

## Design for Use: A Case Study of an Authentically Impactful Design Experience.

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### Abstract

The design process is often introduced with project-based learning employing “authentic” or “real world” design projects. This paper explores the educational potential of a design project with authentic outside-of-the-classroom impact. Students designed and built single-burner alcohol stoves that were used to cook meals on a four-day wilderness expedition. Half of the students used stoves that they designed and built for themselves, experiencing the impact of their own decisions. The other half of the students designed stoves that were used by classmates, experiencing the responsibility of designing for an external user. There was no difference in the style of stove chosen or the technical complexity of the stoves built between the two groups of students. Stoves students made for self-use were more likely to be reported as working in the wilderness than stoves made for an external user (Fischer’s exact test,  $p=0.012$ ). However, there was not a significant difference if we only consider stoves as “working” when used to cook food regularly while on the expedition (Fischer’s exact test,  $p=0.401$ ). Interviews revealed differences between the motivation expressed by students, the challenges experienced, and the understanding of the perspective of the user. An unexpected finding was that students often did not believe the stove would be used for the full four-day expedition. We find that the authentic integration of use into the learning environment may help increase students’ understanding of human-centered design principles.

**keywords:** human-centered design; project-based learning; authentic;

### 1. Introduction

The design process is central to the practice of engineering and often introduced at the undergraduate level in project-based learning environments using *authentic* or *real world* design projects [1-2]. Proponents of project-based learning argue that these authentic projects drawn from outside the classroom help increase student engagement and understanding, better preparing students for eventual professional practice [3]. As authentic design projects continue to be increasingly incorporated into undergraduate engineering curricula, it is necessary to more carefully consider the role played by authenticity in design education.

Despite the popularity of authentic design projects in the design education literature, what makes a project authentic is typically neither explicitly discussed nor defined [4]. The common implicit definition is that authenticity is the result of an association with industry. This industry association may be in the form of industry involvement in the selection and provision of design problems (task-authenticity) or a focus on mirroring the team-based work environment and self-directed nature of the professional design process (context-authenticity).

While task- and context-authentic design projects are the two most commonly discussed paradigms in design education, there are other possible authentic approaches. Strobel et al. [4] reviewed recent literature concerning design education and proposed four categories of authenticity: task-authenticity, context-authenticity, personal/value-authenticity, and impact-authenticity. Of these, it is ironic that design projects allowing students to see the impact of their project outside of the classroom (impact-authentic projects) are the least commonly discussed in the recent literature evaluated by Strobel et al. given that the profession of engineering is primarily concerned with designing products or processes that impact society.

Impact-authentic projects are an underutilized paradigm in engineering design education. This paper examines a project that is particularly representative of an impact-authentic approach. Students were challenged to design and build a single-burner alcohol stove with the knowledge that they would be using the stove to cook meals while on a four-day wilderness expedition. Our analysis highlights potential benefits and pitfalls associated with impact-authentic learning environments. A key finding that we will

return to is that it may be more difficult to create impact-authentic learning experiences than expected due to students' assumption that learning environments are inherently inauthentic.

## **2. Project Background**

For the past several summers, the Global Leadership Program (GLP) has brought together approximately 35 students from Singapore University of Technology and Design (SUTD) and ten students from Massachusetts Institute of Technology (MIT) for ten weeks on MIT's campus to participate in an academic enrichment program. GLP introduces students to MIT's academic culture while developing engineering and leadership skills. During GLP, students participate in a class called the *Wilderness Engineering Experience* that combines project-based learning and wilderness education to support impact-authentic design projects.

The Wilderness Engineering Experience was designed around impact-authenticity to allow students to generate useful artifacts and directly experience the outcome of their design process. Students are challenged to apply the design process while solving problems arising from preparing for and embarking on a multiday wilderness expedition. Along with cooking meals on the stoves they made, students construct haul systems to store food securely, build shelters to sleep under, and produce safe drinking water.

