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Bringing in the World: Internationalizing the Curriculum of a First-Year Introduction to Engineering Course at a Large Public American University

Prof. Jennifer DeBoer, Purdue University, West Lafayette

Jennifer DeBoer is currently Assistant Professor of Engineering Education at Purdue University. Her research focuses on international education systems, individual and social development, technology use and STEM learning, and educational environments for diverse learners.

Mr. Shreyas Vathul Subramanian, Purdue University

Shreyas Vathul Subramanian is a PhD candidate in the school of Aeronautics and Astronautics Engineering at Purdue University. His research involves studying the impact of multi-disciplinary collaboration in the design, analysis and optimization of engineering products. He also has a keen interest in incorporating topics such as global education, effective collaboration, and the use of open source tools into basic, introductory engineering courses.

Prof. Mushtak Al-Atabi, Taylor's University

Professor Mushtak Al-Atabi is currently the Dean of School of Engineering at Taylor's University, Malaysia. His research interests include engineering, entrepreneurship, education and leadership. He is an Honorary Chair at the School of Mechanical Engineering of the University of Birmingham (UK) and the Editor-in-Chief of Journal of Engineering Science & Technology. Professor Al-Atabi published two books, "Think Like an Engineer" and "Driving Performance" and he has numerous research publications, awards and honours. He is a Co-Founder of the Global Challenges Alliance, Fellow of the Institution of Mechanical Engineers (FIMechE) and a member of the Global Engineering Deans Council. Professor Al-Atabi is an innovative educator; he pioneered the CDIO (Conceive, Design, Implement, Operate) and delivered the first MOOC (Massive Open Online Course) in Malaysia. He trains executives from Multinational Corporations including banks and energy companies.

Dr. David A. Delaine, Universidade de São Paulo and IFEES

David A. Delaine has a Ph.D. in electrical engineering from Drexel University, in Philadelphia, USA. He currently serves as an executive member of the International Federation of Engineering Education Societies (IFEES), as Vice President for Student Engagement, Diversity, and Inclusion. IFEES aims to strengthen engineering education practices around the world. He has recently completed his tenure as a Fulbright Scholar and is currently performing research as a FAPESP postdoctoral researcher with Prof. Dr. Jose Roberto Cardoso at the Escola Politécnica da Universidade de São Paulo for his project titled "Assessing the Impact of One Boundary Spanner on University-wide STEM Educational engagement" where he will attempt to optimize community/university relations for broadening participation in the STEM fields." He has ambitions to significantly diversify and broaden the global pipeline of STEM talent and help guide the evolution of the methods used to develop engineers.

Prof. josé aquiles grimoni jabg P.E., polythecnic schoool university of são paulo

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Engineers must work within multinational and multicultural environments, but incorporating international experiences into a packed undergraduate curriculum in a meaningful and scalable manner is difficult. This paper addresses the need to better understand how course instructors can effectively internationalize their learning materials in a domestic engineering classroom. The course used as a qualitative case study in this paper is an Introduction to Engineering course *at a large public university in the United States. We highlight a* Scholarship of Teaching and Learning *case study of one course's efforts to provide international experiences in a domestic classroom.*

Introduction and Rationale

Engineers must work within multinational and multicultural environments, which requires global competency and ongoing, lifelong learning to better understanding engineering cultures around the world [1], [2]. Accreditation bodies and universities recognize that the preparation of lifelong globally competent engineers begins during the undergraduate degree [3]. However, incorporating international experiences into a packed undergraduate curriculum in a meaningful but affordable manner is difficult for course administrators and instructors. Furthermore, little is known about the effectiveness of existing efforts. This paper addresses the need to better understand how course instructors can effectively internationalize their learning materials in an engineering classroom.

The course used as a qualitative case study in this paper is an *Introduction to Engineering* course at a large public university in the United States (US), which includes about 30% international students (29% identify their home country as somewhere besides the US), and students in this first-year course will matriculate into all engineering disciplines at the university. This unique section included assignments contextualized for international clients as well as direct interactions with international stakeholders via email/Skype.

Background and Literature

Conceptual Framework

This study fits into the paradigm of the Scholarship of Teaching and Learning, as it includes journals and reflections from the instructor and course team as well as information on student learning and performance on assignments tailored to international and multinational "clients". In addition, groups' design reviews were conducted by international collaborators, providing external validity checks as to the demonstration of global competence in students' learning.

We utilize these data within a qualitative case study investigation to better understand the following: (a) what was the nature of the additional changes to the curriculum from the perspective of the instructor, the instructional team, and the students?, (b) what levels of global competence and perceptions of global engineering were demonstrated in student assignments, and (c) what challenges arose in implementation of curricular changes?

