COIL Multidisciplinary Global Engineering Capstone Class Impact: Faculty and Student Insights Across Four Countries

Dr. Jamie R Gurganus, University of Maryland Baltimore County

Dr. Jamie Gurganus is a Teaching Assistant Professor in the Engineering and Computing Education Program and the Associate Director of STEMed Research in the College of Engineering and Informational Technology. She also directs the Center for the Integration of Research, Teaching and Learning (CIRTL) in the graduate school. Her research is dedicated to addressing the complex challenges of educating and developing engineers, teachers, and communities at every level—from P–12 to post-graduate studies. Her work spans engineering identity and mindsets, global and entrepreneurial competencies, failure culture, first-year experiences in engineering, capstone design thinking, and the integration of service and authentic learning into the classroom and developing future faculty. In addition, she is committed to implementing innovative instructional methodologies and optimizing design through both traditional and non-traditional manufacturing techniques.

Dr. Yashin Brijmohan, Utah State University

Yashin Brijmohan is a registered professional engineer and Assistant Professor Engineering Education at Utah State University. He is also an Executive committee member of the Commonwealth Engineers Council, Board Member of the UNESCO International Centre for Engineering Education, and Chair of the Africa Asia Pacific Engineering Council.

He was the founding Executve Dean of Business, Engineering and Technology at Monash South Africa, former Vice President of the World Federation of Engineering Organizations, and led several committees in the engineering profession.

Yashin has both leadership and specialist experience within the engineering power industry and education sectors and is known for his thought leadership in capacity building and engineering education.

Lani McGuire, The Ohio State University

Lani McGuire is a first-year PhD student in Engineering Education at the Ohio State University. His research interests lie in exploring undergraduate and pre-college engineering student opportunities and experiences.

Mr. Michael M. Malschützky, Hochschule Bonn-Rhein-Sieg, University of Applied Sciences, Germany

Michael M. Malschützky is a Research Associate at the Centre for Teaching Development and Innovation (ZIEL) as well as Affiliate Faculty at the Department of Management Sciences at Hochschule Bonn-Rhein-Sieg, University of Applied Sciences (H-BRS), Germany. He received his Diplom-Ingenieur (FH) in Mechanical Engineering from H-BRS in 2005. After working as Test & Validation Engineer (TIER-1) and Program Management Engineer (OEM) in the automotive industry, he returned to academia in 2013, receiving his BSc (2017) and MSc (2023) in Business Psychology from H-BRS.

Dr. Anderson Harayashiki Moreira, Instituto Mauá de Tecnologia

Graduated in Control and Automation Engineering from Instituto Mauá de Tecnologia (IMT) (2008). Master in Mechatronics Engineering from the Instituto Tecnológico de Aeronáutica (ITA) (2011). PhD in Mechatronics Engineering from the Instituto Tecnológico de Aeronáutica (ITA) (2017). He is currently a professor at the Instituto Mauá de Tecnologia. He develops activities and research in the area of mobile autonomous robotics, control systems, industrial robotics and microcontroller systems.

Albertino Arteiro, University of Porto
Andrea Schwandt, Hochschule Bonn-Rhein-Sieg

Andrea Schwandt received her diploma in Electrical Engineering (Telecommunications) from the University of Siegen, Germany, in 1994. After working as a design engineer and system administrator, she joined Bonn-Rhine-Sieg University of Applied Sciences in Sankt Augustin in 1997, where she is currently a research assistant in the fields of digital design, microcontrollers, and analog circuits. In 2021, she also completed her master's degree in "Electrotechnical System Development" (M.Eng.) at Bonn-Rhine-Sieg University. Her research interests focus on FPGA- and microcontroller-based systems, particularly in the context of remote labs, as well as their integration into international teaching programs.

Joao Santos
Joyce Zampirolli Scrivano
Prof. Steven McAlpine, University of Maryland Baltimore County

Steven McAlpine is an assistant teaching faculty member in the Entrepreneurship and Individualized Study programs at UMBC, as well as a Global Learning Fellow in the Center for Global Engagement. He has been teaching role playing game design and leading campus wide RPG events for the past ten years. He also leads the multidisciplinary sustainable design course entitled INDS 430: The Kinetic Sculpture Project, which won the grand prize in the 2015 Baltimore Kinetic Sculpture race.

