Changes in Design Thinking through Participation in Design Based Wilderness Education

Chris Saulnier
MIT, Cambridge, USA
saulnier@mit.edu

Aikaterini Bagiati
MIT, Cambridge, USA
abagiati@mit.edu

Benjamin Ahn
MIT, Cambridge, USA
bahn@mit.edu

John Brisson
MIT, Cambridge, USA
brisson@mit.edu

***Abstract**: In the summer of 2014, 30 students from the Singapore University of Technology and Design and 6 students from the Massachusetts Institute of Technology participated in a 10-week Global Leadership Program (GLP) in Cambridge, Massachusetts. GLP provides students with the opportunity to develop design thinking and engineering science competencies alongside leadership skills. A curriculum combining elements of design-based learning and wilderness education was developed and implemented to holistically address the development of these three skillsets. This pilot study is the group's first attempt to investigate the effect of participation in design-based wilderness education on student design thinking. Through qualitative analysis of student interviews 8 major themes that students associated with changes in their design thinking were identified: being flexible, the importance of high-fidelity testing, the value of simplicity, the importance of trying, survival as motivation, having empathy for others, trusting the process, and identifying team strengths*

Context

In the summer of 2014, 30 students from the Singapore University of Technology and Design (SUTD) and 6 students from the Massachusetts Institute of Technology (MIT) participated in a 10-week Global Leadership Program (GLP) in Cambridge, Massachusetts. GLP is a fully funded exchange scholarship program that encourages interaction between SUTD and MIT students while exposing SUTD students to MIT's academic culture. The SUTD students attending have completed their first three semesters of study, including an intensive design experience. GLP consists of a variety of components that address the development of design thinking and engineering science competencies alongside leadership skills. To complement more traditional on-campus lessons while attempting to holistically address the development of all three capacities, a curriculum combining elements of design-based learning and wilderness education was developed and implemented.

Wilderness Education as Pedagogy

Wilderness education was chosen as a pedagogical framework as it may be well suited for engineering education. Wilderness education programs create a supportive small-group 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" (Gookin, 2006).

Many of the outcomes from wilderness education map well to those desired for engineering education. Participants in wilderness education experiences typically express long-term increased competency in skills such as leadership, teamwork, self-confidence, and communication (Sibthorp, Furman, Paisley, & Gookin, 2008). Wilderness education programs seem to be more effective at helping students transition into new academic cultures than traditional orientation programs (Bell, Gass, Nafziger, & Starbuck, 2014). Most strikingly, unlike other interventions “the effects of adventure programs continue to increase over time, and are maintained over considerable time” (Hattie, Marsh, Neill, & Richards, 1997).

Curricular Framework

The curriculum consisted of a series of lab and classroom activities that helped to prepare students for the goal of embarking on a 3-day backpacking expedition to the While Mountain National Forest in New Hampshire. The curriculum was developed using the Teaching for Understanding Framework which focuses on the development of generative topics, understanding goals, performances of understanding, and on-going feedback (Wiske, 1997). Wilderness education components of the curriculum were based on best practices from Outward Bound (Crane et al., 2008) and the National Outdoor Leadership School (Gookin, 2006).

While developing the curriculum we considered the role of student design thinking. Described by Dym, Agogino, Eris, Frey, & Leifer (2005), design thinking “reflects the complex processes of inquiry and learning that designers perform in a systems context, making decisions as they proceed, often working collaboratively on teams in a social process”. Design thinking has been explored through many frameworks broadly divided into two paradigms: design as a rational problem solving process, and design as a process of reflection-in-action (Dorst & Dijkhuis, 1995). Schön’s notion of reflection-in-action is well suited to integration with wilderness education as the same paradigm of learning through experience underlies both. We hope that designing in and for a wilderness environment will provide the “surprises, pleasing and promising or unwanted” that will encourage students to respond as reflective practitioners (Schon, 1983, p. 56).