The initial design and construction of the stoves took place on campus during two three-hour sessions. Using aluminum cans and hand tools, students constructed stoves of varying levels of complexity, from simple open flames to stoves utilizing convection or producing pressurized jets of fuel. After completing the design project on campus, students used their stoves on a four-day sea kayaking expedition, cooking their meals in three-person cook groups. While on the expedition, students had the tools and supplies necessary to modify their current stoves or construct new stoves. The stove design project was included in GLP three times (2014, 2015, 2016) and successively refined after each implementation. This paper only considers data from the 2016 class.

We identified two variables that may contribute to the outcomes associated with an impact-authentic design project: the magnitude of the impact and who experiences the impact. The stove project was selected for analysis because it has a high impact – the stove was used to meet a survival need while in a remote wilderness environment. To explore the role played by who experiences the impact, students were divided into two groups. The first half were students who used the stoves that they designed and built, thus experiencing the impact of their own decisions. The other half of the students designed stoves for classmates, thus were given the responsibility of designing for an external user. As a part of this exchange students would be using a stove during their expedition that was designed and built by someone else.

This quasi-experimental setup allowed us to test our belief that students would be motivated to generate a higher quality artifact when designing a stove for someone else to use. When building a stove for themselves, even though it must perform an important function, students may be more willing to accept suboptimal results that require trial-and-error or careful attention for effective operation. Students may be more motivated to produce a polished and reliable final product when designing for someone else.

For each group of students, we will examine how the quasi-experimental condition influenced a) the quality of the final product and b) the learning objectives emphasized by the experience. While not initially a research question, one of the more notable findings is that students did not believe that they would have to use their stoves in the wilderness environment. As we will return to, students are resistant to the idea of a classroom environment resulting in an impactful project. These results provide indications as to how design projects can be structured to emphasize certain aspects of the design process and influence future student success.

## **3. Related Literature**

Accredited engineering programs in the United States are required to prepare students for engineering practice “through a curriculum culminating in a major design experience” that combines earlier course work with “appropriate engineering standards and multiple realistic constraints” [5]. This requirement is most commonly met through project-based capstone design classes [1]. To better provide an “authentic” or “real world” experience, projects for capstone design classes are increasingly often drawn from industry

partners [2]. The following two sections explore project-based learning in design education, and the use of authentic and meaningful experiences in design education.

### *3.1 Project-Based Learning in Design Education*

The pedagogy of project-based learning is rooted in the educational philosophy of John Dewey and the learning theories of constructivism and later constructionism. Dewey [6] argued for the role of experience in education. He puts forward that all learning takes place in the context of a social and physical environment, building on previous experience. Constructivism, as originated by Piaget, regards all learning as an ongoing process of new experience being tested against and integrated into current understanding [7]. Constructionism, developed by Papert [8-9], extends constructivism by emphasizing the importance of the physical representations of ideas. As defined by Kafai and Resnick [10], “constructionism suggests that learners are particularly likely to make new ideas when they are actively engaged in making some type of external artifact—be it a robot, a poem, a sand castle, or a computer program—which they can reflect upon and share with others.” Constructionism is essentially a theory of *learning-by-making* (Papert and Harel 1991).

Project-based learning as a pedagogy can be thought of as a grounded application of constructivist and constructionist theories of learning. A project-based learning curriculum is structured around students developing a personally “meaningful artifact” [7] that “makes their understandings visible to others” [3]. Project-based learning increases student engagement and develops deep understanding by having “students engage in real-world activities that are similar to the activities that adult professionals engage in” [3].

Project-based learning in engineering education has the additional constraint that students must apply an engineering design process to generate their artifact [1]. While work has been done to identify effective practices in engineering design [12], it is unclear exactly how much and in what way effective industry practices should inform the structure of engineering design curricula [1, 13].

