Design Based Wilderness Education

A Cross-Cultural Experience in Engineering Education

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Abstract—**The Massachusetts Institute of Technology (MIT) has been collaborating since 2010 with the Singapore Ministry of Education to help develop the Singapore University of Technology and Design (SUTD). One element of this collaboration, the Global Leadership Program (GLP), aims to provide SUTD students with the opportunity to interact with the MIT community and experience MIT's academic culture, while at the same time participating in programming to assist with the development of leadership skills. This paper describes a curriculum combining the pedagogies of design-based learning and wilderness education that was implemented in the summer of 2014 as a component of GLP. Wilderness education was selected as a pedagogical framework for this program as it may be well suited to create effective learning environments for engineering education, cross-cultural learning, and fostering conceptual change. Through design activities both for and in a natural environment, students were encouraged to develop competency in engineering science while exploring the diverse attributes essential for success as an engineer.**

Keywords—Wilderness Education; Design-based Learning; International Collaborations; Cross-cultural Learning

I.   INTRODUCTION

The Massachusetts Institute of Technology (MIT) has been collaborating since 2010 with the Singapore Ministry of Education to help develop the Singapore University of Technology and Design (SUTD). This collaboration aims "to accomplish the development of a new engineering-oriented university that will reach the Engineer of 2020 vision, while in parallel addressing the timely formation of an institutional identity and culture that borrows from those of MIT" [1]. Through this collaboration, MIT is involved in faculty training, the development and deployment of curriculum, and supporting student life related initiatives, such as the development of co-curricular and leadership activities [1]–[4]. In the summer of 2013, the MIT-SUTD Collaboration Office ran the first Global Leadership Program (GLP) in support of the leadership activities of the collaboration. The GLP brings between 25 and 30 SUTD students to MIT for ten weeks during the summer semester. It aims to provide SUTD students with the opportunity to interact with the MIT community and experience MIT's academic culture, while at the same time participating in programming to assist with the development of leadership skills. This program exists broadly in the context of a series of activities designed to encourage academic cultural transference between MIT and SUTD.

This paper introduces a component of GLP that combines the pedagogical approaches of design-based learning and wilderness education to create a novel learning environment for engineering students. This component, designed with the multifaceted nature of the MIT-SUTD collaboration in mind, was implemented as a prototypical curricular element during the 2014 iteration of GLP lasting from June to August of 2014. The design-based wilderness education curriculum culminates with a traditional wilderness education objective, a 3-day backpacking expedition in the White Mountains of New Hampshire, after a series of more traditional classroom and lab activities implemented on the MIT campus.

Wilderness (and Adventure) Education programs aim to create a supportive environment in which students learn through the experience of challenge and adventure, relying on "the lessons available from the direct experience of nature and extended wilderness expeditioning" [5]. Wilderness Education curricula are typically focused on developing leadership and teamwork competencies, wilderness skills, and the personal character development of participants [5], [6].

This approach serves as an effective pedagogical model as travelling in the North American wilderness will provide a novel experience for the SUTD students and may be well suited for application in cross-cultural learning experiences due to the unique learning environment that is developed. Furthermore, despite the fact that the skills and attributes developed through wilderness education appear to map well to the skills and attributes desired in engineering education, design-based learning in the wilderness appears to be a novel approach to informal engineering education, as teaching engineering competencies within the framework of wilderness education is rarely discussed in the literature.

II.   UNDERSTANDING THE LEARNERS

The design-based wilderness education curriculum has been specifically developed taking into account the context of the MIT-SUTD Collaboration and expectations regarding the students participating from SUTD:

- The 30 SUTD students attending GLP have already completed an intensive Introduction to Design course during their first year at SUTD.

- MIT's motto "Mens et Manus", Latin for "Mind and Hand", captures the hands-on academic culture that is found at MIT. Exposing SUTD students to this academic

culture is one of the primary goals of GLP. While MIT students are expected to be familiar with a culture that values hands-on do-it-yourself approaches to problem solving, this cultural attitude is not the norm in Singapore and it is not expected that this approach will align with the previous experience of the majority of the SUTD students.

- The North American environment is unfamiliar to SUTD students. The flora, fauna, climate, terrain and remoteness of the expedition area all present new and unexpected challenges for the students. Singapore is a relatively flat island with very little area that could be considered wilderness, with consistently warm and humid weather. Conversely, New Hampshire has vast expanses of remote wilderness and a more temperate climate prone to large variations in temperature between day and night.