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Introduction

Engineers today face multifaceted global challenges, climate change, health challenges and industrial expansion, requiring more than technical expertise. The demand for global competencies, such as cross-cultural sensitivity, social responsibility, and the ability to collaborate in diverse, multicultural environments, has become increasingly critical. Research highlights the role of international mobility in cultivating these skills, showing that students who participate in cross-border academic experiences often demonstrate heightened global competence, particularly in communication and adaptability [1-6].

Digital-mediated education unlocks new possibilities for collaboration across borders, enabling meaningful engagement on a global scale. However, success in an increasingly interconnected and diverse world requires cultivating a global mindset. This includes one that shapes our self-awareness, fosters appreciation for diverse perspectives, and enhances our ability to collaborate across cultural and experiential boundaries. [2]

Increasing attention is being directed toward aligning engineering education with the United Nations Sustainable Development Goals (SDGs) [7] to develop globally competent engineers capable of addressing complex global challenges. ABET [8] has incorporated global competency into its student outcomes, encouraging curricula that foster global awareness, cross-cultural collaboration, and ethical leadership. European initiatives similarly emphasize inclusivity, gender equity, and democratic principles, while programs such as the European Green Deal [9] and the Erasmus+ framework [10] actively support sustainability and cross-border collaboration in education. Additionally, initiatives like the Grand Challenge Scholars Program [11] and Engineers Without Borders [12] promote experiential learning opportunities, encouraging students to address pressing global issues through innovative and community-centered solutions. These efforts collectively highlight a transformative shift in engineering education, prioritizing sustainability, cultural understanding, and social justice to equip engineers for a rapidly evolving, interconnected world [1].

Contemporary insights into the competencies sought by European engineering firms highlight critical deficiencies in recent graduates, including interpersonal communication, adaptability, and engineering self-efficacy [2]. Additionally, attributes such as emotional intelligence—particularly empathy, as emphasized in design thinking—and cooperative skills are often underdeveloped [2].

Universities are addressing the challenges of fostering global competence by promoting international academic partnerships that encourage mobility for students, faculty, and staff. Traditional in-person exchanges, however, often face obstacles such as financial burdens, caregiving duties, intensive workloads, and hesitations about adapting to prolonged stays in unfamiliar environments [3]. To make international experiences more accessible, institutions are increasingly turning to virtual mobility through digitally facilitated courses, offering a flexible and inclusive approach to global learning that transcends the limitations of physical exchange programs.

In 2012, the Mechanical Engineering department at a minority serving US institution and a university in Portugal, collaborated to create a digital mediated course (Global Engineering) for mechanical engineering students held in cooperation at both institutions. Learning objectives in this course included (a) discussions about the characteristics of a Global Engineer with guided (self-)reflections of own strengths, weaknesses, and needs, (b) review of engineering techniques and challenges in a pluralistic and globalized world, and (c) presentations by a specialist with a global background (faculty, researchers, industry professionals) the approach is based in particular on the active collaboration of mixed student groups with presentation of their work projects with peer review of other mixed teams. In the fall 2022, a study found, when examining the students' development throughout the course, measured by Global Perspective Inventory (GPI) [2], that participating students showed in three of the six the GPI dimensions comparable or significantly higher values than students spent in in-person semesters abroad [4].

In the summer of 2024, this course was restructured and integrated into the College of Engineering's newly established unit, Engineering and Computing Education Program (ECEP), transforming it into a multidisciplinary, cross-listed undergraduate/graduate capstone-style course using Collaborative Online International Learning (COIL) and Social Entrepreneurial framework. The course now spans diverse fields, including information systems, computer science, human-centered computing, engineering management, and mechanical, chemical, and computer engineering. Additionally, the program expanded its international collaboration with the inclusion of two new partner universities from Germany and Brazil, further enriching its global perspective and academic reach.

This study aimed to assess the impact of a newly redesigned Global Engineering course delivered through a Collaborative Online International Learning (COIL) framework involving institutions from Germany, Brazil, Portugal, and the United States. The primary objective was to explore how the course promotes the development of a global perspective among engineering students. To achieve this, a mixed-methods approach was adopted, combining interviews with students and faculty from all participating countries and employing the Global Perspective Inventory (GPI) [1], [5], a validated psychometric tool.

The evaluation focused on two key aims:

- Evaluation Aim #1: Assess the impact of the redesigned Global Engineering course on students' global perspectives and social entrepreneurial mindset.
- Evaluation Aim #2: Examine students' and instructors' perceptions regarding the course's effectiveness in enhancing cultural understanding and global competencies.