Some scholars in the learning sciences argue that learning environments should not be made to resemble professional practice in any way. Kirschner, Sweller, and Clark [14] argue that using the procedures and practices of a discipline to solve authentic problems is not an effective instructional approach. Solving ill-structured problems in a minimally guided learning environment is cognitively overwhelming for students. Instead, direct instruction, worked examples, and process worksheets are proposed as alternate effective learning practices for novices. Despite these criticisms, project-based learning has been shown to result in greater student motivation and there is some evidence that it also increases content knowledge [3].

### *3.2 Authenticity in Design Education*

Project-based learning and constructionism both emphasize the importance of *authentic* and *meaningful* experiences in education. However, project-based learning for engineering design typically places the interests of industry as central, rather than the interests of the individual. Projects are defined as authentic based on their association with industry (i.e. [13]). Meaning does not arise from the personal values and interests of the learner; the association with real-world problems found in the profession of engineering brings meaning to a project. This is reflected in findings of Strobel et al. [4] that context-authenticity and task-authenticity are the two most commonly used paradigms for authentic design projects.

While the majority of projects in the literature examined by Strobel et al. did not consider the personal values and interests of students, constructionism is primarily concerned with encouraging the personal interests of an individual. After discussing how his childhood fascination with gears provided a deeper understanding of the world, Papert writes:

*“A modern-day Montessori might propose, if convinced by my story, to create a gear set for children. Thus every child might have the experience I had. But to hope for this would be to miss the essence of the story. **I fell in love with the gears.** This is something that cannot be reduced to purely “cognitive” terms. Something very personal happened, and*

*one cannot assume that it would be repeated for other children in exactly the same form.” [15]*

Constructionism explicitly recognizes the affective value of projects that are personally meaningful and relevant to the learner. Constructionist approaches to education encourage others to “create for themselves something like what the gears were” for Papert. The category of personal/value-authenticity proposed by Strobel et al. captures design projects that embody the constructionist ideal of students being able to pursue projects that are individually relevant by being organized around personal interests and values.

Impact-authentic projects have the potential to effectively combine elements of professional engineering practice with tasks that are personally relevant. Strobel et. al concluded that impact-authentic experiences are the least studied of the four categories of authentic design projects and require further investigation to understand their potential role in engineering education. A project that is impactful outside of the classroom can be both personally and professionally meaningful. The personal meaning arises from the authentic use of the project whereas the professional meaning can arise from an externally assigned task or theme. While the stove project was externally assigned, we hope that personal meaning arises from cooking meals for themselves and providing for a basic need.

## **5. Methods**

The 45 participants of GLP in 2016 were invited to participate in a research study to investigate the role an impact-authentic design experience could play in design education. Thirty-four students (76%) enrolled in the study. Of the enrolled students, 23 (68%) identified as male and the remaining 11 identified as female. Twenty-seven (79%) of the students were from SUTD, and the remaining seven were from MIT.

The SUTD students were all sophomores and had completed an intensive project-based introduction to design class while at SUTD. Singaporean men are required to complete two years of national service before starting university; therefore most of the men had gone through a jungle-warfare training program. Many of the SUTD students (both male and female) had also completed an outdoor education course with Outward Bound Singapore. The MIT students were mostly sophomores and had a variety of design experience ranging from none to having taken an intensive introduction to design class. Most of the MIT students were unfamiliar with the wilderness environment.

A quasi-experimental condition was implemented to explore the role of the user in an impact-authentic design project. Students were randomly assigned to one of two class sections. The first section designed and built a stove using a list of functional requirements they generated for themselves and used this stove while camping. The second section designed and built a stove for an external user, one of their classmates, based on a list of functional requirements generated by the user. The students were randomly assigned between the two sections.

The two sections traveled on separate wilderness expeditions. Within each expedition, students were divided into separate camps so that the external user of a stove would not be at the same campsite as the stove designer.

The analysis will be divided into two parts. First, an analysis of the students’ stoves will provide an indication of the technical complexity, quality, and use of the stoves during the expedition. The second half of the analysis will use interviews to provide insight into the experience of students while participating in the project.

