Cross border collaborative learning through Capstone Engineering Projects

Dr. Immanuel Edinbarough P.E., University of Texas, Rio Grande Valley

Immanuel A. Edinbarough received his B.Sc. (Applied Sciences) degree from PSG College of Technology, University of Madras, India, his B.E.. (M.E.) degree from the Institution of Engineers, India, M.E. (Production Engineering) degree from PSG College of Technology, Bharathiar University, India, and his Ph.D. in mechanical engineering from the Bharathiar University, India. He is currently a professor and director of engineering technology at the University of Texas, Brownsville (UTB). Prior to joining the UTB faculty he was a visiting professor at the Rochester Institute of Technology and an associate professor of production engineering technology at PSG College of Technology, Bharathiar University, India, where he served as the director of the Computer Vision Laboratory and National Cadet Corps – Engineering Division Director. With over 26 years of teaching and research experience in manufacturing/mechanical engineering and engineering technology, he currently teaches in the areas of CAD/CAM/CIM, robotics and automation, product and process design, materials and manufacturing processes, machine design, renewable energy and micro-manufacturing. His current research interests include robotics, CIM, sustainable manufacturing, micro machining and engineering and technology education. He has published several papers in these areas in various national and international conferences and journals. He has worked in heavy and light manufacturing industries, manufacturing pumps, motors, and CNC machine tools in the areas of system design, production planning, and control and manufacturing. Edinbarough also served in paramilitary forces and in the Air Force. He is a Life Member of the ISTE, a senior life member of the IE (India), a member of ASEE and SME, and a licensed Professional Engineer (P.E.) in the state of Texas.

Adriana Olvera, University of Texas Rio Grande Valley

Adriana Olvera is currently a lecturer of Manufacturing Engineering at the College of Engineering and Computer Science, The University of Texas Rio Grande Valley (UTRGV). She received her Masters in Architecture from the School of Architecture of the Universidad Nacional Autonoma de Mexico (UNAM), in 2011. She received her Bachelor's in Architecture from Universidad de Monterrey (UDEM), in 2007. Her current research interests include sustainable building design, building automation, and smart environments.

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Abstract

Capstone engineering projects are essential to demonstrate engineering graduates' industry-readiness; however, in a bi-national region, international preparedness is becoming an essential requirement for engineering graduates. This paper describes the process of collaborative learning resultant of a cross-border capstone engineering project in an effort to create an undergraduate research network towards a cross-border learning environment in the Rio Grande Valley.

Background

The Rio Grande Valley (RGV) in southeast Texas and the north east of Tamaulipas, Mexico is a region known as one of the fastest growing metropolitan areas of the world, holding a regional population of over 3.5 million people, amongst USA and Mexico, and hosts broadly diverse manufacturing industries. As a result, higher learning institutions are working towards incorporating higher education as a dynamic regional element.

The University of Texas Rio Grande Valley (UTRGV), was created in 2013 by the Texas Legislature as an unprecedented and remarkable move to bring together the assets of the two most important regional higher education institutions: The University of Texas at Brownsville (UTB) and The University of Texas Pan American (UTPA) [1]. As a new institution, UTRGV is emerging as a regional research institution projecting to grow as a leader among minority-serving research institutions.

As a young institution, with an innovative organization, and with two years since it started operations, UTRGV can be proud of a mission on-route: to provide a high quality, innovative, and affordable education to the students of South Texas, Texas, the United States and the world. The University will transform Texas and the nation through student success, research, healthcare, and commercialization of university discoveries[1]. A temporary vision that has become a statement broadly implemented throughout the different Colleges and Schools within UTRGV, engages faculty and staff into expanding the possibilities from the current multicultural and multidisciplinary programs to cross-border collaboration.

Collaboration with universities across the border provides an opportunity to deliver a better service to the bi-national community in the 150 mile-wide RGV region. The legacy institutions had previous experiences in the development of bi-national programs and collaborations, but by promoting cross-border regional collaboration, the new university demonstrate its commitment to prepare the future engineering professionals.