Background/Literature Review

Why Global Engineering for engineers?

The globalization of engineering practice has made global competence essential for 21st-century engineers. Addressing complex challenges that transcend national borders requires not only technical expertise but also cultural awareness, ethical judgment, and the ability to collaborate across disciplines and cultures. As noted in [1], "the global world requires an essential emphasis on sustainability," underscoring the importance of developing competencies that enable engineers to operate effectively in diverse, globalized environments.

Global competence encompasses adaptability, intercultural communication, and sustainability awareness, allowing engineers to engage with people from various backgrounds and address global, intercultural, and local issues [2]. For example, the TA VIE project [3] highlights how international mobility experiences enhance critical competencies among engineering students, including communication, flexibility, and collaboration skills. However, research indicates that graduates often lack essential global competencies, particularly in interpersonal communication, adaptability, and engineering self-efficacy [1].

Downey et al. [13] emphasize the need for cross-cultural communication skills and the ability to collaborate within international, multidisciplinary teams. Jesiek et al. [14] further advocate for engineering education that fosters cultural diversity awareness, global systems understanding, and ethical decision-making. Additionally, Schell and Hughes [15] identify emotional intelligence—especially empathy—as a critical factor for navigating cultural differences and fostering inclusive collaboration.

These insights collectively stress the need for engineering curricula that integrate global awareness, emotional intelligence, and adaptability alongside technical knowledge, preparing engineers to meet the demands of an interconnected world [14], [16–18].

The need to develop Global and Social Entrepreneurial skills in higher education

Higher education institutions play a pivotal role in equipping students with the competencies necessary to navigate and address complex global challenges. Robertson emphasizes the importance of fostering global competence through experiential learning, interdisciplinary projects, and global perspectives, cautioning that "without embedding such opportunities into core curricula, their impact remains limited" [19]. Similarly, Jiaxin, Huijuan, and Md Hasan highlight the critical role of global competence in higher education, concluding that "institutions must adapt their curricula to include cultural awareness, critical thinking, and collaboration for sustainable development" [20]. Parkinson argues that "engineering education must transition from a narrow technical focus to a broader multidisciplinary framework that incorporates global socio-economic and environmental systems" [21].

Social responsibility is another indispensable competency. Krensky and Steffen suggest that service-learning is an effective means to inculcate social responsibility into students' mindsets [22]. Moreover, Reimers underscores that entrepreneurial education aligned with the United Nations Sustainable Development Goals (SDGs) fosters creativity and innovation, enabling students to address real-world problems effectively [23]. Experiential learning initiatives, such as internships, exchange programs, and community projects, are essential for cultivating practical problem-solving and leadership skills [24].

COIL methodology

Collaborative Online International Learning (COIL) has become an innovative pedagogical approach that uses virtual exchange to connect students and faculty across borders, enabling interdisciplinary and intercultural collaboration. By integrating global perspectives into curricula, COIL fosters intercultural competence, global awareness, and digital literacy while providing a cost-effective and inclusive alternative to traditional study-abroad programs. This approach democratizes international education by removing financial and logistical barriers, allowing students from diverse socioeconomic backgrounds to engage in meaningful cross-cultural interactions [25], [26]. Through collaborative projects, students enhance their teamwork, communication, and problem-solving skills while navigating cultural differences and utilizing digital tools [27], [28]. Institutions benefit from COIL by achieving internationalization at home, embedding global perspectives directly into classroom activities without requiring physical mobility [29], [30]. Additionally, COIL prepares students for the demands of a digitally interconnected world by improving their digital literacy [28]. It also promotes inclusive education, broadening access to international learning experiences and reducing disparities in global education opportunities [25], [31].

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Overview of Multidisciplinary Global Engineering Course Senior/Graduate Elective

As a multidisciplinary initiative that integrates engineering technology, entrepreneurship, sustainability, social responsibility, and cultural understanding to address complex global challenges. The course emphasizes how societal, environmental, and political factors influence engineering practices worldwide and prepares students for international collaboration and problem-solving.

Key topics covered in the course include the global scope of engineering; variations in engineering practices worldwide; cultural, environmental, sustainability, and political influences; strategies for navigating foreign environments; and preparation for international work or study experiences. Studentsengage in multidisciplinary, authentic projects, guided by lessons from guest speakers and instructors who share insights from real-world global engineering cases where technical and cultural considerations are deeply intertwined. As an example the students worked on developing an appropriate technology for Ukrainian Refugees.

