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A Comparison of Student Design Activity Preferences Before and After a Design-Based Wilderness Education Experience

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Background

In 2010 the Massachusetts Institute of Technology (MIT) entered into a collaboration agreement with the government of Singapore to found the Singapore University of Technology and Design (SUTD). The Collaboration broadly consists of curriculum development, faculty training, collaborative research, and the development of student culture. One activity focused on student culture is the Global Leadership Program (GLP), a ten-week academic cultural exchange that takes place on and around MIT's campus. GLP brings approximately 30 students from SUTD and 5 students from MIT together to interact with the MIT community and experience MIT's academic environment by participating in a curriculum designed to assist with the development of leadership and engineering skills.

In 2014 a class was introduced to GLP that combined the pedagogical approaches of design-based learning and wilderness education to create a novel learning environment for engineering and architecture students. This class was developed to address the development of design thinking, engineering science, and leadership skills. The curriculum for the design-based wilderness education class consists of classroom and lab activities implemented on MIT's campus, followed by a wilderness expedition. Initial exploratory investigation indicated that the design-based wilderness education curriculum resulted in self-reported increases in student leadership capacity and potentially beneficial changes to students design-thinking[1,2].

After the 2014 iteration of the program, students were interviewed. During the interviews, students were asked how the experience had changed the way they thought about the design process. In response to this question the eight major themes that were identified were: 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[2]. This paper continues our initial exploration into how design-based learning in a wilderness environment impacts students' perception of the engineering design process.

Design Based Wilderness Education Pedagogy

When developing a curriculum targeting the engineering design process, the role that design-thinking plays within a design-based learning environment is of particular interest. As described by Dym et al., 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"[3]. 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[4]. The wilderness environment is particularly well suited towards the notion of design as a process of reflection-in-action. The same paradigm of learning through experience underlies both Schön's notion of reflection-in-action and wilderness education pedagogy. Designing in and for a wilderness environment is intended to provide the "surprises, pleasing and promising or unwanted" that would encourage students to respond as reflective practitioners to design-based learning prompts[5].

The design-based wilderness education curriculum was specifically developed to take advantage of the unique benefits that experiential education pedagogies can afford to engineering and architecture students in the natural environment. GLP is expressly structured to help transition SUTD's students to MIT's academic culture, and the wilderness environment provides an unfamilar environment for both the MIT and SUTD students in which to interact, potentially leveling the playing field. It has been our experience that the North American wilderness is often as unfamiliar to American students as it is to the students from SUTD. This novel environment appears to be beneficial for enabling effective transitional experiences, as wilderness education programs seem to be more effective at helping students transition into new academic cultures than traditional orientation programs[6].

Wilderness education programs are typically associated with long-term increased competency in skills such as leadership, teamwork, self-confidence, and communication[7]. These skills are associated with effective engineering practice, and a desired learning outcome of the GLP. Wilderness education was an attractive pedagogy to include in GLP, a summer enrichment program, for its 'wow factor' as GLP hopes to provide a lasting impression on its students. A unique feature of wilderness education programs is that unlike other program types "the effects of adventure programs continue to increase over time, and are maintained over considerable time"[8].

Curricular Framework

The 2015 design-based wilderness education module was a modified version of the 2014 curriculum. The curriculum consisted of a series of lab and classroom activities that helped to prepare students to embark on a 3-day sea kayaking expedition off of the coast of Maine. 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[9]. Wilderness education components of the curriculum were based on best practices from Outward Bound[10] and the National Outdoor Leadership School[11].

In the design-based wilderness education module students were presented with projects and challenges that could be solved through the application of a design process. While the course was conceived as a design experience, as we will see, the actual activities of the design process undergone by students during design tasks were truncated from their broadest possible conception. As the students were presented with specific challenges to solve through design, they did not have to undergo early stages of a comprehensive design process such as identifying a need, defining a problem, or performing market research. Similarly, students did not have to worry about concerns at the late stages of a design process such as manufacturability, lifecycle analysis, or ongoing maintenance.