The unique environment of the American wilderness provides an opportunity for students to explore a problem-space with which they may be initially unfamiliar. The first lesson takes advantage of this unfamiliarity, focusing on how basic scientific principles (i.e. thinking of clothing layering systems as a heat transfer problem) can be used to understand this seemingly new problem domain. Figure 1 outlines the timeline of activities for the design-based wilderness education curriculum. Throughout the program students are encouraged to explain the world around them using prior knowledge of basic scientific principles and through the exploration of new scientific concepts. Students take part in various design projects to illuminate elements of the wilderness environment. Students design *for* the natural environment by constructing single burner alcohol fuel stoves, which they rely on for cooking while backpacking. Students design *in* the natural environment by building shelters using plastic sheeting and rope instead of relying on commercial tents. Students are also responsible for constructing bear hangs (a system to haul food into a tree using mechanical advantage) and participate in a design challenge to build a “rope-bridge” with the stated goal of helping assist a person with a broken leg across a stream. The curriculum is more fully described in a previous publication (Saulnier, Ahn, Bagiati, & Brisson, 2015).

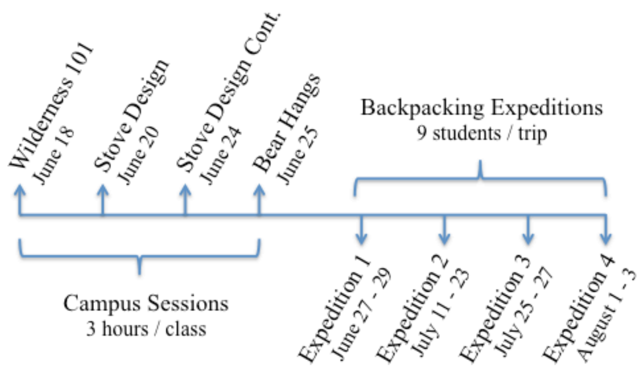

Figure 1: Design Based Wilderness Education Timeline

To consider how to best encourage students to transfer their experiences during the design-based wilderness education curriculum to future classroom environments we used Perkins & Salomon (1988) model of teaching near and far transfer. Students engage in backwards-reaching transfer as they apply their existing engineering skillset to novel problems found in the wilderness environment. This backwards-reaching transfer is engaged in the spirit of parallel problem solving, with the intention that students will then be more willing to transfer lessons from the wilderness environment to future design environments. Other tools for teaching transfer (anticipating applications, generalizing concepts, using analogies, and metacognitive reflection) were used throughout the lessons to aid in developing the encouraged transfer.

Study Purpose

This pilot study is a continuation of a series of investigations into the potential value of design-based learning that incorporates elements of wilderness education. A previous study indicated that participation in this curriculum developed student leadership capacity (Saulnier et al., 2015).

This pilot study investigates the effect of participation in a design-based learning experience incorporating elements of wilderness education on student design thinking. Rather than explicitly focusing on design instruction, students were expected to transfer their pre-existing knowledge of engineering design to the novel context of a wilderness expedition. The analysis that follows illuminates the aspects of design thinking that students felt were emphasised while designing in and for a natural environment.

While the emphasised themes are of interest to help understand the experience of students participating in the program, we are also interested in exploring which, if any, of the themes align with recognized effective practices. A short analysis follows the thematic analysis where we see that some themes do align with effective practices found in the literature on student engineering design.

This alignment helps us explore the notion that design-based wilderness education may be particularly suited as a pedagogical approach for encouraging certain types of design thinking and learning. These themes provide inspiration for future research questions. They also aid in the development of new exploratory curricula to better take advantage of unique strengths of this novel approach to engineering education.

Methodology

During the initial implementation of the curriculum, all 36 students, 30 from SUTD and 6 from MIT, enrolled in a research study examining the effects of participating in design-based wilderness education on leadership ability, design thinking, and the application of engineering science. Of the 36 participants in the study, 14 were female.

The 30 SUTD students attending GLP have already completed an intensive Introduction to Design course during their first year at SUTD. All male Singaporean citizens are conscripted for two years of National Service (commonly army service) prior to entering university. Many of the students therefore demonstrated strong pre-existing leadership and teamwork capability in physically and emotionally challenging environments. The 6 MIT students had various levels of pre-existing design experience and very little in the way of pre-existing wilderness experience.