### *5.1 Stove Artifact Analysis*


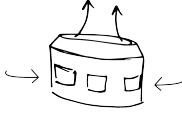
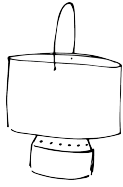
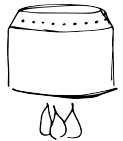

Thirty of the students participated in semi-structured interviews within a week of returning from the wilderness experience. During the interviews, students were asked to sketch the stove that they had designed and built while explaining how it worked. The interviews were transcribed and the sections concerning the stoves were excerpted for analysis alongside the sketches of the stove. When students were the external user of a stove designed by someone else, the description of the stove they received was also included in the analysis.

While designing and building stoves, students were asked to send photographs of their prototypes along with written descriptions of decisions made. Relatively few students submitted this information, but the photographs and text descriptions were used as supplemental information for the analysis when possible.

Using the information from sketches (n=29), interviews with stove designers (n=30), interviews with stove receivers (n=14), photographs of prototypes (n=11), and email communication (n=4), information was gathered on 35 unique stoves. Of the 35 stoves identified, seventeen were used by the stove's designer and eighteen were used by a student other than the designer.

All of the information available for each stove was used to categorize the stove into one of five categories of roughly increasing conceptual and physical complexity. Table 1 provides a guide to the five categories of stove identified for analysis. Category 1 and 2 stoves are essentially an open flame. Category 3, 4, and 5 stoves each use enclosed chambers in some way to take advantage of the high vapor pressure of denatured alcohol to create pressurized jets of fuel. These stoves are more conceptually complex than Category 1 and 2 stoves and require more precise assembly. Figure 1 provides examples of common stoves and their operation.

**Table 1 Categories of stoves and their descriptions**

Stove Category	Diagram	Description
<b>Category 1 (open flame)</b>		Stoves that are open flames. These stoves consist of an open cup which fuel is poured into before being lit.
<b>Category 2 (convection)</b>		Stoves that rely on convection to assist in combustion. Fuel sits in an open cup with holes cut to allow for airflow. An example of convection-assisted combustion is an oil lamp where the glass enclosure creates a chimney effect.
<b>Category 3 (two-stage)</b>		The fuel is initially allowed to burn as an open flame until the stove heats up sufficiently. While in use the open flame is covered, either by placing the pot over the large hole or some other method, to force the fuel to jet out from ancillary holes from the now enclosed chamber. See Figures 1a and 1b.
<b>Category 4 (externally primed)</b>		Typically the stove will sit in a priming tray with a small amount of fuel that is burned to heat up the fuel in the enclosed stove sufficiently for the vapor pressure to start forcing pressurized jets of fuel from the chamber. See Figures 1c and 1d.
<b>Category 5 (double wall)</b>		These stoves have additional internal structure that creates a smaller pressurized chamber around the outside of the can, often with an open flame in the center used for priming.



**Figure 1 Examples of common single-burner alcohol stoves**

Along with determining the category of the stove, the interview process was used to determine if the stove:

- worked for the designer of the stove;
- was brought on the expedition;
- worked for the external user (if designed for someone else); and
- was regularly used to cook meals during the expedition.

Five stoves were excluded from further analysis, as there was not enough information to accurately determine the category of the stove and/or answer the above questions. The remaining 30 stoves had enough information to be able to be accurately categorized and will be discussed in the results.

## *5.2 Interview Analysis*

While the interviews covered the entire range of classroom and wilderness activities during GLP the following analysis was limited to students experience of building and using the stoves. Discussion of activities other than the stove was excluded from analysis. General lessons learned and conclusions reached by students were also excluded unless the student explicitly linked them to the stove activity.

The interview transcripts were read through while listening to the audio recordings to ensure transcript accuracy. The interviews were then read through again and analyzed with an open coding scheme [16]. Each thought related to the stove project was given a gerund code. After all 30 interviews were coded, the codes were grouped into major themes that emerged across all 30 interviews.

