Usability Testing: Influencing Design Decisions and Improving Documentation

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Abstract

Instruction-writing is a genre of engineering communication frequently taught in both technical writing classrooms and engineering design classes, as students might, for example, be asked to write a manual documenting how to assemble, operate, or maintain the objects or equipment they have designed. The benefits of user testing of instructions are well established in both professional practice and academic literature. In the technical communication classroom, the pedagogy of usability emphasizes having test subjects (as representative of target users as possible) use a draft of the instructions to complete the desired action, in the process exposing flaws in the text of the instructions: areas of ambiguity, lack of clarity, need for visuals, organizational problems, and the like. The instructions are then revised based on user feedback. The authors of this paper (professors of technical communication, physics and optical engineering, and mechanical engineering) have created and teach a multi-disciplinary course inspired by the NAE's Grand Challenges for Engineering, in which the students design, build, and document a technology meant to address one or more of the challenges in a particular location (for example, harness solar energy economically to build infrastructure in Haiti). This is a full-time, 12-credit hour summer program, and this summer we added usability testing to the design and documentation process. Instead of just testing their design, students also tested their user documentation. The professors served as test subjects, and many problems with the intended process and documentation were exposed. Students then revised not only the instructions they had written for their intended users, but also details of the design itself and its method of deployment. This integrated testing and revision process was a source of satisfaction for the instructors beyond that found in the stand-alone technical communication or engineering design classroom.

Introduction

Instructions are an important genre of engineering communication, one that is frequently assigned and taught in technical communication courses. (Future) engineers need to know how to clearly convey step-by-step procedures for building or assembling an object, testing an apparatus, or carrying out a process. They need to learn to choose carefully elements of document design, visual depiction, inclusion of any needed warnings, cautions, or tips, word choice, and sentence structure. A basic instruction-writing assignment in a technical communication course might be to build an original Lego creation, and then write instructions so that other individuals can successfully reproduce the exact same design. As a warm-up assignment, one of the authors has her students write instructions for how to use the instructional technology in the classroom. Summers and Watt have described "quick and dirty" instruction-writing projects assigned in their technical writing courses, such as creating paper prototypes of mobile applications, and revising existing instructions for putting on and taking off Personal Protective Equipment in hospital settings.[1]

To ensure that instructions are effectively written for the target users and rhetorical situation, usability testing is carried out on draft instructions. The benefits of user testing of instructions are well established in both professional practice and academic literature.[2] In the technical communication classroom, the pedagogy of usability emphasizes having test subjects (as representative of target users as possible) use a draft of the instructions to complete the desired action, in the process exposing flaws in the text or design of the instructions: areas of ambiguity, lack of clarity, need for additional visuals, organizational problems, and the like. The instructions are then revised based on user feedback.[3] In the technical communication classroom, the design of the technology itself is usually taken as a given and cannot be changed, thus only the instruction documentation can be reviewed, revised, and improved. However, in the unique interdisciplinary setting described below, the authors of this paper found that not only could the documentation be improved through the usability testing process, but that testing the draft instructions could also lead to changes to the design of the technology itself, its components and assembly process.

Program Structure and Project Theme

Our unique interdisciplinary teaching setting is a full-time summer program in which students earn credit for a technical elective, a science elective, and a communication course (12 total credits, which would be equivalent to a full-time load during a trimester and credit hours are split evenly). Most of the engineering and science disciplines offered at Rose-Hulman require ~190 credit hours for graduation. For this program, the students are physically in the classroom with the instructors for at least six hours a day for the summer term (~10 weeks) and the number of students that participated in the course ranged from 6-12 students depending on the year. The students' majors included physics, civil engineering, mechanical engineering, electrical engineering, and chemical engineering. The students were either rising sophomores or rising juniors; however, this past year included a graduate student. The courses are not taught separately, but rather all participants (the three instructors and the students) are together most of the time--sometimes in the classroom, sometimes in the machine shop, and sometimes in the meeting room. The students are introduced to the National Academy of Engineering's Grand Challenges, and they work on an engineering design project connected to one or more of the Challenges. Because we have wanted to also include a global dimension, we have focused the students on a particular geographic area. The first summer, students developed a water purification device that utilized solar energy as well as filtration methods for potential deployment in Kenya. Our teaching approach is primarily just-in-time instruction, with scientific principles, design methodology, and communication tasks incorporated with the project work.[4]