Shortly after the conclusion of the program 34 of the students participated in exit interviews of approximately 15 minutes in duration. During the exit interview, students were asked to reflect upon their learning experience while participating in the curriculum and to compare the class to previous design experiences. The interview transcripts were analysed using a constructivist grounded theory approach (Charmaz, 2014). The interview transcripts were coded in two stages. Initially each thought was gerund coded. The gerunds were then used to identify emergent themes and a thematic coding scheme was generated and subsequently applied to each of the transcripts in a second round of coding. After the analysis was complete, we explored the engineering design literature to identify effective design practices that seemed to align with emergent themes from this study.

As raised by Maxwell (2010), two of the major threats to validity for qualitative research are researcher bias and reactivity, two threats abundantly present in this study. The first author developed the curriculum, instructed the course, and coded the data for this pilot study. It has been necessary to carefully balance these sometimes competing and sometimes complementary roles. An important consideration is that, as the instructor of the program performed the interviews, student responses may have been influenced by a social desirability bias. While responses were consistent across interviews, the interviews have not been triangulated with other sources of data. Furthermore the population participating in this pilot study is unique and likely not representative of other academic populations.

With these threats to validity in mind, this pilot study describes how students articulated changes to their design thinking after participating in design-based wilderness education.

Findings

To understand how students had integrated their experience with design-based wilderness education into their design thinking, towards the end of each interview students were asked, "What lessons are you taking away from this experience and do you think it will change how you approach design in the future?" Student responses ranged from specific skills they planned on transferring beyond their wilderness experience to "I'm not sure". Table 1 summarizes the responses of the 30 students who responded to this question into eight primary themes. Three students responded that they were unsure or did not know, and one student was unintentionally not asked this question. These responses are not reflected in the 8 themes.

These eight themes provide a starting point through which to examine various ways students discussed their design thinking in relation to participation in the design based-wilderness education curriculum. To provide narrative structure for this paper student responses have been classified into a singular theme that best reflects the overall idea expressed by each student. As we will further explore, the themes identified by individual responses were inevitably present as threads across many of the interviews. While exact counts are not given in the analysis, the themes explored in the following sections would typically be discussed at some point across a third, or even more than half, of the interviews.

Table 1: Themes of Responses to Lesson Learned Question

# Students	Theme
6	Flexibility
6	High-Fidelity Testing
5	Simplicity
5	Importance of Trying
4	Survival
2	Empathy for Others
1	Trusting the Process
1	Identifying Team Strengths

Flexibility

While participating in design-based wilderness education, students felt themselves pushed to be flexible, creative and improvise. Students contextualized flexibility in three different ways that we will examine in turn: being open to the ideas of others, thinking on their feet, and having to improvise due to a lack of skill or knowledge.

For many, flexibility meant being open to the ideas of others, equating it in some contexts with teamwork and cooperation. Being less rigidly attached to their particular way of doing things, students saw that listening to others provided opportunity to learn different ways of solving the same problem. This willingness to listen to others in their group may have been connected to the small supportive group environment that was deliberately encouraged. Expeditions were limited to nine students and two instructors. The students in turn were further divided into smaller cook groups of 2 or 3.

The wilderness environment often required students to be flexible and improvise, as students were often surprised. Students felt they had to “think on their feet” and creatively solve problems as they encountered them, expressing Schön’s notion of reflection-in-action. This was apparent during construction of the bear hangs outside. The first step in constructing a bear hang is to get a rope over a branch at least 20 feet above the ground. Students did not realise in advance how difficult this task would be. While going through the curriculum, students often felt that they were constrained by the resources that were available. Having limited resources required students to innovate with available materials, oftentimes taking advantage of the natural resources that were available in the wilderness setting such as sticks and rocks.

The third factor driving students to feel the need to be flexible during the course was not an intentional curricular element. In some cases students felt that they were forced to innovate due to a lack of skill or knowledge. This was most common when building artifacts that required knots such as the bear hang, rope bridge, or shelters. Even though many students did not remember the knots they were taught, they were still able to improvise successful solutions. This did provide an opportunity for peer-learning, as some students had a strong grasp of knots. Peer-learning was an effective strategy for some students to master new knowledge. As one student put it, “during class I didn’t pay that much attention to the knots and the stuff you taught us but during the trip I actually put that into practice and I had other people teach me. And that’s when the knot tying and stuff really solidified.”