The College of Engineering and Computer Science (CECS) at UTRGV promotes cutting-edge research with international impact as a path to a better life, built on compassion, community, and technology, and foresee every performed activity as a promoter for economic prosperity and commitment to the global community [1]. With an extensive selection of undergraduate programs in the engineering field, the Department of Manufacturing and Industrial Engineering provide a setting for technology development and applied research in the Engineering Technology (ENGT) program. According to the program description, engineering technology education emphasizes primarily on the applied aspects of science and product improvement, industrial practices, and engineering operational functions[2].

Introduction

Considered as an essential contributor to industrial efficiency, the practice of multidisciplinary engineering design teams performs an important role in engineering problem solving and managerial performance[3]. Thus, the capstone engineering course role in engineering education is essential to prepare the students to resolve industry challenges. Nowadays, innovative methods in teaching, including the cross-cultural student integration have proven effective to enhance success in multidisciplinary engineering design teams.

Examples of academic international programs, such as study abroad, student exchange or online courses, allow students to experience certain advantages of cross-cultural education. However, a more active participation would provide the students with opportunities to develop an understanding of working in international settings and gaining the skills to successfully interact through diverse cultures[4].

As a bi-national region, we can consider this a privileged geographical area to experience cross-cultural mobility. Therefore, cross-border collaborative learning through capstone engineering projects is developed as a regional, cooperative scheme to provide additional societal settings for technology development in undergraduate applied research for students on both sides of the Rio Grande Valley.

Capstone Engineering Course: Promoting International Preparedness

The Engineering Technology program at UTRGV offers a wide range of options from where the students will develop engineering skills to address engineering and technological challenges. At the end of the coursework, the students must complete an industry-related, research-based capstone project, which in specific cases involve the design and development of a functional prototype.

The capstone design project is developed in a two-course sequence of Senior Project I and II. In Senior Project I, students use their time to identify an engineering problem and proceed to develop an optimum solution. At this stage, they also conduct a thorough research on the topic and complete planning and design of the project. The subsequent Senior Project II is used to build and test the functional prototype. These capstone courses are planned to develop a year-long project that will provide students with an opportunity to practice the skills that they have learned and developed through the coursework.

For this cross-birder project, special attention was focused on the following course objectives: improvement in the student’s ability to function effectively as a member of a technical team; ability to apply written, oral, and graphical communication; ability to identify and use appropriate technical literature and understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity[2].

To provide a collaborative academic environment for cross-border students, an emphasis was placed on technology development in multidisciplinary teams. Collaborate with the Computer Systems (CSE) engineering program from Tecnológico Nacional de Mexico /Instituto Tecnológico de Matamoros (TecNM/ITM), presented an opportunity for the students to share ideas and analyze how other engineering program frame the problem and conceptualize the potential solutions.

The language barrier was present, but the international engineering standards and diverse software platforms were used by the students as the initial bridge to start communicating their early ideas. The overall language performance may be limited by the lack of culturally-contextual understanding; in a multi-cultural team having different levels of expertise in the common shared language, the member seemed as less skilled may be cataloged as less adept to provide a useful contribution to the project[4]. As faculty advisors, we determined this situation not to inhibit the student's experience, but to prove the student there is always starting point for improvement and this could be used as a jump-start for their improvement in communication skills.

Including cross-border collaboration in capstone course

UTRGV-ENGT and TecNM/ITM-CSE students actively worked with faculty advisors and engineering professionals, to achieve one main objective: to combine knowledge and practices needed to work on engineering projects that require innovative and interdisciplinary skills. The proposed project to develop between the two programs was an intelligent closet: the expected outcome was to innovate a conveyor design outlined by accessibility guidelines, operated by a user-friendly interface and open to future improvement, considering a residential setting.

At an initial stage of cross-border collaboration, online communication was encouraged, such as the use of social media groups. As faculty advisors, our main concern was to simplify the external variables that would cause additional communication problems since language diversity was already part of the list.

The language component represents a challenge not only in direct collaboration, but also in other cross-cultural methods such as Global Virtual Teams (GVTs), where additional problems must be handled, such as the extent of diversity or lack of commitment from some team members, resulting in fading of the individual performance[4].

Active and continuous self-learning was incorporated throughout the project, as the students continuously searched for new ideas and information on how to successfully implement a viable solution. The engineering technology students had the need to learn new concepts on software design applications and the computer systems students faced the need to learn engineering design and product manufacturing.