Figure 1 outlines the intended timeline of classroom activities and expeditions. For the on-campus sessions the 34 students in the class were divided into two sections and each class was given twice. For the sea-kayaking expedition the 34 students were divided into four teams that were expected to complete the 3-day trips on subsequent weekends. Due to an illness on the instructor team, expeditions 2, 3 and 4 instead took place on the same weekend and additional instructors were brought on so that students could be divided into two separate groups for travel and design activities.

To demonstrate to students that an engineering science mindset can be applied to understand problem domains in which they are initially unfamiliar, an introductory lesson introduced clothing layering systems, clothing fabric selection, and backcountry sleeping systems through the framework of heat transfer. By considering the role of conduction, convection, radiation and evaporative cooling, students were able to understand the concept behind the common saying that ‘cotton kills’ in the wilderness. Throughout the program students are encouraged to continue developing an engineering science worldview by explaining 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 throughout the course to illuminate different elements of the wilderness environment. Students design *for* the natural environment by constructing single burner alcohol fuel stoves over two on campus sessions. Taking advantage of the relatively high vapor pressure of denatured alcohol at low temperatures, students are able to construct efficient pressurized stoves out of simple materials such as aluminum cans. Unlike many design projects that end in the classroom, students then rely on these stoves for cooking while on the sea kayaking expeditions.

The stove design task was introduced by providing a quick reminder of the conditions necessary for combustion and an overview of the high vapor pressure of denatured alcohol at low temperatures, focusing on how that could be harnessed to create a pressurized jet of fuel. Students were shown some example stoves, fabrication tricks, and techniques for working with aluminum cans as a building material. Students then had two three-hour classroom sessions in which to design and build a final stove that they would bring on the expedition.

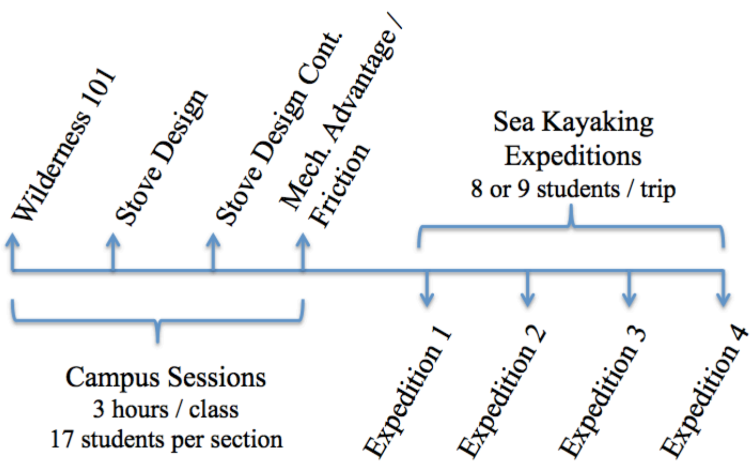

Figure 1 Class Schedule

The final on campus design activity explores mechanical advantage and friction through the construction of hauling systems on campus. In a wilderness environment these systems would be used as 'bear hangs', a system to haul food into a tree using mechanical advantage, securing it from bears and (more likely) smaller rodents at night. While most students have come across diagrams of pulley systems in textbooks, very few have had the chance to construct them or experience the real life impact of friction, which quickly overtakes mechanical advantage as being the most significant force in a system.

Along with designing *for* the natural environment, students were challenged to design *in* the natural environment by building thermal and solar desalination devices using kits that were provided while in the wilderness environment. Being on an island surrounded by salt water provided context and motivation for the design task. The kits included a stainless steel pot, bowl and bottle, various opaque and clear plastics, various aluminum foils, duct tape, copper tubing, and a large plastic bin. Students were not aware that they would be taking part in this design challenge before the trip, and were given the kit while on expedition and asked to design and build a thermal or solar method of desalination. Students had two two-hour sessions to work on their artifacts throughout the trip. Students were able to use their stoves as a heat source, and as previously mentioned, students also relied on the stoves to cook on while in the wilderness.

Methods

At the beginning of the design-based wilderness education experience, 31 of the 34 students participating in GLP enrolled in a research study examining the effects of participating in design-based wilderness education on leadership ability, design thinking, and the development of an engineering science worldview. Of the enrolled students 29 were from SUTD and 2 were from MIT. Eighteen of the students were male (56%).