Across 30 student interviews, 250 excerpts related to the stove artifact were coded with 162 unique (but not distinct) gerund codes. Multiple codes could be applied to the same excerpt. These gerund codes were grouped into 14 emergent themes.

After the interviews were analyzed and the codes were sorted into thematic groups, the results of the thematic coding were analyzed as two separate batches, students who designed a stove for themselves and students who designed a stove for someone else, to determine if there were any differences in the learning outcomes or constructed experience of the two groups of students. Our analysis will focus on the differences between the quasi-experimental groups, previous work more fully considers the general learning outcomes from this activity [17–19].

There were two instructors present on the course and their impressions and observations will also be used to add context to the analysis and discussion.

## **6. Results**

### *6.1 Stove Artifact Analysis*

All of the stoves made by students were two-stage, externally primed, or double walled stoves, as summarized in Table 2. These stoves all took advantage of the high vapor pressure of denatured alcohol at low temperatures to create pressurized jets of fuel. Of the thirty stoves included in the analysis, exactly half were made for self-use and half were made for external users. The vast majority of students made stoves that were externally primed (n=28, 93%) as five of the double walled stoves also required external priming. There is essentially no difference between the style of stove chosen and the technical complexity of the stoves built by the two groups of students.

Table 3 summarizes the results of the descriptive analysis of the stoves. Of the students who made a stove for themselves, almost all of the students (n=14) reported that their stove worked, and all of the working stoves were brought on the expedition. While on the expedition, three students who made stoves for themselves decided to not use their stoves to cook regularly. Two of these students reported that their stove was unstable as it was too tall, and the third student settled on a division of labor in which she took on the task of cooking while the others in her cook group were responsible for keeping their stoves lit.

**Table 2 Stove Categorization**

Stove Category	Designed for Self	Designed for External User
1 (puddle)	0	0
2 (convection)	0	0
3 (two-stage)	0	1
4 (primed)	12	11
5 (double wall)	3	3
<b>Total:</b>	15	15

**Table 3 Summary of Stove Analysis**

Who was the end user of the stove?	Designed for Self			Designed for External User	
	15 stoves			15 stoves	
Did the designer claim it worked?	Yes 14	No 1		Yes 14	No 1
Was it brought on the expedition?	Yes 14	No 1		Yes 12	No 3
Did it work for the external user?	- -	- -		Yes 7	No 5
Was it used to cook with regularly?	Yes 11	No 3		Yes 7	No 5

As for the stoves that were made for external users, once again all but one of the stoves were reported as working by the designer (n=14). In three cases, the external user did not bring the stove on the expedition. Two of these stoves were lost before the expedition, and the third stove was purposefully left behind as the external user said it was not completed (although the designer reported that it was completed). Of the 12 stoves that were brought on the expedition, the external users reported that five of them did not work (42%). The remaining seven stoves were used successfully, often with reported difficulties.

The number of stoves that were described as working in the wilderness significantly differed between students who made the stove for themselves and students who made the stove for an external user (Fischer's exact test,  $p = .012$ ). That is, when considering all of the stoves that were made, stoves made for an external user were less likely to be described as working in the wilderness environment.

However, of the stoves that were brought on the expedition, the number of stoves that were regularly used for cooking did not significantly differ between students who made a stove for themselves and those that were made for others (Fischer's exact test,  $p=.401$ ). That is, if we only consider the stoves that were used regularly for cooking, there is not a significant difference in the proportion of working stoves between stoves made for self and stoves made for external users.

## 6.2 Interview Analysis

The themes that emerged during the interview analysis were predominantly present across both groups of students. While designing and building stoves on campus, students learned from each other, often outright copying peers' successful designs. Students emphasized iterating and testing when discussing the role of the design process. Engaging in this project helped students increase their conceptual understanding of



combustion, and many decisions throughout the project were based on this increased understanding. The wilderness environment played a large role both on campus and while on the expedition. The upcoming trip served as a source of motivation while on campus and as a source of material for improvisation while on the expedition; many students used rocks and twigs to modify their artifacts on the fly. The process of cooking was surprisingly impactful and personally meaningful; many students had not cooked for themselves before and enjoyed the creativity associated with making something from the available ingredients.

