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A Case Study of Integrating Leadership Competencies in a Global Engineering Design Course: A Work in Progress

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Introduction

Engineers have a strategic leadership role in tackling the world's challenges such as the global environmental challenges, infrastructure modernization needs for an expanding population, technological innovations and developments demands, and global health problems [1].Similarly, the engineering world has become increasingly global with many companies establishing global partnerships, international alliances, cross-border mergers and acquisitions for increased productivity and competitiveness [2][3]. For instance, the recent merger between two tech companies, Broadcom and VMWare, required approval from twelve countries [4].This highlights the need for global engineering leadership competencies that can enable graduate engineers to collaborate with diverse stakeholders across disciplines, geographical locations and cultures to work on complex global problems. Hence, engineering accreditation and research funding organizations have mandated that futures graduates develop global engineering leadership competencies including global perspectives, multidisciplinary teamwork, and complex collaboration skills that can enhance employability [5][6].

Conventional pedagogical approaches by engineering institutions for incorporating engineering leadership education comprise of experiential service-learning projects, problem-based learning, interdisciplinary/ multidisciplinary team competitions, intercultural team projects, mentoring as well as through other avenues such as industry-sponsored initiatives, industry-paid projects, industry internships, networking and institutional cooperation [7]. However, most approaches have been implemented via separate programs involving single courses, and extra-curricular activities that are not accessible to the broader student population due to scheduling constraints and equity challenges such as time and distance constraints, familial responsibilities and work commitments[8][9].Hence, educators are exploring strategies for integrating engineering leadership into the mainstream engineering curriculum, to help more students gain these professional competencies that are crucial for the 21st century workforce [10]. One attractive approach is engaging multidisciplinary student teams on complex collaboration projects situated in global settings [11].While complex collaboration projects can allow students to work together with diverse partners across organizational, disciplinary, cultural, or geographical boundaries, they can also result in misunderstanding, disruption and conflict [12][13][14]. However, these boundaries, which can be seen as unfamiliar practices or differences in perspectives and communities of practices, may not necessarily result in problematic conflicts, they can also lead to productive conflicts and opportunities for transformational learning to occur [15] [16].

This study examines complex collaboration boundaries to understand how they can support engineering students' development of leadership competencies. This is work-in-progress, and part of a larger project that aims at exploring students' development of global competencies. The current paper advances our understanding of boundary crossing that occur within an engineering design team, and it asks: a) what boundaries were encountered in globally situated engineering design projects in a Canadian University and, b) how can these boundaries enable students to make productive progress in their global leadership skills?

Theoretical Perspectives

The study was guided by three theoretical perspectives namely: 1) Vygotsky's social constructivist perspective allowed for the study of students' learning and development through socially co-constructed interactions in their team projects [17], 2) Akkerman and Baker's boundary crossing, refers to situations where individuals transition and interact across different sites or communities of practice, allowed for the investigation of the students' interactions and learning experiences[16] [18], and 3) Jehn's group conflict concept guided the analysis of the student's conflict management interactions in their design teams [12]. Jehn's study highlighted three types of conflict -- namely process conflicts, which refers to issues that focused on how tasks would be accomplished, cognitive conflict which is associated with the content, and relational conflict which is focused on interpersonal relationships [12].Together the three perspectives enabled the examination of students' team interactions to ascertain boundary-crossing experiences and associated conflicts that can supported their development of global engineering leadership competencies.

Methodology

Global Engineering Design (GED) Course

This research examines engineering leadership within the context of a global engineering design (GED) course at a large North American University that enabled students to tackle real world design challenges with global significance and build high fidelity prototype solutions. In the course, engineering leadership is defined as the ability to combine leadership skills [19] of social judgement, problem solving, and knowledge with management skills [20] that are focused on administration and performance with the aim of effecting change within a multidisciplinary engineering design project domain of influence [21]. Guided by the transformational leadership model [20], the GED course focused on design as a humanistic process [22] while prioritizing collaboration, communication and reflection throughout the design work. The GED course was mandatory for second-year engineering science students with two requirements in year one that fostered students' leadership in team and local community settings respectively. The course introduced students to cultural awareness within the concept of culturally responsive design to support their global perspective development. The course was delivered in a hybrid format to about 250 students via three interactive class lectures each week. The students also participated in weekly practical labs comprising about 6 small teams of 4 to 6 members each. The teams had the flexibility of working together in both in-person and virtual settings.

Building Engineering Project Leadership Skills

Although the course focused was technical skill building, students applied project management principles [23] which enabled them to take ownership of relational and cognitive tasks in their globally situated design projects. Building on the concept of leadership as a relational process, students utilized team charters, project roles, and communication protocols to establish collaborative teamwork structures [14]. These tools supported students' decision-making and conflict management practices thereby enhancing productivity. In addition, support systems for inclusivity and accountability such as the responsibility matrix, team building ice breakers or activities, and action items trackers facilitated trust management and relationship building [24].

Furthermore, team management artefacts such as project schedule(s), task list(s), meeting notes, procurement and budget tracker(s) supported students' efficient time management practices. While the project schedule facilitated planning of design project activities, the task lists facilitated work transparency; meeting notes enabled progress tracking of tasks, and the procurement tracker allowed for cost transparency of design project purchases. The artefacts supported students' self-regulation and engineering leadership competencies. Engineering project leadership evaluation was conducted via self-assessment surveys, peer reviews and team reflections. These reflections allowed students to describe, analyze, and critically consider new knowledge and team experiences in relation to their self-aware engineering leadership development [25]. This approach encouraged students to employ inclusive collaboration and transparent teamwork practices that supported the development of core leadership competencies.