III. DEVELOPING A DESIGN-BASED WILDERNESS EDUCATION CURRICULUM

There are currently substantial efforts underway to reform engineering education and encourage global collaboration. In the United States, the introduction of the Engineering Criteria 2000 (EC2000) by ABET (formally the Accreditation Board for Engineering and Technology) required students in engineering programs to "learn to function on multidisciplinary teams", "communicate effectively", and "understand the impact of engineering solutions in a global, economic, environmental and social context" [7]. This trend towards outcome and competency based criteria targeting professional competencies is not limited to the United States. The 23 signatories of the Washington Accord, representing accreditation bodies from an array of countries in North America, Europe, Asia and Oceania, recognize the substantial equivalency of their individually accredited programs. Under this accord, a statement of graduate attributes and professional competency profiles requires engineering graduates be able to "assess societal, health, safety, legal and cultural issues", act "as a member or leader in diverse teams and in multi-disciplinary settings", and "communicate effectively on complex engineering activities with the engineering community and with society at large" [8].

Adding a sense of urgency, the National Academy of Engineering released a report entitled *The Engineer of 2020: Visions of Engineering in the New Century*, arguing that a broad range of skills should be inculcated into engineering graduates, including ingenuity, problem-solving capability, scientific insight, creativity, determination, leadership, conscience, vision, curiosity and wonder [9]. While strong analytical skills remained foundational, this report highlighted a complex world filled with social, environmental, political and economic considerations that would increasingly become a part of daily life for engineers. To help encourage success in this new context, engineering educators were challenged to engender creativity, communication, leadership, boldness, courage, dynamism, agility, resilience and flexibility in their students, attributes that would help engineering students meet the challenges of the modern world [9].

Despite efforts to embed curricula addressing the development of new skills and competencies, and the work of international collaborations, some indicators point to these efforts as being largely unsuccessful. Cech [10] found in a longitudinal survey of students at four US colleges (MIT, the Franklin Olin College of Engineering, Smith College, and the University of Massachusetts-Amherst), that engineering education may foster a culture of disengagement, resulting in graduating students "less concerned with the importance of professional and ethical responsibilities, understanding the consequences of technology, understanding how people use machines, and social consciousness" than when they started their programs.

A design-based wilderness education curriculum is being developed and implemented within the context of the aforementioned discussion. Through this curriculum, the MIT-SUTD Collaboration hopes to add to the rich tapestry of methods through which future engineers around the world are prepared to meet global challenges. The curriculum has been developed using the Teaching for Understanding Framework which focuses on the development of generative topics, understanding goals, performances of understanding, and on-going feedback [11]. The wilderness education components of the curriculum are based on best practices from both Outward Bound [6] and the National Outdoor Leadership School [5]. With a curriculum that combines elements of design-based learning and wilderness education, students will be situated in an environment in which they will be able to experience conceptual changes in their understanding of the engineering profession and its role within an increasingly global society, while developing the skills and characteristics required to succeed in an increasingly modern interconnected world.

Through design activities both for and in a natural environment, students will explore the diverse attributes essential for success as an engineer, while also considering the global social context in which engineering inexorably exists. As the following sections explore, there are indications that wilderness education may be well suited as a learning environment for engineering education, cross-cultural learning, and fostering conceptual change.

A. Wilderness Education for Engineering Education

As discussed earlier, many international outcome and competency based accreditation processes require students to "assess societal, health, safety, legal and cultural issues", act "as a member or leader in diverse teams and in multi-disciplinary settings", and "communicate effectively on complex engineering activities with the engineering community and with society at large" [8]. To help address these topics, many engineering programs include hybrid problem and project based learning approaches, most often in the form of capstone design projects, structured to allow students to work with industry partners on real world problems. This industry connection helps to contextualize the social and professional aspects of engineering, such as teamwork and communication [12].

Wilderness Education also has the potential to positively impact many of these professional engineering competencies in a lasting manner. Participants in wilderness education experiences typically express long-term increased competency

in skills such as leadership, teamwork, self-confidence, and communication skills [13].