While many of the themes were uniform across both groups, there were a few clear differences between the students who made a stove for self-use and those who made a stove for an external user. While there was some differentiation in the *motivation* expressed by students, there was not nearly as much as expected. The *challenges* identified by students while using a stove in the wilderness were very different between the two groups of students. Students who designed a stove for someone else discussed the *perspective of the user* after experiencing the perspective afforded by using a stove designed by someone else. These three themes will be explored in greater depth in the following sections.

### 6.2.1 Motivation

When designing the quasi-experimental condition, we imagined that designing a stove for a classmate would motivate students to create a more robust final product than designing a stove for themselves. While students often discussed their motivation, a sharp differentiation of motivation did not arise between the two groups of students. A handful of students did explicitly discuss being motivated by the knowledge that they were designing a stove for someone else. Sam<sup>1</sup> felt a “responsibility to [the] task” based on “the idea that you’re the engineers for someone else”. He “couldn’t just build a sub-standard stove” and assume that it would work.

While Sam was motivated by the user of his project, the other students designing stoves for classmates discussed being motivated by the practical and tangible nature of the project, the creativity the project afforded, or the sense of accomplishment they felt from making something that worked outside of the classroom. Having the opportunity to see authentic impact of the project outside of the classroom environment seemed to be a more important source of motivation for many students than who the eventual user of the stove would be.

An unexpected finding may have influenced the motivation of students. Many students did not believe that they would have to use their stoves for the full four days of the wilderness expedition, despite being explicitly told so at the beginning of the course. Sarah was having difficulty getting her stove to work while on campus but did not expect this to be as much of a problem in the wilderness as it ended up being,

*“I thought there would be a backup stove! I was like, “No way they’re gonna let us just die or make us eat raw rice and vegetables.” Like, “Nu-uh.” But if our stove hadn’t worked or if we hadn’t asked other people, we totally would’ve been. So nature and [the Instructor] are ruthless! No mercy!”*

Like Sarah, many other students expected that backup stoves would be available, or that after using the stoves for one meal they would be provided with commercial backpacking stoves for the remainder of the trip. The belief that the challenge as presented was not authentic was surprisingly robust. While Sarah was on the first expedition, students on the second wilderness trip (two weeks after the first trip returned) expressed similar doubts that they would actually need to use the stove, thinking that their classmates were now helping to maintain the suspected deception.

### 6.2.2 Challenges

While students were similarly motivated to complete the project, the challenges identified varied greatly between students using a self-designed stove and those using a stove designed by someone else. While

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<sup>1</sup> All names are pseudonyms.

using a stove designed by someone else, students focused on the challenges faced while getting the stove to work. In many cases, they concluded that the stove would not work. This failure and frustration often resulted in students taking a step back and considering the perspective of users from a more detached perspective, a perspective that will be fully considered in the following section.

Students using stoves they designed for themselves found far more initial success. This success may be partly attributable to the inherent knowledge of how a design is intended to work, alongside tricks and techniques students figured out along the way that allowed them to operate their stoves. As the weekend progressed, students often noted a degradation of performance over time. Students had different approaches to dealing with this degrading performance, with some students resorting to using only their primers for cooking, no longer using the pressurized stoves they built.