Students work collaboratively in multicultural teams comprising participants from four partner institutions: University of Maryland, Baltimore County (UMBC), Faculdade de Engenharia da Universidade do Porto (FEUP), Hochschule Bonn-Rhein-Sieg (H-BRS) and Instituto Mauá de Tecnologia (IMT). These teams design and present engineering solutions for scoped system outcomes, applying discipline-specific knowledge—such as management, design, and computational methods—to deliver comprehensive solutions that address economic, ethical, and social implications.

Through this experience, students gain valuable skills in cross-cultural collaboration, remote teamwork, and joint research, as well as professional and technical communication. By working on authentic cases in diverse scenarios, participants enhance their ability to navigate global challenges and develop practical, socially responsible engineering solutions [4].

The following topics are covered in the course as it aligns to the framework mentioned in Ortiz-Marcos et al. [1]:

Multidisciplinary Teamwork and Leadership
- RACI Matrix analysis in design (Responsible, Accountable, Consulted, Informed)
- Analytical Hierarchy Method in Design selection [32]
- Working with Engineers, Information Systems and more

Cross-cultural Humility
- Definition of Global Design
- Global Perspective Inventory 6-Dimensional analysis of development of a Global Engineer [5]

Intercultural Communication
- Technical Writing and International Writing
- Intercultural communication and its impacts on culture

- Hofstede's Cultural Dimensions in Design realization [33]

Applied Knowledge (Engineering, Computer, Information Systems)

- Product life cycle and design for end of life
- Materials and Design Life Cycle Analysis – Product Manufacturing and Product Disposal
- Sustainability
- International standards and recommended practices
- Design led selection of materials
- Business applications

Data Collection, Analysis and Decision Making & Stakeholder Analysis and Engagement

- Strengths, Weakness, Opportunity and Threat (SWOT)
- Analysis in design embodiment
- Theory of Inventive Problem Solving (TRIZ) for design embodiment [34]
- External Environment Analysis framework (PESTEL) for Design Selection [35]
- Developing/emerging market dynamics and their effect on business and technology
- Socioeconomic factors that affect adoption of products
- Design/Engagement stakeholder analysis

Example of Projects:

In Fall 2024, students developed appropriate technology using design thinking, later refined to Human-Centered Design in Spring 2025, alongside social entrepreneurial practices. The project required technical notes, midterm and final reports, presentations, and low-fidelity prototypes.

Amid the Ukrainian refugee crisis, with over 7.8 million displaced across Europe, students applied global engineering skills to identify and address specific regional needs, creating sustainable, culturally informed solutions for displaced communities. Below are short descriptions of the technologies developed. One of the groups competed in an entrepreneurial challenge and received second place and startup funding for their project to include a potential investor. Below is a summary of one of teams projects:

> *InteGrate is a web application designed to help Ukrainian refugees adapt to new cultures. It offers multimodal learning modules, interactive quizzes, a database of social services, a messaging feature, and a feedback hub. The app focuses on addressing cultural challenges beyond basic needs, with Germany identified as the launch site. Development included backend prototyping (transitioning from SQL to NoSQL) and user interface design via Figma, with plans for integration, testing, and expansion.*

Methodology

To comprehensively evaluate student development, we employed a mixed-methods strategy that integrated both quantitative and qualitative approaches, offering a complete picture of the outcomes. A validated survey instrument—the Global Perspective Inventory (GPI)—was used to quantitatively assess key dimensions of student growth in cognitive, intrapersonal, and interpersonal areas [2]. In parallel, structured interviews and focus groups were conducted to deepen our understanding of the class's impact. It is also important to note that due to recent scheduling and administrative changes at FEUP—a long-term partner for 13 years—their involvement was temporarily affected. Nonetheless, the instructor remained fully engaged, and Portuguese students are set to return in Fall 2025, with the course offered as an elective. However, for this study, the researchers were unable to incorporate them into the evaluation process.

A. Demographics of class

Table 1: Demographics of Global Engineering Fall 2024		
University-Students	Counts	Percentage
IMT - Brazil	12	28%
H-BRS - Germany	7	16%
UMBC - USA	24	56%
Academic Level		
Undergraduate	34	
Graduate	9	
Gender		
Male	31	72%
Female	11	26%
Non-Binary	1	2%
Ethnic*		
USA	*African/Black American*	22.5%
	Asian	65%
	White American	8%
	Two or more	4.50%
Germany & Brazil	N/A	N/A
Major		
Computer Science	11	26%
Information Systems	2	5%
Engineering Management	10	23%
Human Centered Computing	1	2%
Electrical Engineering	1	2%
Mechanical Engineering	10	23%
Mechatronics	2	2%
Industrial	4	9%
Computer engineering	2	5%

**Ethnicity classifications vary according to each country*
Note: Due to unforeseen circumstances, Portugal students were not able to enroll this semester. However the instructor from Portugal was a full instructor.