The 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 2 MIT students had various levels of pre-existing design experience and very little in the way of pre-existing wilderness experience.

To assess the impact of the 2015 GLP design-based wilderness education module, pre- and post-assessments were given to participants immediately before and after participating in the design-based wilderness education module. The assessment consisted of an inventory of 23 activities commonly associated with the engineering design process; students were asked to identify the six most important and the six least important design activities. An example of the format of the design question is given in Figure 2.

This inventory was developed by Mosborg, Adams, and Kim as a component of a study exploring expert perception of the design process[12]. It is based on an earlier question developed by Newstetter and McCracken[13]. The 23 activities were listed in alphabetical order and are not necessarily mutually exclusive from each other.

Of the twenty-three design activities below, please put a check mark next to the SIX MOST IMPORTANT

___ Abstracting
___ Brainstorming
___ Building
___ Communicating
___ Decomposing
___ Evaluating
___ Generating alternatives
___ Goal setting
___ Identifying constraints
___ Imagining
___ Iterating
___ Making decisions
___ Making trade-offs
___ Modeling
___ Planning
___ Prototyping
___ Seeking information
___ Sketching
___ Synthesizing
___ Testing
___ Understanding the problem
___ Using creativity
___ Visualizing

Figure 2 Example of Design Question Wording

This paper explores the differences identified between the pre- and post-assessment results of the students in the 2015 GLP. We compare these results to those of the expert practitioners in the Mosborg study, and associate these differences with pedagogical decisions made in the creation of the program, exploring the potential implications for design-based wilderness education as pedagogy for design education.

Results

As displayed in Table 1, when students were asked to identify the most important design tasks, four of the top five responses remained consistent between the pre- and post-test. Understanding the problem, prototyping, communicating and making decisions all continued to most commonly be regarded as important before and after participation in the class. In the post-test brainstorming was displaced by seeking information.

Table 1 Top 5 responses by students asked to identify the MOST important design activities (n=28)

MOST important before design-based wilderness education			MOST important after design-based wilderness education	
Statement	**% Students**		**Statement**	**% Students**
Understanding the Problem	93%		Understanding the Problem	64%
Prototyping	61%		Communicating	61%
Communicating	57%		Making Decisions	54%
Brainstorming	46%		Seeking Information	43%
Making Decisions	43%		Prototyping	43%

Table 2 Top 5 responses by students asked to identify the LEAST important design activities (n=28)

LEAST important before design-based wilderness education			LEAST important after design-based wilderness education	
Statement	**% Students**		**Statement**	**% Students**
Sketching	68%		Abstracting	75%
Abstracting	57%		Sketching	57%
Imagining	50%		Decomposing	46%
Decomposing	46%		Synthesizing	43%
Making Trade Offs	43%		Goal Setting	43%
Goal Setting	43%		Imagining	43%

Understanding the problem, while continuing to have the largest proportion of students select it as one of the most important tasks, saw a large decrease between the pre- and post-test. It decreased from 93% of students to only 64% of students after the course. After the program slightly fewer students regarded prototyping as important, whereas communicating and making decisions both saw small increases. Brainstorming was replaced by seeking information.

Table 2 displays the activities most commonly selected by students asked to identify the least important design activities. Before participating in the design-based wilderness education program students most commonly selected sketching, abstracting, imagining, decomposing, making trade offs, and goal setting. In the post-test making trade offs was displaced as one of the most common answers by synthesizing. The same proportion of students selected decomposing and goal setting as one of the least important activities in both the pre-test and post-test. Fewer students identified sketching and imagining as one of the least important design tasks. Abstracting saw a large increase in the number of students regarding it as one of the least important activities.

As we have seen, while there was some change in the rank-ordering between the pre- and post-tests, for the most part the most common student responses remained consistent before and after the program. While the rank order of choices did not change dramatically, examining the percentage change of individual items between the pre-test and post-test results allows us to examine broader trends across-items that may have occurred.

Figure 3 displays the percent change for each activity between the pre-test and the post-test. When considering the percent change across items we see that building, planning, and making decisions are the three actions with the greatest percentage increase of students identifying them as most important. Combined, these terms appear to be related to immediate action. Conversely the actions with the largest decreases are understanding the problem, iterating, prototyping, and brainstorming. Iterating and prototyping are both related to the cyclical nature commonly associated with design. Understanding the problem and brainstorming are both associated with the early exploratory stages of the design process.