The difference between the two groups was not only a matter of perspective. The observations of the two instructors support real differences existing in the challenges faced by students. The lead instructor (and author of this paper) has observed over 100 students using stoves on expeditions, and typically one out of four groups might encounter minor trouble in the form of some spilled fuel or difficulty getting the stove to stay lit. In this case, observing the students using stoves designed by others was mildly concerning. The students using other's stoves had stoves that flew apart when small pockets of fuel-air mixture detonated inside the stove chamber, or stoves that were fully engulfed in flames (often including spilled fuel on the surrounding ground). While most students eventually found some level of success, others borrowed a stove from an instructor or ended up cooking their food on another group's stoves. Observing students using stoves they designed for themselves was a much less exciting experience, with only the occasional minor issue as mentioned previously.

### 6.2.3 *Perspective of User*

Students who made a stove for an external user also received a stove made by someone else to use on their expedition. This dual relationship of being both a designer and a user for the same project created a unique opportunity to examine what it means to have a user in the engineering design process.

As designers, students were able to receive feedback on their artifacts. Jacob was told that his stove had not worked for the external user, which surprised him. After spending some time speculating on how the external user might have been using the stove incorrectly, Jacob suggested,

*"I think [this is] helpful as an engineer because sometimes you design something, and somehow it goes wrong. You cannot assume that it's the fault of the consumer. You should make your design as foolproof as possible. It helped me appreciate that."*

As users, students experienced the difficulties associated with using a product made by someone else. Kim was unable to ignite the stove that had been given to her while on the expedition. She had been instructed to light the stove (the only two stage stove), allow it to heat up for a little bit, and then put a metal top over the open chamber. Each time she followed this procedure, the stove would extinguish itself. After the expedition she had a conversation with the designer of the stove and while Kim "thought a little bit was like two minutes, in reality, it was a lot longer than that." If Kim had known to allow the stove to prime longer she could have been successful.

There were many reasons that students were not able to get their stoves that had been designed by others to work. Charles was considering his experience as the user of a stove. Each person in his three-person cook group had been given a stove and they were unable to get any of them to work. Reflecting on the reason for this failure, he found that they "don't know exactly how their stoves are supposed to operate, how you are supposed to ignite their stoves". Considering this he came to a conclusion similar to that of Jacob:

*"I guess that's what's important when you design for other people. We had to make it fool... not foolproof, but idiot-friendly [...]. The most accessible products*

*usually have very little instruction. It's quite intuitive. But that, in itself, is quite a hard thing to do[.]”*

## **7. Discussion**

The findings of this paper provide an indication of the role that impact-authentic projects could serve in undergraduate design education. The stove project is particularly appropriate for examination as it has a high impact outside of the classroom—the stoves are used to cook food during a four-day wilderness expedition. The analysis considered how the learning environment differed based on who experienced the impact of the project. Half of the designers experienced the impact themselves, while the second half made a stove that was ultimately used by an external user. We established this division as we expected that students would have additional motivation to complete a robust final artifact when building a stove for someone else. Surprisingly, this was not the case, as many students did not mention designing for an external user as a motivating factor. The impact of the project outside of the classroom was often motivation enough.

An unexpected finding was that students often did not believe they (or the external user) would actually use their stoves for the full four-day expedition. This highlights the difficulty in designing curricular elements with authentic outside of the classroom impact. At the beginning of the class, students were explicitly told that they would be building stoves and using them to cook during their upcoming wilderness expedition. It was surprising when students returned from the trip and revealed that they were not expecting to have to use their stoves the whole time. Students are so used to educational experiences being contrived and sometimes even dishonest [9, pp. 38–54] that their natural reaction when presented with an authentic and impactful project was to doubt the truth of the underlying premise. During the Wilderness Education Experience, many students would rather believe that they were being lied to than believe that they were capable of building a stove to cook on for four days. This finding has implications for the design of authentically impactful experiences; students may need extra scaffolding alongside the project prompt to fully illuminate the truth behind the expectations. This is also a limitation of the study, as students may have behaved differently if they believed the full impact-authenticity of the project.

While the act of designing for others did not affect motivation as expected, understanding emerged when students were forced to confront the interplay between their intentions when designing a product and their experiences when using someone else's product. The value of this experience was not necessarily in designing a product for someone else, it was found in the experience of using a stove that someone else had designed. Students not only participated in an authentic design experience, they participated authentically as users of a product. When using a stove designed by someone else they could not fully understand the intention of the designer and did not have a clear understanding of the decisions that resulted in the final product.

