lucena, J. C., Moskal, B. M., Parkhurst, R., Bigley, T., Hays, C., ... & Lehr, J. L. (2006). The globally competent engineer: Working effectively with people who define problems differently. *Journal of Engineering Education*, *95*(2), 107-122.

[13] Grandin, J. M., & Hirleman, E. D. (2009). Educating engineers as global citizens: A call for action / A report of the national summit meeting on the globalization of engineering education. *Online Journal for Global Engineering Education*, 4(1), 1–28.

[14] Parkinson, A. (2007). Engineering study abroad programs: Formats, challenges, best practices. *Online journal for global engineering education*, *2*(2), 2. Available at http://digitalcommons.uri.edu/ojgee/vol2/iss2/2

[15] Allert, B. I., Atkinson, D. L., Groll, E. A., & Hirleman, E. D. (2007). Making the case for global engineering: Building foreign language collaborations for designing, implementing, and assessing programs. *Online Journal for Global Engineering Education*, 2(2), 1–14.

[16] Jesiek, B. K., Zhu, Q., Woo, S. E., Thompson, J., & Mazzurco, A. (2014). Global engineering competency in context: Situations and behaviors. *Online Journal for Global Engineering Education*, *8*(1), 1. Available at http://digitalcommons.uri.edu/ojgee/vol8/iss1/1

[17] Yadav, A., Alexander, V., & Mehta, S. (2019). Case-based Instruction in Undergraduate Engineering: Does Student Confidence Predict Learning. *International Journal of Engineering Education*, *35*(1), 25-34.

[18] Berndt, A., & Paterson, C. (2009). Complementing business case studies with humanitarian case studies: A means of preparing global engineers. *IEEE transactions on professional communication*, *52*(4), 398-410.

[19] Rectanus, M. W. (2013). Transdisciplinary Case Studies as a Framework for Working in Global Project Teams (2013). *Online Journal for Global Engineering Education*, *6*(1), 9.

[20] Knight, D. B., Davis, K. A., Kinoshita, T. J., Twyman, C., & Ogilvie, A. M. (2019). The Rising Sophomore Abroad Program: Early Experiential Learning in Global Engineering. *Advances in Engineering Education*.

[21] Matveev, A. V., & Milter, R. G. (2004). The value of intercultural competence for performance of multicultural teams. *Team Performance Management: An International Journal*.

[22] De Castro, A. B., Dyba, N., Cortez, E. D., & Genecar, G. (2019). Collaborative online international learning to prepare students for multicultural work environments. *Nurse educator*, *44*(4), E1-E5.

[23] Guth, S. (2013). The COIL Institute for Globally Networked Learning in the Humanities. Final report. *White paper. SUNY COIL Center.* Available at https://coil.suny.edu/sites/default/files/case_study_report.pdf

[24] Vahed, Anisa. "Factors enabling and constraining students' collaborative online international learning experiences." *Learning Environments Research* (2021): 1-21.

[25] Appiah-Kubi, P., & Annan, E. (2020). A review of a collaborative online international learning. *International Journal of Engineering Pedagogy*, *10*(1).

[26] Chhabra, R. P., & Richardson, J. F. (1999). *Non-Newtonian flow in the process industries: fundamentals and engineering applications*. Butterworth-Heinemann.

[27] Association of American Colleges and Universities (AAC&U). (2009). Teamwork VALUE Rubric. Retrieved from https://www.aacu.org/value/rubrics/teamwork

[28] Nishio, T., Fujikake, C., & Osawa, M. (2020). Language learning motivation in collaborative online international learning: an activity theory analysis. *Journal of Virtual Exchange*, *3*, 27-47.

[29] Stump, G. S., Hilpert, J. C., Husman, J., Chung, W. T., & Kim, W. (2011). Collaborative learning in engineering students: Gender and achievement. *Journal of Engineering Education*, *100*(3), 475-497.

[30] King Ramírez, C. (2020). Influences of academic culture in Collaborative Online International Learning (COIL): Differences in Mexican and US students' reported experiences. *Foreign Language Annals*, *53*(3), 438-457.

[31] Kleinhenz, P., Pinnell, M., Mertz, G., & Eger, C. (2005). Leveraging Students' Passion and Creativity: ETHOS at the University of Dayton. *Proceedings Frontiers in Education 35th Annual Conference, Indianapolis, IN, 2005, pp. F4F-11, doi: 10.1109/FIE.2005.1612148.* Available online at https://ieeexplore.ieee.org/document/1612148

[32] Pinnell, M., Daniels, M., Hallinan, K. P, and Berkemeier, G. (2014) Leveraging Students' Passion and Creativity: ETHOS at the University of Dayton. *International Journal For Service Learning in Engineering, Special Issue: University Engineering Programs That Impact Communities: Critical Analyses and Reflection*. Available online athttps://ojs.library.queensu.ca/index.php/ijsle/article/view/5547.

[33] Levonisova, S. V., Savage, R. E., Streiner, S. C., & McCave, E. J. (2015). Identifying factors that enhance undergraduate engineering students' global preparedness. In *122nd ASEE Annu. Conf. Expo.* (Vol. 12356, pp. 1-18).

[34] Hartman, E., Lough, B. J., Toms, C., & Reynolds, N. (2015). Assessing intercultural capacities, civic engagement, and critical thinking: The global engagement survey. *Going glocal in higher education: The theory, teaching and measurement of global citizenship*, 127.

[35] Mazzurco, A., Jesiek, B., and Godwin, A. "Development of Global Engineering Competency Scale: Exploratory and Confirmatory Factor Analysis," Journal of Civil Engineering Education. Volume 146, Issue 2. (April 2020). Available at https://ascelibrary.org/doi/epdf/10.1061/%28ASCE%29EI.2643-9115.0000006

[36] Davis, K. and Knight, D. B. "Impact of a Global Engineering Course on Student Cultural Intelligence and Cross-Cultural Communication," *Journal of International Engineering Educatio*n. Volume 1, Issue 1, Article 4. (2018) Available at https://digitalcommons.uri.edu/jiee/vol1/iss1/r