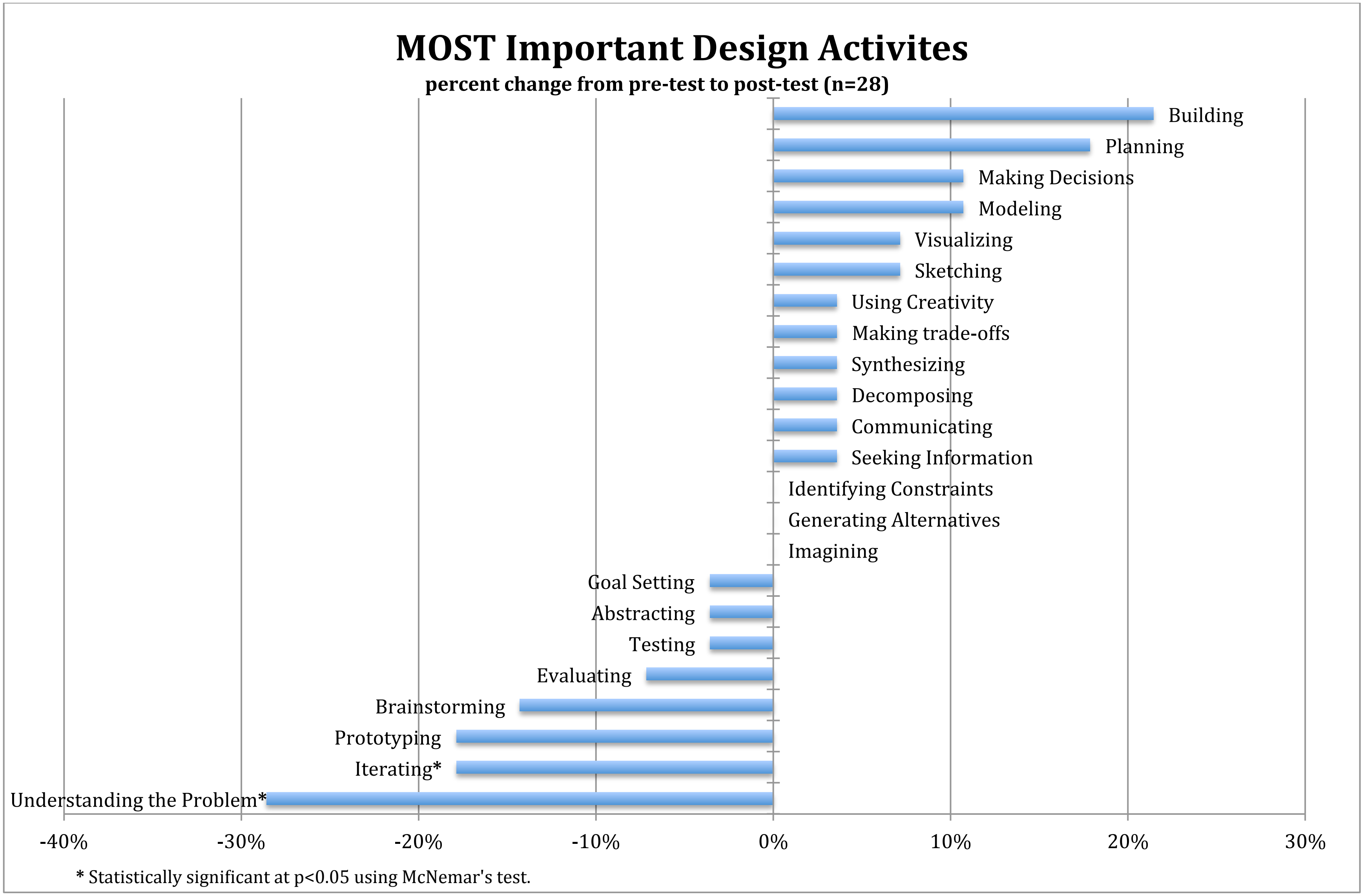

Figure 3 Percent Change for Most Important Design Activities

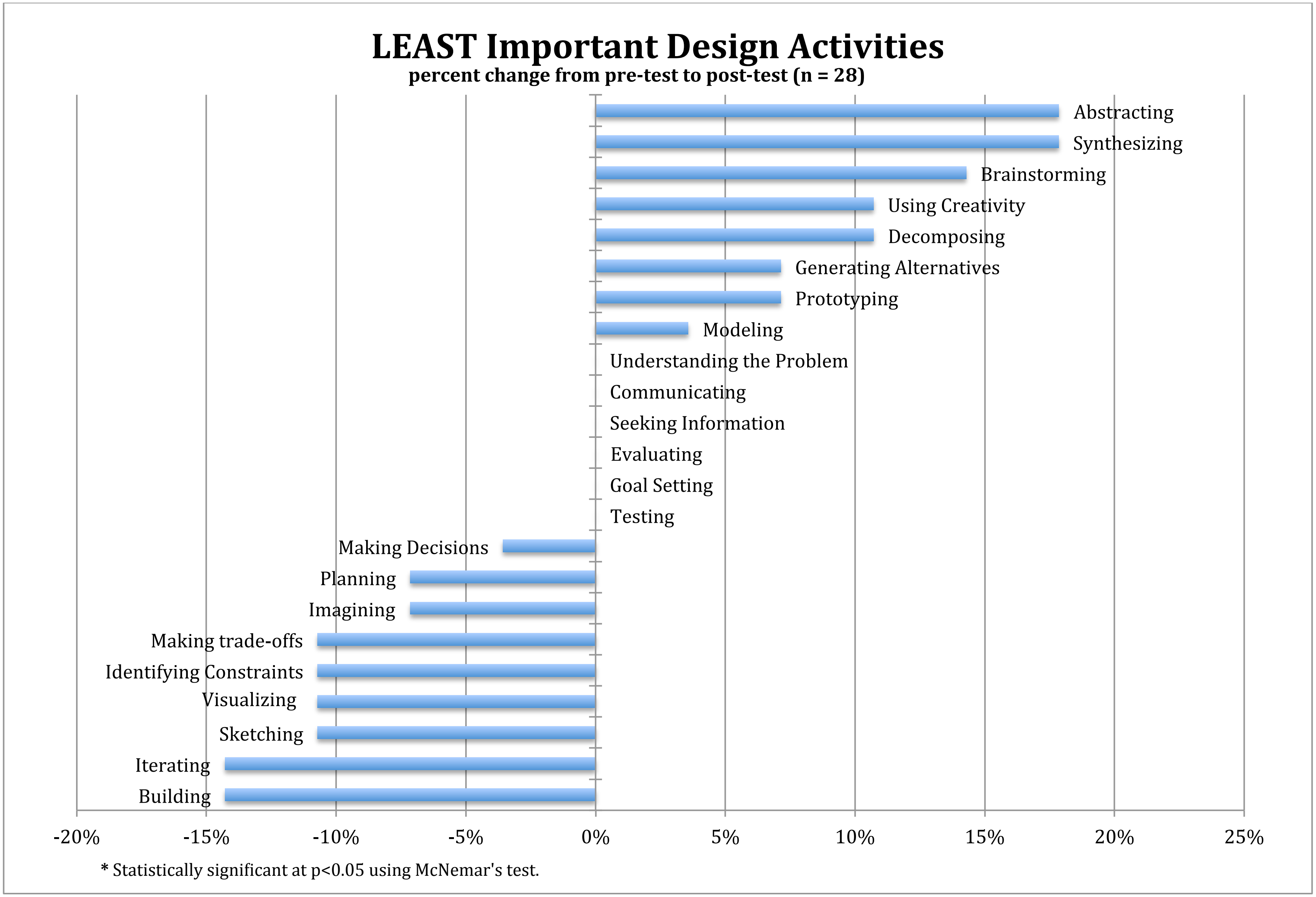

Figure 4 Percent Change for Least Important Design Activities

When examining the percent change between activities identified as the least important by students in Figure 4, we see that it is not simply the inverse of the changes identified when considering the most important design activities. While iterating saw 17% fewer students identify it as one of the most important activities after participating in the course, it also had 14% fewer students identify it as one of the least important design activities. Iterating appeared to be pushed towards the center of student rankings, being less regarded as one of the most important activities while also being less regarded as one of the least important design activities.