The second summer, we shifted our focus from Kenya to Haiti, motivated by the humanitarian and environmental crises that persisted following the earthquake in 2010. Students researched the multiple challenges Haitians were facing, and decided they wanted their project to make use of the large amount of plastic trash that had accumulated in the canals. Ultimately, they prototyped a device that melted the plastic trash using only solar heat collected via a trough, with the idea that the melted plastic could then be employed as a building material (addressing the NAE Grand Challenge of Restore Urban Infrastructure, as well as the theme of Sustainability). This prototype was still very rough, however, at the end of that summer's work (2014). During the summer of 2015 the Grand Challenge students chose to work on further testing and development of the device targeted at Haiti. We were contacted by leaders of a humanitarian nonprofit organization affiliated with another university that specializes in work in Haiti. The leaders of that nonprofit became informal clients for our project, providing feedback and suggestions to our students as they worked through their design process. The 2015 design can be seen in Figure 1 below.

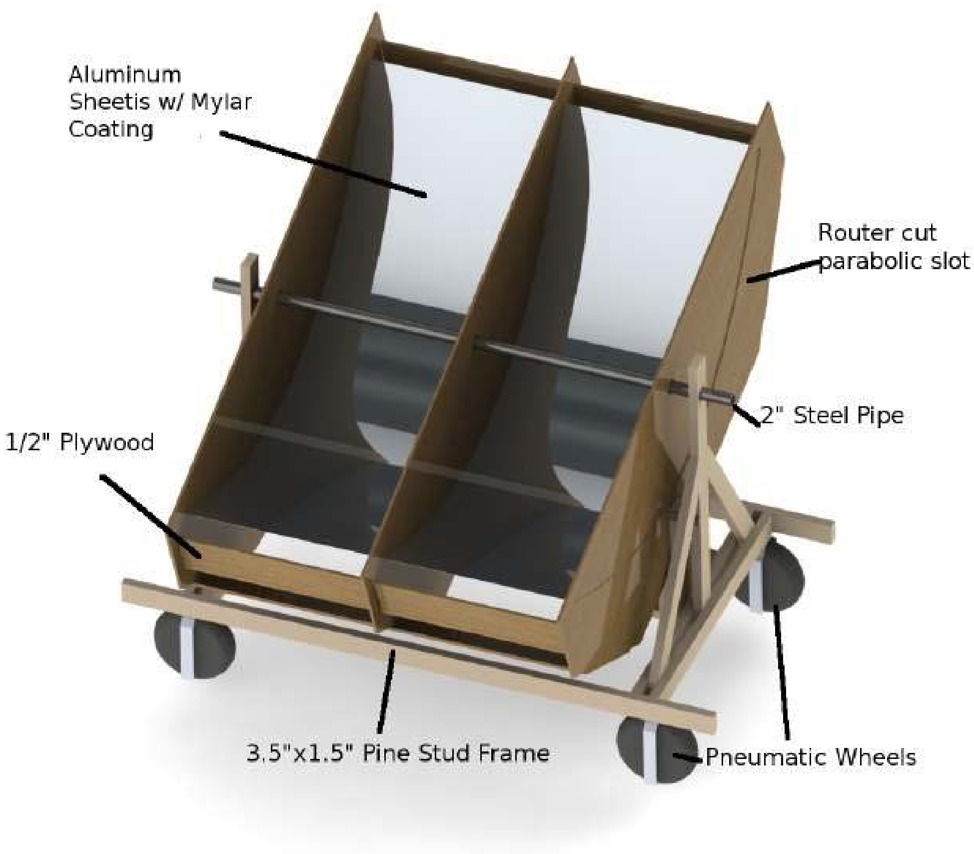

Figure 1: The 2015 Device Prototype

The students designed the device so that it could be shipped as a kit that is then assembled on the ground in Haiti. Among the major deliverables the students produced was a final report written for those nonprofit leaders. Included in the report were detailed sections of instructions for construction and operation of the device. (In the final version of the report, the sections offering instructions for construction and operation of the device occupy 23 pages of a 73 page report. These instructions are not brief ones meant for Haitians, but rather comprehensive ones written for their nonprofit client.)