B. Wilderness Education as a Cross-Cultural Experience

Learning and teaching can be regarded as inherently cultural processes [14] and culture plays two important roles within the context of this international collaboration. The instructors delivering the design-based wilderness education curriculum will be instructing students from different cultural perspectives and backgrounds, while simultaneously attempting to inspire and encourage the SUTD students to transfer elements of MIT's academic culture back to SUTD.

In the context of cross-cultural learning, successful out-of-school learning environments typically have scaffolding that consists of, "(1) organizing participation in activities in ways that address basic human needs for a sense of safety as well as belonging; (2) making the structure of the domain visible and socializing participants for dispositions and habits of mind necessary for expert-like practice; (3) helping novices understand possible trajectories for competence as well as the relevance of the domain to the learners; and (4) providing timely and flexible feedback" [14].

Wilderness educators recognize that wilderness experiences are a cross-cultural experience for most learners, no matter their cultural background. Mapping common wilderness education practices to this scaffolding, (1) conceptual models, such as Maslow's hierarchy of needs [15], are often used as a model to discuss physiological needs and security needs from the perspective of risk-management and creating an effective learning environment; (2) demonstrations, modeling, and coaching are all used to illustrate and encourage expert-like practice; (3) students are motivated by learning skills that are directly relevant to basic needs in their current living situation; (4) the natural environment is able to give direct and regular feedback to students, as there is no "need to contrive challenge, difficulty or especially risk" when students are engaged with the natural world [5].

The 2014 iteration of the GLP has 30 participants from SUTD and 6 participants from MIT. The inherent cross-cultural element of wilderness education can contribute to leveling the playing field between the SUTD and MIT students participating in the program, placing all students in an unfamiliar learning environment in which they will have to rely on each other for support.

Academic culture is often instilled through the deliberate use of academic orientation experiences. Outdoor orientation programs have been indicated to be particularly effective at helping students transition into the academic culture of college, almost 200 colleges in the United States and Canada use outdoor orientation programs to help students "develop a sense of belonging and status in transition", often resulting in long term measureable increases in factors such as retention rate and GPA [16]. These positive benefits, like others observed for wilderness education, have been attributed to a positive learning environment consisting of small and supportive peer groups. While there are some seemingly universal benefits, specific outcomes influenced by outdoor orientation programs depend partially on the focus of the curriculum [16].

C. Wilderness Education for Conceptual Change

Ultimately this program seeks to support a learning environment in which students can examine, and perhaps change, their internal conception of the importance of various attributes and professional competencies expressed by engineers. Wilderness Education programs have the potential to provide substantial and lasting outcomes regarding a student's perception of self, and changes in life perspective. In the literature this potential is exemplified by a study interviewing participants 17-years after a 5-day wilderness orientation program. The participants consistently reported that the experience had helped them challenge assumptions of self and others, indicating that the program had provided "direction in their careers, direction in their personal lives, development of personal values and skills, and development of life-long friendships" [17].

Increased self-confidence and changes in life perspective are often reported in studies on wilderness education, and this effect is noticed even when not purposefully targeted by a curriculum [13]. As concluded in [13], "Wilderness education provides a unique social environment that allows participants to explore beliefs and assumptions that they hold, seemingly allowing for lasting changes in life perspective." A meta-analysis of 96 studies found that adventure programs have a greater effect on students' self-concept than traditional classroom-based interventions. Most strikingly, unlike other interventions it seems that "the effects of adventure programs continue to increase over time, and are maintained over considerable time" [18].

IV. CURRICULUM

A. Design

As a subcomponent of GLP, the prototypical design-based wilderness education program is focused around a classic wilderness education objective, a hiking expedition. A series of progressions that take concepts from more traditional classroom settings to wilderness environments are used to attempt to effectively develop further competency in the application of engineering science, while simultaniously developing engineering leadership competencies.

The design-based wilderness education curriculum as implemented consists of four 3-hour long sessions on campus over two weeks, followed by groups of 9 students and 2 instructors embarking on 3-day backpacking expeditions over 4 weekends.

Students are initially prompted to consider the generative question of, "What role can engineers play in how individuals relate to the natural environment, each other, and society as a whole?" While examining aspects of this prompt, students will prepare for, and travel through, a true wilderness environment. Engaging with a learning environment that strips away much of the infrastructure and technology that has built up in society over time, students will be able to better examine their personal relationship with technology and engineering. Through imagining, building and using artifacts of their own design to survive and thrive in the wilderness, it is hoped that students will continue to develop their competency in engineering

science while directly experiencing the individual and social impact that engineering artifacts produce. On an ongoing basis, students will be encouraged to transfer this learning experience to their conceptualization of the engineering profession and its role within society.