On the other hand in most other cases the behavior was more as we would expect. For example, 14% fewer students considered building one of the six least important design activities while 21% more students now considered it one of the six most important design activities.

Discussion

When considering the percent change between students identifying a task as most important from the pre-test to the post-test we see that students tended to place increased emphasis on tasks oriented towards immediate action such as 'building', 'planning' and 'making decisions'. Decreased emphasis was placed on exploratory activities such as 'understanding the problem', 'iterating', 'prototyping' and 'brainstorming'.

This shift towards an emphasis on action-orientated activities may be a reflection of the rapid pace of the curriculum, along with its underlying structure. As mentioned previously, students were assigned tasks or design-problems such as building a stove or designing a thermal desalination artifact. These tasks were fairly straightforward (or at least appeared to be so), and therefore did not require students to place significant emphasis on understanding the problem. During the program, students were observed launching into action very quickly after being assigned a task, rather then spending time reflecting and exploring the problem space.

It was intended that the simple materials used during design challenges would allow students to rapidly prototype and iterate towards a final design. During the stove-building activity this was not the behavior that was observed by instructors. Instead of building multiple prototypes and iterating to a final 'best' design students would build a stove, test it, and if it worked would stick with that model. If the stove did not work, or did not work well, students would try and modify their current stove to make it work.

Instead of seeing rapid prototyping and iteration as a means to achieve a high quality final product using the same material, students were perhaps instead attempting to complete a 'final product' on the first attempt. As the materials that could be used for prototyping and a final product were the same, a lack of separation between what could be considered a prototype and what could be considered a final project may have led students to not recognize that they were iterating and prototyping on the way to a final product.

In the 2005 study by Mosborg, Adams, and Kim, the top terms chosen as most important by 19 expert engineers were "understanding the problem" (chosen by 15 individuals), "identifying constraints" (chosen by 13), "communicating" (chosen by 12), and "seeking information" (chosen by 10)[12]. The students taking part in the design-based wilderness education curriculum similarity emphasized ‘understanding the problem’ and ‘communicating’ before taking part in the program. As illustrated by Table 3, while ‘communicating’ saw a small increase in the post-test, demonstrating movement towards expert thinking, ‘understanding the problem’ saw a 29% decrease in the number of students identifying it as one of the most important design activities. This movement is counter to the thinking demonstrated by experts.

While “identifying constraints” was emphasized as being important by a majority of experts, it was not one of the most common student responses. In addition, there was no change in the number of students considering it most important between the pre-test and the post-test. This was surprising, as previous research examining student interviews demonstrated that discussion of constrained resources was quite common. However rather than focusing on needing to identify resource constraints, student interviews focused on how the constrained wilderness environment necessitated simple and often surprisingly effective designs[2].

This result may indicate that students considered the constraints imposed by the wilderness environment simply an element of the structure of the course. Having easily identified, very restrictive, constraints did not provoke students to recognize the importance of identifying the less easily identified, yet still important, constraints present when working in a more traditional engineering environment.

In the same study of experts previously mentioned, the terms regarded as least important were “decomposing” (chosen by 15), “abstracting” (chosen by 14), “building” (chosen by 13), and “synthesizing” (chosen by 10)[12]. As demonstrated by Table 4, building was not commonly selected as one of the least important design activities as identified by students. In fact, building saw the largest percentage decrease being identified as least important after the class. It also saw the largest percentage increase being identified as most important after the class. This observed difference appears to be moving students away from the expert perspective on design.

It was notable that ‘sketching’ was selected as one of the least important design activities by a majority of participants in the class. While students did not regard it as an important design activity many students communicated ideas to each other and to the instructor team through sketches. This observation may indicate that what students self-report as important design activities may not accurately reflect the behaviors as expressed by students.