Capstone project description: An Intelligent Closet

The main goal of the capstone project as a cross-border collaborative setting is to engage senior students in multidisciplinary projects in practicing the acquired knowledge during their corresponding coursework. This capstone program is developed as a two consecutive course sequence. During the first semester, students use their time to identify an engineering problem and proceed to develop an optimal solution. It is required to conduct a thorough research on the topic and complete the planning and design of the final project. The subsequent, and last semester is used to build and test the completed prototype model.

The main characteristic of a successful capstone project is the innovation and technological development. The project completed is a totally functional real-size prototype of a clothing, storing and retrieving system: The Intelligent Closet. It was designed following accessibility guidelines, characterized by innovative hardware and software solutions in the domain of home automation; the project primarily focuses on the applied aspects of product innovation, industrial practices, and engineering operational functions, to offer useful services and solutions to disabled and the elderly.

Figure 1. 3D Model - overall closet view within walls.

Figure 2. Fabricated prototype.

The students worked as a team on every single design stage; they discussed the best practices to innovate in the conveyor mechanical system; 3d modeling design for the parts was required (Figure 1), and the fabrication and assembly process of their own designs was an enriching experience for the students (Figure 2). Once the parts were fabricated, the product assembly process demonstrate the students the importance of teamwork, as the final product was created.

The software development and communication integration process provided the students with different settings and scenarios to try during the product testing phase. The first version of an automated clothing storage and retrieving system was achieved by incorporating a series of smart environment scenarios in the domains of home automation.

Student Learning Outcomes and Assessment tools

The ultimate goal of the proposed cross-border collaborative capstone project is to provide the student with the opportunity to develop an specific assignment that includes the application of skills, knowledge, and techniques, concepts in the design and manufacturing, learned through the program coursework in a multidisciplinary approach. Formative assessment provides faculty with the tools to analyze results obtained by following an established pathway and to reorganize project phases and activities to successfully complete the final model, by describing the learning objectives and criteria for evaluation, providing feedback to move the learning process forward.

This course is designed to train students:

SLO1. Develop an understanding of the basics involved in teamwork and in becoming an integral part of a team;
SLO 2. Able to combine knowledge and practices needed to work on engineering projects that require innovative and interdisciplinary skills.
SLO3. Apply state of-the-art computer-aided engineering tools and engineering graphics techniques and methodologies.
SLO4. Analyze human factors, ergonomics, and safety issues as part of the requirements for design of engineering systems, products and services.
SLO5. Analyze production problem and design and/or develop a manufacturing system
SLO6. Gain experiences in applying the basics of manufacturing technology as related to problem-solving and critical thinking.
SLO7. Integrate engineering project management standards for efficient and competitive design of engineering products and processes.
SLO8. Research possible solutions to an actual problem in an industrial setting; develop and understanding and knowledge of writing a proposal outlining the problem, budgeting, scheduling of events, etc. to solve that problem;
SLO9. Gain expertise in preparing and delivering formal technical presentations to technical as well as non-technical personnel and groups.
SLO10. Conduct objective assessment of self as well as team members' performance; Work with academic advisors as well as industry personnel to achieve stated goals and objectives of the research project

The tools used as assessments throughout the project are: weekly meetings with faculty advisors, including a written report to document project updates; project presentations are used to provide the students and faculty with a broad feedback during the critical phases of the project, such as project definition, model design, testing and final project evaluation. To keep a record of the methodology used, a Project Binder is used to organize the problem statement, background research, project description, objectives, methodology, software and hardware, testing setup, expected/obtained results, conclusions, references, revisions, scketches, and other information relevant to the project.

Weekly meetings with faculty advisors and written report. Weekly meetings with faculty advisors for project-update are mandatory throughout the project. Minutes are used to record meeting items and issues covered. Students are responsible to provide updates on the list of To-Do tasks discussed during the weekly meetings. Student-development assessment by faculty advisors represents 20% of the final grade.