B. Survey assessment using the Global Perspective Inventory

Students were asked to complete the Global Perspective Inventory (GPI), a validated instrument [2], at the beginning and at the conclusion of the semester. This instrument is used to evaluate students' global perspectives across three developmental domains: cognitive, intrapersonal, and interpersonal. These domains are further assessed through six subscales based on cultural development and intercultural communication frameworks. The cognitive domain includes *Knowing*, which examines the importance of cultural context in evaluating knowledge, and *Knowledge*, which measures understanding of cultural interactions globally. The intrapersonal domain assesses *Identity*, focusing on self-awareness and acceptance of one's identity, and *Affect*, which evaluates sensitivity and respect for diverse cultural perspectives. The interpersonal domain includes *Social Responsibility*, assessing concern for societal interdependence, and *Social Interactions*, which evaluates engagement with individuals from different cultural backgrounds. Each subscale uses a five-point Likert scale, with higher averages indicating stronger development. The GPI has demonstrated robust reliability (test-retest: r_{tt}=[.49, .81]) and validity (face, concurrent, construct), making it a reliable tool for assessing global perspectives. Normative data from cross-sectional studies provide benchmarks for comparing current perspectives or identifying areas for improvement. Using Qualtrics, the students completed the survey and immediately received their results on each of the domains allowing self-reflection of their own global perspectives.

C. Qualitative

Focus groups and interviews were conducted with both the global engineering faculty team and the students. Student focus groups were organized for each team formed during the class, providing an open forum for participants to share their experiences. To minimize bias and encourage candid feedback, the lead instructor recruited and trained external researchers with no affiliation to the class. Additionally, one-on-one interviews were conducted with the lead faculty members from each partner institution, offering valuable insights into their perspectives on the course's structure, implementation, and outcomes. Open-ended questions were asked around motivations to participate in the course, challenges and opportunities, improvements and cultural and global perspectives and development.

Results

Quantitative

A. Global Perspective Inventory Pre-Post Measurement

Table 2: Students who filled GPI at one instance		
University	**Counts**	**% of Total**
UMBC - USA	24	67%
IMT - Brazil	8	22%
HBRS - Germany	4	11%

In average their age is $M = 22.22$ years ($SD = 3.62$) with a minimum of 19 and maximum of 38 years. According to an one-factorial ANOVA the students age differs significantly ($F(4, 29) = 4.00$, $p = .029$) between the US ($M = 22.95$, $SD = 3.64$, $n = 22$), Brazil ($M = 19.14$, $SD = 0.38$, $n = 7$), and Germany ($M = 24.00$, $SD = 4.36$, $n = 3$). According to post-hoc tests the Brazilian students are significantly younger than the US students ($p_{Tukey} = .033$). For 64 % ($n = 21$) of the participating students, English is not their native language.

Table 3: Distribution of experience abroad across participating universities				
	University			
Abroad	**UMBC - USA**	**IMT - Brazil**	**H-BRS - Germany**	**Total**
No, I have never been abroad.	3	1	0	4
Yes, I spent multiple vacations abroad.	10	3	2	15
Yes, I spent a winter/summer school abroad.	1	2	0	3
Yes, I spent a semester or longer at a University/internships abroad.	5	0	1	6
Yes, I lived six month or longer abroad and visited a local school or employment.	3	1	1	5
Total	22	7	4	33

The experience of spending time abroad is highly diverse and comparable between the participating universities ($p_{exactFisher} = .660$).

In examining the dimensions of the GPI only the pre- and post-data of 19 students (16 from US and 3 from Germany) could be matched.