Table 3 Statements chosen as MOST important by experts compared to student percent change

Statement	Experts selecting as MOST important (n=19)	Percent difference in students selecting as MOST important	Percentage of students selecting as MOST important after the course
Understanding the problem	15	-29%	63%
Identifying constraints	13	+0%	29%
Communicating	12	+4%	61%
Seeking information	10	+0%	43%

Table 4 Statements chosen as LEAST important by experts compared to student percent change

Statement	Experts selecting as LEAST important (n=19)	Percent difference in students selecting as LEAST important	Percentage of students selecting as LEAST important after the course
Decomposing	15	+11%	57%
Abstracting	14	+18%	75%
Building	13	-14%	14%
Synthesizing	10	+18%	43%

Limitations

This exploratory study only provides some indication as to the learning outcomes of participating in a design-based wilderness education program. In this paper we only examine a single data source from a module that takes place as a component of a larger summer enrichment program. While students responded to the survey question in the context of the design-based wilderness education module other activities were taking place concurrently.

Another component of GLP, not discussed in the context of this paper, consists of students designing and building electric-powered human-piloted boats. Students race these boats on a local river after an eight-week design and construction period. While this experience-based immersive design-project shares some similarities with the design-based wilderness education curriculum, it is likely counteracting (or perhaps even reinforcing) elements of the design-based wilderness education experience and inadvertently influencing the student responses to this survey.

Conclusions

While design-based wilderness education is an interesting approach, further work is required to understand how it can best be utilized in the broad field of engineering education. We have observed that a experiential hands-on approach to design in a natural environment has seemingly encouraged students to value activities such as ‘building’ that are not regarded as important by expert engineers. This approach has seemingly also minimized the importance of activities such as ‘understanding the problem’ that are at the core of engineering design.

This paper provides some indication that the way in which a curriculum is structured may inadvertently and strongly affect the learning outcomes of a program. Careful attention needs to be paid to ensure that students are able to transfer the lessons that are desired to their ongoing professional practice.

References

1. Saulnier, C. R., Ahn, B., Bagiati, A. & Brisson, J. G. Leadership Development through Design Based Wilderness Education. *Int. J. Eng. Pedagog.* **5,** 47–56 (2015).
2. Saulnier, C. R., Bagiati, A., Ahn, B. & Brisson, J. G. Changes in Design Thinking through Participation in Design Based Wilderness Education. in *Proceedings of the REES 2015 Symposium* (2015).
3. Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D. & Leifer, L. J. Engineering Design Thinking, Teaching, and Learning. *J. Eng. Educ.* **94,** 103–120 (2005).
4. Dorst, K. & Dijkhuis, J. Comparing paradigms for describing design activity. *Des. Stud.* **16,** 261–274 (1995).
5. Schon, D. A. *The Reflective Practitioner: How Professionals Think in Action*. (Basic Books, 1983).
6. Bell, B. J., Gass, M. A., Nafziger, C. S. & Starbuck, J. D. The State of Knowledge of Outdoor Orientation Programs: Current Practices, Research, and Theory. *J. Exp. Educ.* **37,** 31–45 (2014).
7. Sibthorp, J., Furman, N., Paisley, K. & Gookin, J. Long-term Impacts Attributed to Participation in Adventure Education: Preliminary Findings from NOLS. in *Research in Outdoor Education* **9,** 86–103 (2008).
8. Hattie, J., Marsh, H. W., Neill, J. T. & Richards, G. E. Adventure Education and Outward Bound: Out-of-Class Experiences That Make a Lasting Difference. *Rev. Educ. Res.* **67,** 43–48 (1997).
9. Wiske, M. S. in *Teaching for Understanding: Linking Research with Practice* 61–86 (Jossey-Bass, 1997).
10. Crane, N. *et al. Outward Bound Staff Manual*. (Outward Bound U.S.A., 2008).
11. Gookin, J. *NOLS Wilderness Educator Notebook*. (National Outdoor Leadership School, 2006).
12. Mosborg, S., Adams, R. & Kim, R. Conceptions of the engineering design process: An expert study of advanced practicing professionals. in *Proceedings of the 2005 ASEE Annual Conference & Exposition* (2005).
13. Newstetter, W. C. & McCracken, W. M. in *Design Knowing and Learning: Cognition in Design Education* (eds. Eastman, C. M., McCracken, W. M. & Newstetter, W. C.) 63–77 (Elsevier Science, 2001).