As we will return to when discussing the theme of survival, some students expressed that the wilderness environment provided pressure that prevented flexibility, innovation and creativity.

High-Fidelity Testing

Prototyping is an important stage of any design process, and through their experiences in design-based wilderness education students became advocates for the importance of high-fidelity testing, placing prototypes in situations that closely matched their final use. When considering how their design thinking had changed, one student said, “whatever we design has to be tried out like in real life against... real life circumstances before going through a second round of prototyping and not just imagining it or thinking a similar situation but in the actual situation itself.”

The importance of high-fidelity testing was apparent as students were often forced to deal with unexpected consequences of their actions. The contrast between theory and practice became increasingly obvious as students became users of their own products. Using their stove for the first time outside, a group of students were surprised when the ground was not as flat as a workbench. While sticks may be an attractive material to create a level platform for a stove, those sticks will quickly light on fire. After the sticks were doused with water the students switched to rocks as a building material.

Simplicity

The wilderness environment uncovered the value of simplicity through two mechanisms. Having constrained resources encouraged some students to explore simple and often surprisingly elegant and effective designs. For others, the motivation of survival resulted in valuing simple yet functional designs for their likelihood to be, and remain, functional and have a minimum chance of failure.

While discussing the role limited resources played, one student said, “it was a great way to be creative about it, and there’s different combinations so you aren’t just limited by your materials, you’re just limited by the way you think.” Having simple and limited resources encouraged creativity and out of the box thinking by students.

In response to the pressure of using their own design in a wilderness environment, some students were able to recognize the value in “thinking of the simplest way to do something instead of being very complicated and elaborate. The easiest thing that will do the job is usually also what will have the least room for error.” This was a practice that the student could see herself continuing to apply in the future.

Importance of Trying

While at times tasks in the wilderness environment, or simply the expedition itself, may have seemed overwhelming, upon reflection students recognized the importance of “just trying”. There were two distinct reasons students suggested that just getting started was a valuable lesson and future practice. It wasn’t just starting that students found important, starting was discussed in close connection with being adaptable to change, and expecting that change would be necessary. Others felt that excessive planning was unnecessary and often occurred in their groups.

While discussing building a shelter to sleep under, one student prone to analysis paralysis said, “You just give it a shot and then you realize that oh, shucks, it’s off to the right. So tomorrow just change it, I mean, you can still change it. But if you don’t start somewhere you won’t get there, right?” To succeed at a task, he argued that, “The biggest thing is just to start, right, and be more adaptable to changes”.

Some students saw excessive planning as detrimental to the efficient implementation of the design process. One student complained that his group spent a lot of time talking and indicated that after a short planning session the team should “just choose a direction and get on with it. And then, if it doesn’t work, just go back and choose another idea and move on with it”. Once again, through this experience we see that students are flexible and counting on having to change their plans.

Survival

The theme of survival permeated the course, with students being told that they would be expected to thrive, not just survive, in the wilderness. Survival was discussed by students in three distinct contexts: as a motivation to be successful, as a way to connect design to everyday experience and, as some students identified as their primary lesson, a path through which to develop empathy for others.

The survival aspect of the expedition resulted in a very different set of incentives for students participating in the curriculum than more traditional design-based classes. One student compared her experiences by saying, “It’s a bit different because you feel a bit more vulnerable when you are outdoors and so you put a little bit more effort into the little details. Compared to school where you just get a grade, it’s not like a live or die kind of decision.” Some students felt this motivation helped them master certain skills. One student reported, “I need to do the ropes in order to survive so when someone taught me, I caught on immediately, and, well, I don’t think I can ever forget how to do the clove hitch [knot].”