In one progression, beginning in a classroom environment, students are provoked to consider what it means to design for a natural environment, developing a set of general design principles (such as durability, transportability, and repairability). Still on campus, students are challenged to design and build a prototype of a single burner alcohol stove. This design activity will require consideration of the physics of combustion, properties of the selected fuel, and the limitations of available materials. This design project follows students into the wilderness expedition as they are expected to use the stoves that they have designed and built to cook while camping. This use of their own design project, in the context of fulfilling a survival need, will provide a very visceral context in which to consider the individual impact that engineering technology has on members of society.

Another progression will challenge students to consider what it means to design in a natural environment. To begin to develop the skills necessary to use rope as a tool, students will engage in an activity on campus challenging them to build 'bear hangs' (systems designed to elevate food above the ground in a forest so that bears can not reach it). To do this students will have to understand and construct hauling systems using mechanical advantage, taking into account factors such as system extension under load, force on anchors, frictional force, and material breaking strength. Students will then use this system while on the wilderness expedition, examining how the build process and design considerations change when implementation is performed in an unknown natural wilderness environment. Further extending this concept, while on the backpacking expedition, students will be challenged to design and construct a method to assist a person with a broken leg to cross a chasm or river. To successfully construct a 'rope bridge' students will have to apply the skills learned during previous activities in novel ways.

Additionally, while on the backpacking expedition students will be sleeping under tarp shelters of their own design and construction. Using only plastic sheeting and string, students will independently design and construct a shelter that they will sleep in for two nights. During initial construction students will be encouraged to consider various design tradeoffs that may be apparent. After the first night students may choose to adjust their shelters based on their new experiences.

V. EXPECTED OUTCOMES AND EVALUATION PLAN

The 30 SUTD and 6 MIT students are participating in a study to evaluate the manner in which students transfer design processes to novel environments, and to evaluate the potential effectiveness of a design-based wilderness education curriculum in developing engineering leadership and engineering science competencies. Table I sets out the data that is being collected during the ongoing study.

TABLE I.   DATA COLLECTION PLAN

Type of Data[a]	Contributors	
	Students	*Instructor*
Video of in-class design and synthesis	X	
Video of outdoor design and synthesis	X	
Reflective Journals	X	
Questionnaires	X	
Exit Interviews	X	
Field Notes		X

[a.] Video-recorded data refers to only students and curriculum; all other data also refers to the instructor.

The questionnaire devised to provide an indication of program effectiveness is based on an inventory developed in [19] that measures "leadership, adaptability to change, and synthesis abilities." This questionnaire will be administered as a retrospective post-then-pre test to minimize response-shift bias and measure learners' perception of change [20].

Findings will be used as guidelines for future enhancement of design-based wilderness education curricula, and for the design of a more holistic research study.

VI. PRELIMINARY RESULTS

As of July 2014, the on-campus sessions have been completed and one group has undertaken the 3-day wilderness expedition. Preliminary observations indicate that participants were able to quickly synthesize new knowledge in an unfamiliar domain by applying an engineering science mindset to wilderness education problems, such as examining clothing layering and sleeping systems as a heat transfer problem. So far, students have successfully completed the intended design projects. It appears that the practical design activities exposed incorrect conceptual models of physical phenomena and have required students to develop more sophisticated understandings of concepts such as friction and combustion mechanics.

Students demonstrated strong pre-existing leadership and teamwork capability. This was expected as all male Singaporean citizens are conscripted for two years of National Service prior to entering university. Consequently, many activities were designed for individuals or small groups to allow for a focus on individual self-reliance and resilience rather than teamwork. The perceived benefit of these activities is yet to be determined.

The process that students use when participating in design activities varied greatly. On individual tasks students would often dive into construction, seemingly without understanding the necessary engineering science. At other times, especially during group activities, students would pull out a notebook, even in the middle of the forest, to sketch out possible solutions. In most cases students would attempt to iterate through designs when solutions did not work as expected.

As these are only preliminary interpretations based on an incomplete data set, they are subject to change as the remaining students complete the program and the data is formally analyzed.

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