Project presentations. Scheduling a series of presentations throughout the course provided the students with the opportunity to gain experience in preparing and delivering formal technical presentations to technical as well as non-technical personnel and groups. Presentations are scheduled at the beginning of the first semester to discuss the problem framing and project outline, in the middle of the semester to discuss the project definition and expected timeline, and at the end of the semester to finalize the project proposal and expected results. During the second semester, three additional presentations are scheduled, at the beginning, middle and end of the semester for project updates, testing of results and project improvements. The series of presentations represents 50% of the final grade.

The Project Binder includes, a series of documents containing the problem statement, background research, project description, objectives, methodology, software and hardware, testing setup, expected/obtained results, conclusions, references, and other documentation required by the project. Students are encouraged to write a self-evaluation report to reflect on their experience during the project development, to have a written record of their perceived achievements, learning experience, challenges faced, cultural and professional experience, networking, the impact on their development as professionals and opportunities for improvement. A complete Project Binder represents 30% of the final grade.

The association amongst the items evaluated (product, presentation and project binder), the criteria for evaluation and the designated learning outcomes are described in Table 1, below:

Item	Criteria/Rubric evaluation	Learning Outcome
Prototype/Product	• Design ideas; • Design approach, testing, and results; • Justification of choices; • Hardware and software solutions; • Methods, process, strategies, planning and implementation.	SLO1, SLO 2, SLO3, SLO4, SLO5, SLO6, SLO7, SLO8, SLO10.
Presentations	• Background and overview of the project goals; • Conceptual approaches appropriate for the problem; • Organizational pattern; • Supporting details.	SLO1, SLO 2, SLO4, SLO8, SLO9,
Written Report	• Background information and project goals; • Information about design process and results; • Methods, process, strategies, planning and implementation; • Hardware and Software description; • Conclusion and reflection.	SLO1, SLO2, SLO5, SLO8, SLO10

Table 1. Learning Outcomes Assessment and Criteria/Rubric Evaluation

Lessons Learned

The students have proved their ability for continuous self-learning, by understanding how to address professional responsibilities, including a respect for diversity. As a result of the different personalities coming together to work on a demanding assignment, friction between students was not a problem, and did not cause any disturbance in team collaboration; by the end of the project, cohesion became evident and individual performance showed improvement.

Students' commitment and self-confidence in their work, from the beginning of the project, was vital for the successful completion of the prototype. Stressful situations and technical difficulties tend to drop the students' interest in the project, but true commitment and enthusiasm of participate in an innovative, groundbreaking project kept the students on track; for this assignment, students remained aware of the challenges resulting from participating in a cutting-edge engineering project and the high level of commitment involved.

At the end of the project, the students learned the importance of organization, scheduling and made the best use of the meeting sessions to achieve specific tasks according to schedule; wise used technology to improve the project outcome is essential for student success. The project success was validated by the functionality of the real-scale prototype.

Communication between faculty advisors was vital to create and promote a learning-friendly environment, determine project definition and identify benchmarks to ensure outcomes. Weekly team meetings are recommended to confirm completed benchmarks and analyze results.

Faculty must foresee challenges and have a possible solution in advance, to avoid delays affecting the project outcomes. It is vital for the faculty advisors to formulate multidisciplinary teams with critical thinking skills since the beginning of the project, linking different learning backgrounds to achieve improvement in the overall team performance[3].

Conclusions and Future Work

Engineering solutions influence society at every foreseen and unforeseen level. Therefore, engineering education strategies must be developed to prepare undergraduate students for the ever changing global environment. The undergraduate research experience, through cross-border collaboration can improve the graduates' ability to work in an international setting.

With the use of new technologies, the proposed cross-border collaboration techniques can lead to the development of international projects that will benefit people across borders. Working as one multicultural team, students from two different countries can successfully solve an engineering problem, to prove the effectiveness of cross-border collaboration that is proficient in technology development and innovation through the undergraduate basic and applied research.

Evaluation and analysis of student learning outcomes through cross-border collaborative capstone projects describe the qualitative values of the student understanding on the impact of engineering in a social and global setting. Self-learning and continuous education are expected, yet, a multidisciplinary engineering design team can effectively provide a wider range of viable solutions, improving expected outcomes.

The integration of cross-border collaborative learning through capstone engineering projects can be implemented as a collective regional improvement in undergraduate education, and eventually, progress to a cross-border educational learning culture.

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