Table 4: Pre-Post GPI Dimensions *N*=19					
Measure	***M* (Pre)**	***M* (Post)**	**Significant* Δ*M***	***SD* (Pre)**	***SD* (Post)**
Affect	4.08	4.26	+0.18	0.34	0.39
Identity	3.96	4.1	+0.14	0.47	0.39
Knowing	3.63	3.62	NA	0.27	0.41
Knowledge	3.87	3.91	NA	0.42	0.53
Social Interactions	3.54	3.7	NA	0.5	0.62
Social Responsibility	3.69	3.68	NA	0.57	0.6

*$p < .05$

One-sided t-tests for paired samples demonstrate that there was a significant increase in the dimensions Affect ($t(18) = -2.62$, $p = .009$. $d = 0.60$) from prior visiting the course ($M = 4.08$, $SD = 0.34$) to after the course ($M = 4.26$, $SD = 0.39$). The dimension Identity showed a significant increase ($t(18) = -1.85$, $p = .040$. $d = 0.43$) from prior visiting the course ($M = 3.96$, $SD = 0.47$) to after the course ($M = 4.10$, $SD = 0.39$), too. The other dimensions did not show significant differences between pre- and post-measurement.

Qualitative

Themes Derived from focus groups and interviews

Interviews and focus groups revealed that the global engineering class offered faculty and students a valuable multicultural learning experience, despite challenges with communication, workload management, and assignment clarity. Participants consistently reported that the course fostered critical technical and professional skills essential for effective global collaboration. Instructors also viewed the course positively, emphasizing its success in developing global competency, project management abilities, and a problem-solving mindset. However, feedback highlighted opportunities for improvement, including enhanced pre-course preparation, a stronger focus on cultural integration, and strategies to address post-pandemic engagement challenges. Key themes emerged from the both groups that encompassed communication, cultural differences, team dynamics, instructional design and challenges, post-pandemic impacts, global competency development, entrepreneurial mindset, and technical and professional skill enhancement.

Participants of the study

To mitigate bias, two external, non-participant individuals reached out to students and faculty. Emails were sent inviting participation, with students ($n = 20$) asked to join focus groups based on their respective class teams. Faculty ($n = 5$) members were individually approached for one-on-one interviews from each representative country. To ensure anonymity, the participants were labeled with corresponding codes shown in Table 5.

Table 5: Participant Codes		
Acronym	**Interview conducted with**	**Description**
SG1 - SG5	Student Groups (1-5)	Each group had representatives from USA/Brazil/Germany
F1 -F5	Faculty/Staff (1-5)	Representative Faculty from USA, Brazil, Portugal, and Germany

Themes

A. Communication

Time zone differences

Instructors indicated that students struggled with communication across time zones, particularly the German students who had to manage expectations of online availability during late hours [F3].

Students from all six groups reported experiencing communication challenges in their global engineering projects. These challenges were mainly attributed to time zone differences and language barriers. Specifically, students from Germany and Brazil struggled to coordinate with their American counterparts across multiple time zones, which made it difficult to schedule convenient meeting times.

> *"It was very hard to set a meeting... considering all the time zones."* SG1

Instructors have recommended offering students a pre-course or introductory module to more effectively prepare them for the challenges and expectations associated with global, collaborative project work. This should particularly focus on improving time management and communication across different time zones [19, 21]. Additionally, instructors noted that students faced difficulties with communication across time zones, especially German students, who often had to navigate the expectations of being available online during late hours [5].

Language Barriers

One student noted, "*Definitely some communication issues, especially with some Brazilian students they couldn't really speak English well, so the other Brazilian student had to translate for him a lot*." [SG2]

Another student said, "*I… couldn't express myself very clearly and I sort of end quickly*" SG5, revealing the difficulties of expressing oneself in a non-native language.

B. Team Dynamics

Students generally reported positive experiences with their team members. They found value in collaborating with students from different countries and disciplines. However, some students noted some challenges. Some groups reported that certain members, particularly international students, were less engaged or contributed less work than others. Additionally, some teams faced initial disagreements regarding project goals and features. Such early-stage misalignment on objectives or responsibilities was common and led to delays in progress. These issues were effectively resolved through brainstorming, discussion, and compromise.

> *"We haven't reached an agreement on what exactly we should build. So should it be an app or should it be a website or something like that? So we had to spend a couple of weeks brainstorming ideas."* [SG4]

Student participants highlighted how team members stepped up to fill gaps, leveraging each other's strengths.

"And we also got to know about each other's strength what each other is good in. When we were doing our project. We divided our parts in what expertise we hold." [SG3]

Student teams generally reported positive interactions, with no significant cultural or ethnic tensions. When asked the question: "Did you find any issues around ethnic and cultural awareness?", the response was:

"We did not find anything, as we did very good communication by asking each other's feedback and what each other are thinking…I don't think we found any ethnic and cultural difference.." [SG3]

Student participants valued the exposure to cultural and professional differences, which fostered adaptability and broadened problem-solving approaches.