Students develop a more comprehensive understanding of the design process when they learn to appreciate the relationship between designer and user through impact-authentic design projects. As Charles concluded after grappling with the knowledge that his external user struggled to use his stove, “the most accessible products usually have very little instruction. It's quite intuitive. But that, in itself, is quite a hard thing to do.” This is, in essence, a restatement of the human-centered design philosophy of Donald Norman, that “complex things may require explanation, but simple things should not. When simple things need pictures, labels, or instructions, the design has failed” [20, p. 9]. The stoves that students built are simple things, and the difficulty faced by external users clearly illuminate the challenges associated with effective human-centered design.

One of our original research questions was to understand any differences between the stoves designed by students for themselves and the stoves designed for external users. The categorization of the stoves constructed by each group was nearly identical with all the stoves taking advantage of pressurized chambers for increased power output and almost all the stoves using external primers. Both groups of designers shared similar success with 14 out of 15 in each group reporting that their stoves worked. Differences between the two groups of designers only began to emerge when the stoves were being put to use in the wilderness environment.

Statistical analysis revealed that stoves made for an external user were less likely to work in the wilderness environment. However, this effect disappeared when we only considered stoves that were used to cook regularly throughout the expedition. In other words, if we only consider “working” stoves to be those that were used regularly, we cannot reject the null hypothesis that a stove made for self-use was just as likely to work as a stove made for use by an external user. It is possible that the effect disappears due to the small sample size; a larger sample may have the statistical power to illuminate the difference between the two groups of students. In either case, while our analysis does not conclusively support a difference in the functionality of stoves between the two groups, it does indicate that student definitions of “working” appear to differ from that of instructors, and this difference may be correlated with who designed the stove they were using. Students may simply have been more willing to describe a stove that they made for themselves as working. This finding, alongside our observations, leads us to believe that between-group differences were not due to a difference in the functionality of the stoves, but rather the attitudes and perspectives of the users of the stoves.

If we accept that the stoves were of comparable quality, the difference in success that was observed may be primarily attributable to the attitudes and perspectives of the user of the stove. The interviews lend some credibility to this theory. We saw that students using stoves they designed for themselves described their stove as working even when faced with substantial difficulties and degrading performance. By the end of the expedition, some of the designers were only using their primer to cook the food, the stove itself no longer contributing to the cooking. Conversely, external users did not have inherent knowledge of how a stove design was supposed to work, and their self-worth was not tied into the stove’s successful operation. It is possible that students struggled initially because they were not familiar with the stove and also willing to give up relatively quickly when faced with difficulties. These two factors together could explain why it appears that stoves designed for an external user were less likely to work in the wilderness environment even if the stoves were of equivalent quality.

A limitation of this study is that while the data available indicates that the stoves were of a similar construction quality it is quite possible that a difference in quality does exist that was not discernable from the available data. In either case, the attitude and perspective of the user would still contribute to the success and failures experienced by students.

## **8. Conclusion**

The most significant contribution of impact-authentic experiences to design education may be that students are able to better understand and appreciate the relationship between designer and user. This is made possible by the authentic integration of using into the learning environment – a curricular approach of *design for use*. Use may help to increase students’ understanding of human-centered design principles by allowing students to receive feedback from users of their products. In this case, it appeared that greater opportunity for learning arose when students were using products designed by their classmates.

Further research is necessary to better understand how stepping into the role of being a user during impact-authentic design experiences supports the design learning environment. In the case of the stove project, students both designed and used the same product. This experience may have been particularly impactful because the students could consider frustrations they experienced using another person’s stove in the context of someone else using their design and perhaps experiencing similar frustrations. Future research should consider the similarity of projects, and if/how the experience changes if students design and use different products.

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