Relying on survival for motivation was not without its drawbacks. As mentioned previously, some students felt that the pressure of being in a survival situation made them not want to take risks or spend time innovating while designing. As explained by one student, “when you’re in the wilderness you really struggle between trying to stay alive and comfortable and then the other side, which is doing innovation. So, when you’re out there and dealing with that you don’t want to focus too much on the innovation part rather you tend to just lean towards the struggle to survive part.” This concern was for the most part moderated by the division of the curriculum between on-campus and expedition activities. This was especially true for the stove, which was designed and built on campus and then used in the wilderness environment.

Using their own artifacts for the purpose of survival also helped students connect design to their everyday life experience. “I guess it would make me realize that design is part of your ability to survive. It’s not just like a far off concept like designing the next big technological thing but it’s in every aspect of my life, so it will probably make me think more about my daily decisions realizing there are better ways of doing things like cooking, eating, and sleeping.”

While two students identified a lesson regarding empathy as their primary take-away, that theme is best considered as a continuation of our discussion on the effect that survival has on motivation. Having experienced their artifacts as users, some students reflected on how the experience made them more likely to empathize with the users of products they would design in the future. Students felt that they would be able to make better choices, and come up with better designs, by being more willing to “put on the shoes of someone who’s actually using your design”.

Trusting the Process

The response of one student somewhat defies classification yet also exposes the underlying goal of design education. The student responded to the original prompt by saying, “Have more faith and follow the taught methodology very carefully and more often then not I’ll end up fine … this definitely is something that I will take away from this. I think I can apply it to everywhere in my life.”

A design process gives structure to a complex, difficult task. In the context of design-based wilderness education the design process is being applied to tasks that can be perceived as threatening comfort and personal safety. Experiencing success in that context may provide tangible evidence for some students that the design knowledge they have is truly effective.

Identifying Team Strengths

When asked to identify changes in their design thinking, one student was unsure but followed with, “I guess to identify the strengths in the group is very important… to get to know the people.” While not directly related to design thinking, this student highlights a theme that ran deeply through the interviews. Students identified and leveraged the strength of their teammates by readily accepting help from each other and offering help to each other.

Comparison to Effective Practices

Many of the practices that students felt were emphasized by the design-based wilderness education curriculum seemingly align with recognized effective practices found in the design literature. These aligned themes provide inspiration for future curriculum development and research opportunities. It may be that design-based wilderness education is particularly situated to encourage certain mechanisms of effective design thinking.

One of the more direct comparisons is that the wilderness environment motivates students to appreciate simplicity. A student who learns to appreciate simplicity may be more successful in future classwork. When investigating the role of design complexity in classroom outcomes Yang (2005) found that “prototypes with fewer parts correlate with better design outcome, as do prototypes that have fewer parts added to them over the course of development.”

The wilderness environment also required students to consider the notion of having constrained resources. In a comparison of the use of design language by freshmen, seniors, and experts Atman, Kilgore, & McKenna (2008) found that “identifying constraints grew in importance from the first year of an engineering education to the last, and most experts shared a perspective that this activity is important”.

We found that students emphasized the importance of high fidelity testing. This could indicate that students were open to failure and learning at late stages of the design process. A study by Adams, Turns, & Atman (2003) found that seniors with higher quality final projects were more open to re-defining the problem throughout the entire design process, and open to the idea of failure.

For some students, the curriculum encouraged flexibility, creativity and innovation. While there is on-going research considering how to define, measure and teach creativity as part of design thinking, there is a clear consensus that creativity plays an important role in the design process (Dorst & Cross, 2001; Dym et al., 2005; Howard, Culley, & Dekoninck, 2008).

Discussion

This pilot study has explored, through qualitative analysis of student interviews, how participation in a design-based wilderness education curriculum affects student design thinking and intended future practice. It appears that design-based wilderness education is an appropriate learning environment for engineering education. We identified 8 major themes that students associated with changes in their design thinking: being flexible, the importance of high-fidelity testing, the value of simplicity, the importance of trying, survival as motivation, having empathy for others, trusting the process, and identifying team strengths.

The previous section began to explore what effective design practices are encouraged by integrating wilderness education pedagogy with design-based learning. These comparisons provide inspiration for future refinements to this curriculum, and begin to identify areas where design-based wilderness education may have unique strengths that could be effectively leveraged by engineering educators.