Data Collection and Analysis

Utilizing a case study methodology [26][27], this paper reports on two student team projects from the GED course. This method is suitable as it provides insights into the complexities of crossing boundaries in an authentic global learning course. The Water Hyacinth project team consisted of four members that strived to build an electromechanical solution that mitigated the invasion of water hyacinths in a Thailand community for improved usability and cleanliness. Water hyacinths are an invasive species of plant that overrun the waterways, known as "klongs". While the Plastic Waste project team, consisting of 4 members, worked to reduce plastic waste pollution in a Ghanaian community by improving the manufacturing process and recyclability of new wood-plastic composites (WPCs). Data was collected from five team meeting recordings and students' learning artifacts. The team recordings were transcribed and thereafter a thematic analysis [28] was utilized to inductively code students' data to capture boundary-crossing interactions, associated conflicts and decision-making practices. These were then categorized and systematically examined for emerging themes around the students' productive exchanges and learning mechanisms.

Findings and Discussion

Our preliminary findings identified three themes around students' cultural and knowledge boundary-crossing experiences with associated cognitive and process conflicts: 1) Unfamiliarity with cultural and environmental impact, 2) Concerns related to Environmental Impact and 3) Unfamiliarity with global conditions within the design space. These are described below with excerpts from the collated data that illustrate when and how they occurred within the respective team processes.

Navigating Cultural Boundaries

A. Unfamiliarity with Cultural and Environmental Impact

Students in the Water Hyacinth project team were unfamiliar with the environmental and cultural impact of their proposed solution. This resulted in some cognitive conflict as the team utilized divergent thinking approaches to explore implementation solutions that would involve minimal structural modifications while conserving the cultural integrity of the host environment. For example, in discussing the potential of modifying an existing canal, a student asked, "I just had a question about … environment analysis… is it compatible? Like, can it be built with minimal structural modification?" While another student offered some assurance, "I also feel like having to sort of dig into just sort of one little area at the end of the canal is not significant structural modification."

B. Concerns related to Environmental Impact

The Plastic Waste project students were concerned about a potential environmental hazard of their proposed solution: "Burning plastic definitely is an environmental concern." This involved some cognitive conflict as they discussed the potential impacts to the host community's environment and brainstormed ideas for addressing the problem.

> "…if we're actually having to melt this stuff, we'll probably want to be conscious about open flame, which like, the wind to actually catch fire..., but the way that we actually melt the plastic", and "It might have some considerations about fumes."
>
> "I'm not entirely sure that we'll have that many issues with like the plastic itself burning and creating too many fumes, since we're gonna be melting at such a low temperature."

Navigating Knowledge Boundaries with Cultural Dimensions

A. Unfamiliarity with Cultural Dimensions of Global Conditions

The Water Hyacinth project students were unfamiliar with the characteristics of a water hyacinth plant, as they had little knowledge and experience with how water hyacinth plants function. This highlights the intersection of knowledge and culture boundaries. In this situation the knowledge boundary has some cultural dimension, specifically the non-commonality of water hyacinth plant in the local Canadian environment. It is this cultural dimension that led to a process conflict as the students deliberated design solution validation options recognizing that they could not touch and feel the water hyacinth plant nor can they test their ideas in the lab:

> "…this feels like a really hard opportunity to work on given the timeframe. Yeah, like, without any access to, you know, water hyacinths to actually test to see if this works even slightly at all.,

To tackle this problem, the students applied mental modeling approaches to help them create an internal representation of the water hyacinth's behavior and visualize its response to mentally simulated tests:

> "…so if you just clear them, and then have people running through the just sort of push them around and stop them from and if we stop them from anchoring to the bottom, then they can't really stick around. Like they have to just sort of float away."

This also highlighted the need for more research work to enable the students to gather more information about the characteristics and behaviors of the host plant to improve the accuracy of their mentally simulated tests.

Conclusion

This paper presents a promising strategy of utilizing a blend of multidisciplinary teams and complex collaboration projects situated in a global context to foster students' development of engineering leadership competencies. The study highlights students' experience crossing the knowledge and cultural boundaries that they encountered in their GED project teams. It also highlights students' use of brainstorming techniques, divergent thinking and mental modeling to navigate the cognitive and process conflicts that they encountered in their design projects. The use of knowledge boundaries with cultural dimensions presents a useful strategy for educators to introduce intercultural learning opportunities in topics that might not easily be adaptable for cross-cultural learning. As the students recognize the intersection of knowledge and culture, they can interrogate the knowledge concepts while gaining renewed cultural perspectives and understanding. The use of the three theoretical perspectives of boundary crossing [16], group conflict [12], and social constructivist [17] in this study, allowed the authors to interrogate students' boundary crossing experiences and curate approaches for supporting global learning. The findings can guide educators to intentionally incorporate boundary crossing situations into their curriculum to stimulate productive conflict and global learning exchanges that can support the development of global leadership competencies.

This study is significant as it demonstrates boundary learning focus areas and strategies for scaffolding students' leadership experiences in global learning contexts. This research contributes to the theory and practice of engineering leadership and learning across boundaries in engineering education. However, the research was limited to data from two team projects and students' perspectives. In the future, the scope of data collection can be expanded to include more team projects with diverse student team members, different engineering disciplines and varying levels of expertise to capture a more comprehensive range of perspectives and to gain broader understanding of boundary-crossing experiences. Furthermore, integrating perspectives from other stakeholders such as instructors, industry partners, or community members could provide a more holistic understanding of the effectiveness of the GED course and its alignment with industry needs. In the longer term, longitudinal studies could be conducted to gain insights on the long-term impact of the GED course on students' leadership competencies, and to assess how their experiences in boundary-crossing projects have influenced their leadership development over time, both academically and professionally.

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