> *"so we are very diversified and we are working as a team and it was exciting.."* [SG1]

Despite their positive experiences, student participants suggested including more structured icebreaker sessions to build rapport among team members.

> *"it's very important to having an icebreak time between other countries…we didn't have set the time to get to know each other..and then just jump into our project and doing assignments. And then it's ended up they don't participate"* [SG1]

While the course aimed to foster global competency, some instructors felt that students could have better utilized the provided tools (like the cultural dimensions analysis) to address cultural differences in their projects [F2, F4].

C. Instructional Design and Challenges

Assessment and Grading

Some instructors indicated that the German university's assessment regulations posed a challenge, requiring the instructor to adapt the syllabus and assessment artifacts to fit the German grading system. Unlike the continuous assessment approach in the global engineering course, German students were used to a final exam-based evaluation system [F3, F5].

Student Engagement and Attendance

Several instructors expressed concern over student attendance and punctuality [F2, F3, F4]. German students were accustomed to not attending classes and relying solely on final exams [F3]. The course's continuous assessment and active participation requirements were unfamiliar, requiring constant reminders about deadlines and the importance of engagement [F3, F5].

Instructors noted a decline in student motivation to attend in-person classes post-COVID, highlighting the need for strategies to re-engage students in active, face-to-face participation [F4].

Expectations, Pace, and Workload

Some student participants struggled with the intensive workload and increased pace at the end of the class.

> *"We didn't do much for the the first weeks and we did a lot in the last weeks. I think we could this distribute the work more evenly to not overwhelm participants in the course.."* [SG5]

Most student participants appreciated the incremental build-up to the final deliverables, though some felt that assignment instructions lacked clarity.

"Sometimes assignment requirements were kind of ambiguous. I think if they were more defined, it would make the projects a little easier.." [SG2]

Therefore some student participants suggested more detailed instructions and earlier guidance on deliverables.

"I think towards like the three-quarters of the semester in, it is made clear…But I feel like a little bit more heads up about that would have been nicer." [SG5]

Course Design and Facilitation

Students praised the professors and guest lecturers for their knowledge, approachability, and willingness to help students. The responsiveness and involvement of facilitators were highly valued. Several groups indicated that the professors were available and helped clarify doubts promptly [SG2, SG3, SG5].

Student participants suggested aligning the lectures more directly with the project tasks to enhance the relevance and application of the course material.

> *"the transition from what we learned from the presentation into the application into our work was a bit of a gap."* [SG4]

Platform Preferences

There was mixed feedback from students about communication tools like Slack, with some groups preferring alternatives like WhatsApp for its informality, quicker response, and familiarity.

"I guess we just stayed in Slack because the professor suggested it and sometimes she would check our group chat to see if we've been talking. But yeah, switching entirely to something else might have been good." [SG4]

Learning Outcomes

Technical vs. Professional Skills

Instructors emphasized that the course had both technical and professional skills, but most indicated that professional skill development was emphasized [F2, F4, F5]. Many student participants expressed that the course enhanced their technical writing abilities, fostered teamwork and collaboration, and deepened their understanding of global engineering concepts [SG1, SG4, SG5].

> *"It's all about like how to collaborate and like how to take take the project to the next step. So they were very helpful for us in that aspect."* [SG3]

Student participants also appreciated the opportunity to apply their learning to a real-world problem and develop a practical solution. One student, though, suggested incorporating field trips to allow students to observe and identify real-world problems that could then be addressed in their projects [S6].

Entrepreneurial Thinking

The project-based nature of the course, focused on addressing real-world problems, fostered elements of an entrepreneurial mindset, encouraging students to identify problems and develop affordable and feasible solutions [F1, F2]. However, some instructors felt that this aspect was not the primary focus of the course design [F2, F4].

Global Competency Development

Instructors highlighted global competency as the ability to interact and collaborate effectively with individuals from diverse cultures, demonstrating tolerance, understanding, and respect for different perspectives [F2, F3, F4, F5]. They emphasized its crucial role in today's interconnected world [13]. They further elaborated that the course facilitated global competency development by providing students with real-life experiences, exposing them to diverse perspectives and problem-solving approaches [F1, F3, F4, F5], and requiring them to work collaboratively in international teams, navigating cultural differences and time zones [F1, F2, F3, F4, F5].