Design as a component of wilderness education may result in a different set of incentives than more traditional classroom experiences. In our case, students are the immediate users of their own design projects, and are often using their projects for the fulfillment of perceived survival needs. This is markedly different to more traditional experiences where the main motivation may be grades that are awarded. Future research will more closely examine the role motivation plays during a design-based wilderness education experience.

The results of this investigation are being used to guide the curriculum being developed for the 2015 iteration of GLP. Further research is needed to understand how the creative inspiration afforded by the wilderness environment can be integrated into different stages of the engineering design process. The persistence of the effects of design-based wilderness education experiences should also be investigated.

While design-based wilderness education shows some promise as a learning environment, it is a resource intensive approach. Further research is necessary to establish if the potential benefits of this novel approach outweigh the costs.

References

Adams, R. S., Turns, J., & Atman, C. J. (2003). Educating effective engineering designers: The role of reflective practice. *Design Studies*, *24*(3), 275–294.
Atman, C. J., Kilgore, D., & McKenna, A. (2008). Characterizing design learning: A mixed-methods study of engineering designers' use of language. *Journal of Engineering Education*, *97*(3), 309–326.
Bell, B. J., Gass, M. A., Nafziger, C. S., & Starbuck, J. D. (2014). The State of Knowledge of Outdoor Orientation Programs: Current Practices, Research, and Theory. *Journal of Experiential Education*, *37*(1), 31–45.
Charmaz, K. (2014). *Constructing Grounding Theory* (2nd ed.). Thousand Oaks, California: SAGE Publications.
Crane, N., Frankel, J., Kager, K., Krebs, J., Kushner, J., Lodato, A., … Wyne, M. B. (2008). *Outward Bound Staff Manual*. Outward Bound U.S.A.
Dorst, K., & Cross, N. (2001). Creativity in the design process: Co-evolution of problem-solution. *Design Studies*, *22*(5), 425–437.
Dorst, K., & Dijkhuis, J. (1995). Comparing paradigms for describing design activity. *Design Studies*, *16*(2), 261–274.
Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering Design Thinking, Teaching, and Learning. *Journal of Engineering Education*, *94*(1), 103–120.
Gookin, J. (2006). *NOLS Wilderness Educator Notebook*. Lander, WY: National Outdoor Leadership School.
Hattie, J., Marsh, H. W., Neill, J. T., & Richards, G. E. (1997). Adventure Education and Outward Bound: Out-of-Class Experiences That Make a Lasting Difference. *Review of Educational Research*, *67*(1), 43–48.
Howard, T. J., Culley, S. J., & Dekoninck, E. (2008). Describing the creative design process by the integration of engineering design and cognitive psychology literature. *Design Studies*, *29*(2), 160–180.
Perkins, D. N., & Salomon, G. (1988). Teaching for Transfer. *Educational Leadership*, *46*(1), 22–32.
Saulnier, C. R., Ahn, B., Bagiati, A., & Brisson, J. G. (2015). Leadership Development through Design Based Wilderness Education. *International Journal of Engineering Pedagogy*, *5*(1), 47–56.
Schon, D. A. (1983). *The Reflective Practitioner: How Professionals Think in Action*. Basic Books.
Sibthorp, J., Furman, N., Paisley, K., & Gookin, J. (2008). Long-term Impacts Attributed to Participation in Adventure Education: Preliminary Findings from NOLS. In *Research in Outdoor Education* (Vol. 9, pp. 86–103). Bradford Woods, Indiana.
Wiske, M. S. (1997). What Is Teaching for Understandng? In *Teaching for Understanding: Linking Research with Practice* (pp. 61–86). Jossey-Bass.
Yang, M. C. (2005). A study of prototypes, design activity, and design outcome. *Design Studies*, *26*(6), 649–669.

Acknowledgements

The authors would like to thank the MIT-SUTD Collaboration Headquarters office staff as well as the SUTD administration for supporting this work. The authors would also like to thank Tory Clark, Jesse DeLaughter, Kate Rhodes and Jacob Rosen for providing invaluable assistance as Instructors during the wilderness expeditions.