Active Undergraduate Classrooms

A variety of classroom-based pedagogies forefront the benefits of involvement of students in cooperation with each other and in authentic problem solving [4]. According to a long-term meta-analysis, small group learning within an undergraduate class is significantly beneficial [5]. Many engineering schools' efforts to incorporate interactive learning techniques, professional skills, and authentic, hands-on projects are concentrated in the first year with "freshman engineering design experiences" [6]. Those upper-level classes that include learning outcomes related to preparing students to work in multi-cultural environments are often product design or global product development, and these courses often comprise cross-national teams working together in a variety of ways (e.g., collaborative or competitive, equal partners or sub-contractors) [7]. National Science Foundation (NSF) investments over recent decades have pushed for comprehensive and design-based introductory courses to support the development of design qualities and to utilize team-based projects [6], and such courses offer a unique, authentic opportunity to internationalize the engineering curriculum.

Internationalizing Local Curricula

University graduates have a great need for intercultural exposure in preparation for today's multicultural job market. Tertiary institutions in the US—across disciplines—recognize the need for undergraduates and graduates to prepare to engage in the global community. Faculty themselves are including curricular materials referencing international contexts and internet-based international exposure to enhance their local classrooms [8]. Cultural competency is explicitly referenced in important accountability levers such as ABET accreditation (e.g., Outcome H "understand the impact of engineering solutions in a global, economic, environmental, and societal context") [abet.org].

In response to the need for engineering colleges and universities to offer international experiences and prepare large numbers of students for a multicultural workforce, some programs have turned to virtual team experiences (e.g., [9]). Such experiences have found that the instructional team needs to support students in navigating intercultural communications. Online education is therefore seen as a vehicle for providing joint opportunities for students to collaborate across international boundaries and still realize professional competencies [10].

International students themselves have been perceived as catalysts for a greater level of multicultural awareness and understanding [11]. University-level programming for international students may simultaneously serve to support international students' integration into the local university, and increase domestic students' cross-cultural understanding and awareness of global issues [12].

Global Competence

ASEE's Corporate Member Council has invested in identifying the characteristics required of a "global engineer" [13]. Practitioners and scholars have identified "global competence" as one of the central attributes of a highly qualified global engineer,

although this characteristic is difficult to assess [14]–[16]. More broadly understood, researchers and instructors see global competence and the challenges associated with working with diverse engineers as a problem of people tackling technical issues differently [14]. Faculty and administrators at Purdue University have proposed that global competency itself forms a third axis of engineering education (in addition to technical and professional skills) [17]. Their group further developed global programming efforts into a comprehensive program with faculty and student exchanges, multinational and domestic internships, and study abroad opportunities [18]. Even this comprehensive program includes a multinational design team experience, which is scaffolded to incorporate both a domestic and on-the-ground international component.

Nature of the Curricular Change

The curricular change implemented by the instructional team consisted of three major components. First, both of the design project assignments included a specified authentic context in which the design project was to be deployed or sold. Second, the assessments of the design projects were aligned with the learning outcome (global competency) and with the design project activity. This alignment comprised authentic clients assessing the projects and authentic feedback from partners in the target location. Finally, one of the design project activities required consulting with an international peer contact as part of the design process. We describe these three components in more detail in this section to illustrate the numerous ways in which instructors could broaden students' international exposure as part of the existing curriculum.

First, both of the required design projects in the class were situated within an international context. For the project where students were asked to design a zero-energy house, groups were assigned to design for São Paulo, Brazil. To successfully do so, they had to recognize that patterns of solar energy potential, seasons, weather, available materials, and other needs would drastically differ from contexts in their immediate vicinity in the US. In discussions with students in class, the instructional team heard students struggle at first to understand the Brazilian landscape. As they built on information literacy skills, they were able to explain and apply the facts they found regarding housing practices and policy, and varied living conditions in São Paulo. Numerous groups reported that they made their designs as cost effective as possible to provide zero-energy residences to *favela* communities in the city. For the second design project, students were further challenged to design an "upcycled" product that would be marketable in the US, Malaysia, and Canada. Student groups immediately turned to information gathering to learn more about all three contexts—including the US.

Assessment of the design projects was tightly aligned with the learning outcome of global competency as well as the design project activity. Both design projects were assessed by evaluators local to São Paulo, Malaysia, or Canada (in addition to the instructional team). Students were reminded during each class period that their projects would be assessed by authentic "clients," who would have an intimate knowledge of the location for which teams were designing their product. Evaluators for the first design project came from the research group of a colleague of the instructor, located in São Paulo. Evaluators for the second project were either master's students working under the instructor's colleague in

Malaysia or Canadian employees of a small mechatronics company with whom the instructor collaborates. In addition, students were provided with authentic formative feedback during the process of their second project from peer evaluators in Malaysia.