Students consistently praised the global engineering course for providing a unique and valuable learning experience, highlighting its focus on real-world applications, intercultural collaboration, and technical writing—elements they felt were lacking in their previous coursework. Participants noted that collaborating with peers from diverse backgrounds allowed them to gain different perspectives, problem-solving approaches, and insights into various cultural norms. Instructors reinforced the importance of equipping students with practical skills and tools relevant to real-world engineering contexts, promoting a pragmatic approach to problem-solving [F2, F3, F5].

Discussion

The interviews provide valuable insights into student experiences within the global engineering course. The identified themes and suggested improvements can inform future iterations of the course, potentially enhancing the overall learning experience for all students.

The thematic analysis reveals a significant alignment between faculty observations and student experiences. Both groups recognize the importance of the global engineering course in cultivating global competency, project management skills, and a problem-solving mindset. Nonetheless, there is a shared acknowledgment of the need for enhancements to address communication barriers, cultural integration, assignment clarity, and challenges stemming from post-COVID engagement.

There were, however, thematic variations that highlighted the differing perspectives of faculty and students. While both parties value the course and its intended outcomes, their priorities and concerns differ based on their respective roles and experiences. Faculty tend to focus on broader pedagogical goals and the development of specific skills, while students are more concerned with practical challenges related to collaboration, communication, and navigating the course structure. For example, German students were used to taking only end of the semester exams, finding the formative project based structure both valuable but unfamiliar with the workload. All the students were challenged in finding common times with their international peers to work on the project outside of class. The faculty felt these were invaluable experiences for the students.

Based on the course's nature as an non-mandatory elective, students exhibited a degree of self-selection bias. This could explain the observed differences in qualitatively reported growth compared to quantitative GPI measurement, where only two dimensions showed significant development. Nevertheless, the course had a profound impact on key areas of personal growth. Students demonstrated a heightened sense of identity and an increased acceptance of diverse perspectives, deepening their understanding of personal values in relation to individuals different from themselves. Furthermore, their emotional awareness in navigating culturally complex situations improved significantly, as reflected in their thoughtful and introspective responses during focus group discussions.

Conclusions and Future work

Although the faculty and students expressed positive experiences on varied outcomes, several cultural and disciplinary challenges impacted both the course design and student collaboration. One major cultural challenge was communication across different time zones, particularly between students from Brazil, Germany, and the United States. Time zone differences made scheduling meetings difficult, and language barriers, especially among Brazilian students, hindered effective communication. To address this, future courses could benefit from pre-course language support and clearer communication guidelines.

Cultural integration also posed challenges. While students generally reported positive experiences, there were initial difficulties in aligning project goals due to cultural differences. To mitigate this, structured icebreaker sessions and an emphasis on cultural understanding early in the course could enhance team dynamics. Furthermore, the multidisciplinary nature of the course created disciplinary challenges, as students from various fields struggled to align their approaches and expertise. Early alignment of objectives and guidance on integrating interdisciplinary perspectives could prevent these issues.

In terms of disciplinary challenges, the transition from a traditional exam-based evaluation system to continuous assessment was unfamiliar to some international students, particularly from Germany. This required additional clarification on assignment expectations and workload management. There was also a noticeable imbalance between the development of technical and professional skills, with some students feeling more confident in technical aspects. Future course designs should ensure a more balanced focus on both technical and professional skill development.

To address these challenges, several improvements are recommended. First, a pre-course module on time management, cultural competency, and communication would better prepare students for global collaboration. Second, integrating cultural exercises, like icebreakers or reflective assignments, could enhance cross-cultural understanding. Finally, revising project guidelines for scope, roles, and deliverables to align with students' cultural backgrounds and needs would further strengthen the course's effectiveness in preparing them for global engineering challenges.

Limitations

The research itself has several limitations. The sample size was relatively small, particularly for the post-course Global Perspective Inventory (GPI) data, which included only 19 students, limiting the representation of diverse student perspectives across the participating countries. Additionally, many of the students self-selected into the course, which may have introduced bias, as they were likely already aware of and valued international experiences. The study also lacked a thorough cross-country comparison, particularly with Brazil, as they were not included in the post-course GPI analysis. Furthermore, the absence of longitudinal follow-up meant that the long-term impact of the course on students' global competencies was not assessed. These limitations suggest areas for future research to address and ensure a more comprehensive understanding of global engineering education.

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