International peer evaluators served as the third major addition to the curriculum. Their formative, collaborative participation with students in the class was only included as part of the second design project. Students were required to get feedback (preferably via a Skype call) and implement revisions before turning in their final designs. Many groups were able to correspond with their peer evaluators by Skype, and some even coordinated so that multiple group members could be part of this consultation. Other groups that were not able to coordinate gathered feedback by email, although it was not clear that this feedback was as tailored or helpful in improving designs.

These three components of the curricular change constituted notable differences from the content of activities of the other sections of this introductory course. However, some of the changes for the instructional team were minimized by keeping the structure of activities and project scope unchanged. The primary changes were made to the content of the assessments. The content was built directly off the instructor's research agenda and contacts, and the instructional team could still underscore the need for student information literacy and the importance of context (instead of answering specific or superficial questions about the location). In addition, evaluation and grading was partially offloaded through the complementary support of international evaluators. Still, the curriculum change was an adjustment for the instructional team, and we highlight important challenges that the instructional team faced in the penultimate section below.

Students' Global Competence and Perceptions of Global Engineering

We report our observations of student outcomes and instructional team experiences here based on our scrutiny of student assignment submissions, graded rubrics and feedback from international evaluators, communications with the instructional team, and our own instructional team experiences. Student teams demonstrated mixed levels of global competence during the first design project. Eight of the twenty-five teams made no mention, or a very minor mention, of the global context, despite knowing that this was an integral part of their assignment and grading rubric. On the other hand, the majority of teams made mention of the location, often in regards to adjustments for the climate and the seasons in the Southern Hemisphere. A few teams demonstrated high levels of self-awareness and global competence in expressing their need to gather more information about the context, preferably in consultation with a São Paulo resident. For example, one team noted, *"Composed of 4 members (from China, Spain, Korea, USA), we are unsure of a Sao Paulo resident's taste in housing. Our vision of an attractive home may be a Sao Paulo resident's worst nightmare. To better cater their needs, we would like to work closely with a Sao Paulo resident on this project."* A small number of teams described in detail how they addressed their lack of local contextual knowledge through information gathering, noting, *"As an American-Asian design team, we had a harder time deciding on how our house met Sao Paulo curb appeal standards. In order to test how our individual solutions compared to each other in Sao Paulo curb appeal, we created a simple test in which we compared our houses to 10 typical Sao Paulo houses found online."*

Overall, student teams demonstrated growth in their level of global competence on the second design project, showing more conscientious information gathering and incorporation of feedback as well as more explicitly formed perceptions of global engineering. Numerous teams highlighted their ability to incorporate feedback from an international peer (the Malaysian master's student who was assigned to consult with their team). They noted that their Malaysian peer consultant was helpful during the design process, e.g., *"Video conferencing with collaborators in Canada as well as Malaysia - helped narrow down to the final idea,"* and *"[Evaluator's feedback] contradicted our original assumption."* Students also noted that international peer feedback was helpful in improving the design product, e.g., *"[Evaluator name] gave us positive feedback on our design, but he suggested we emphasize how our design relates to upcycling."* Many teams' descriptions of their initial and final designs showed how much their products were improved based on evaluator feedback, including a few teams whose pictures reflected how in tune they were with accepting the diverse nature of their customer base.

During the second design project, many student teams began their design process with information gathering about the three design contexts. Most immediately looked for a common issue to scope their problem and were surprised to find the health issue of obesity and diabetes to be common across the three contexts (Malaysia, Canada, US). Some teams attempted to gather information, feedback, and actual data with respect to all three contexts from the very beginning of the project. For example, one group reported, *"We surveyed users from US, Canada, and other countries. We also pulled [university] students for a larger dataset, as well as our Malaysian contact."* Another group used their own networks for information gathering, saying that they *"contacted friends in Canada to see if the product would be useful."* Student teams were excited when they received affirmative feedback from their evaluator: *"Malaysian collaborator said that he would definitely use this product!"* This sentiment was also expressed during class.

International students had different perceptions of the experience from their domestic peers, and these experiences could be more integrally leveraged into classroom activities and reflections. For example, one student in the class was an international student from Malaysia, and her team noted, *"Contact with Malaysian collaborator was easier due to the presence of a Malaysian student in the team."* This student's class engagement changed drastically as a result of this project. Her peer teacher noticed that she was one of the quietest students in the 96-person class before this project, but that during this project, it was "*night and day;"* she was talkative, engaged, and demonstrated leadership and increased levels of confidence working in her team for numerous activities.

We further find that the instructional team and instructor do not experience significant increases in their perception of the course load when activities are closely aligned with the overall learning outcomes and assessments (Biggs, 1996). However, some of the logistic issues and alignment of assessment policies with the course's other assignments created additional load for the team. We further detail these challenges below.

Challenges in Implementing the Curricular Change

We find that student engagement with internationally contextualized activities generally increases, although students also note significant difficulties with logistics (e.g.,

coordinating their discussions with international evaluators across time zones) that mirror real-world multinational industry practices and complexities. In fact, several students complained about not hearing back from their international collaborators. A few other students received a delayed response, which affected progress towards completing the assignment given the course policy of adhering to strict deadlines. As a result of either receiving no response (or a delayed response at best), students were further constrained to only receive feedback from peers and the instructional team. In these cases, the workload of the instructional team was slightly increased due to the additional communication effort introduced via reminder emails to international collaborators on behalf of the students. Allocating multiple student teams to respective international collaborators did not introduce any significant amount of additional workload.

Grades of this course were not assigned on a curve since cooperative learning was encouraged. On the other hand, students were assigned a grade depending on whether they met a particular standard (as recommended in [19]). As a result, consistency in grading across assignments and graders became increasingly important and was achieved through regular meetings held by the instructional team. Since the international collaborators were not involved in these grading specific meetings, the grades provided by them were vastly different in terms of range as well as the mean. At this juncture, we point out that grading was usually more unfavorable when compared to assignments graded internally by the instructional team, which made calibration of these grades necessary. Calibration was performed to match grading standards that the instructional team set for all other assignments in the course.

Student perceptions of the utility of these activities required conscientious effort to navigate. Initial student responses to the international design projects were mixed, with some students being enthusiastic about novel international locations and others skeptical about the relevance of the activities to their engineering degree program. The instructional team consistently highlighted industry's demand for engineers who would be able to work on multinational projects. On the last day of the course, students reflected on the marketable skills they had learned through the international design projects (e.g., ability to coordinate with an international partner). Even so, numerous student evaluations mentioned dissatisfaction with activities they felt were irrelevant to the discipline of engineering.

The importance of understanding the impact of engineering solutions in a global setting was underscored throughout the course. Furthermore, international collaborators provided knowledge of contemporary issues in a societal context. This, however, only came about through the ability to communicate effectively [20]. Along with course specific objectives, students were encouraged to carry out communications with international collaborators in a professional manner. The expected level of professionalism and thoroughness from students were implicitly stated in the introductory emails to the corresponding collaborators and in email correspondence with students during the semester. This was an additional but necessary effort considering that, in general, this was one of the first conversations students had with professionals outside the university.

Sharing of student submissions, assignments and graded rubrics in a manner that adhered to university policies and FERPA also introduced a non-negligible amount of additional effort. International collaborators were also notified about these policies and were generally provided with password protected, non-identifiable documents hosted on a secure university server. Also, additional permissions were required to introduce our collaborators as graders in the course. Finally, graded assignments were required to be transferred securely from the international collaborators to the university-hosted server in order to be compiled before the necessary calibration was performed. This process was greatly simplified due to the existence of robust software solutions made available by the university. However, some of the international collaborators experienced logistical difficulties caused by browser compatibility or using the passwords to access the software to transfer graded rubrics. According to the Brazilian collaborators, these difficulties were managed well; the availability of the American instructional team for communications was critical to navigate logistical challenges as they arose.

Implications

These findings have implications for course instructors and administrators, as they strive to include opportunities to acquire global competence in residential universities. As a result of our experience, we identify a number of our experiences that have implications for other instructors and course designers. Instructional teams can build on their strengths and their own international collaborations to create learning opportunities that mimic real-world engineering practice and international collaborative work. Instructors should allow for students, especially first years, to have multiple opportunities to grow and demonstrate global competence. Instructors can build on the experiences and interests of their own students, although this must be done with care and sensitivity for these individuals, who are not representative of their entire home country. Opportunities for team work and cross-national peer dialogue are useful. Instructional teams should also encourage information gathering and students taking time to learn about authentic contexts throughout the design process. It should be noted that technology, while permitting this type of international collaboration, includes myriad logistical challenges. And, although authentic evaluator feedback is helpful, instructors must align these assessments with the rest of their course activities and grading policies. Our future work will include quantitative metrics and aligned projects for international peer student teams.

This structure was productive for meaningfully creating and building international partnerships for the faculty members and researchers involved. For both parties, this project was a low-risk, minimal time investment that presented a way of "testing the waters" for future research and practice collaborations. Sharing this teaching and learning activity resonated with international collaborators, providing concrete ways to inform their own teaching and an established linkage to another world class university.

It is challenging for all engineering undergraduates to access extensive international experiences such as exchange programs, but thoughtful teaching and learning activities could provide international interactions that mirror real-world business activities. These interactions prepare students from an early stage for lifelong engagement with international colleagues.

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