Course Objectives

The course objectives for this program mirror those typically taught in each discipline-specific component course. (See Table 1 below.) All deliverables are read and graded by the three instructors using grading rubrics (sometimes these are written in advance by the instructors, and in other cases the students participate in developing the rubrics).

Table 1- Course Objectives for the Summer Grand Challenge Program

RH330 Technical and Professional Communication	• Analyzing contexts, audiences, and genres to determine how they influence communication • Crafting documents to meet the demands and constraints of professional situations • Integrating all stages of the writing process, ethically and persuasively, to respond to technical contexts and audiences—from planning, researching and drafting to designing, revising and editing • Collaborating effectively within and across teams with overlapping interests
ME497 Mechanical Engineering Technical Elective	• Provide strategies and practice for design development • Applying a systems approach to develop an innovative design for utilizing solar energy • Learning to approach design problems and alternatives broadly and creatively; for example, broadening and deepening concepts and understanding of solar power • Utilizing best manufacturing practices in design development, including in the choice of materials • Understanding and meeting challenges associated with addressing stakeholder needs from different cultures/environments
PH490 Physics/ Science Elective	• Increase understanding of energy and mass principles • Utilizing heat flow for power conversion • Understanding energy efficiency and constraints • Exploring the relationships among heat, light, and electrical and mechanical energy

Shown below is the rubric used for grading the final report, developed by the students in consultation with the instructors, and based on 130 points available for the project (approximately 15 percent of the overall course grade).

Table 2-Grading Rubric for Final Report

Category	0.65	0.75	0.85	1.00
Executive Summary (20 pts)	Does not resemble standard Executive Summary format, acts as a deterrent for reader to continue reading about the project.	Major errors in formatting, important information either missing or not concise enough for an executive summary.	Generally correct usage of Executive Summary. Generates some interest for non-readers of full report.	Concise, useful summary that inspires interest in the project and motivates reader to read extended report.
Instructions (20 pts)	Instructions are generally confusing and serve to complicate the construction and/or operation of the cooker. No useful pictures/diagrams included.	Instructions are somewhat confusing, making construction and/or operation of the device require unnecessary extra work. Few useful pictures included as aids.	Quite clear instructions, although some parts require educated guesswork by the reader. Good use of visual aids to assist in operation and maintenance.	Clear and concise instructions included. Installation and operation of device able to be easily completed with no prior knowledge. Excellent use of visual aids to assist in operation/maintenance.
Professionalism, Grammar, and Style (15 pts)	Consistent and significant errors in grammar and style. No attempt made at professional layout of document.	Many errors in grammar and style. Somewhat clear and logical sections, but leaves reader disoriented at points.	Few errors in grammar and style. Generally clear and logical sections. Some work required to improve document flow.	Predominantly free of grammatical errors, and the prose is efficient and concise, The report is divided into clear and logical sections; headings and subheadings make content easy to find and provide a sound understanding of each section's main points. The rationale for arrangement is clear and reduces redundancy.
Content (30 pts)	Content of report is poor, reader is generally confused.	Reader understands the majority of the project but some aspects are unclear or omitted.	Reader understands the project and wants to know more. Good use of pictures, graphs and/or diagrams.	Reader is left interested, excited and wanting this project to succeed. All necessary information that reader requires is included. Excellent use of pictures, graphs and/or diagrams to aid explanations of concepts and results.

Documentation (15 pts)	No real attempt at professional documentation.	Many important justifying documents missing, although attempts were made to include some documentation.	Most justifying documentation included, mostly to IEEE documentation standards, with reader able to easily navigate to required information. Some documentation missing or incomplete.	Most/all justifying documentation included in IEEE Documentation style with reader able to easily navigate to required information.
Final Design/Final Product (30 pts)	Product and/or device are poorly thought through and have no prospect of practical implementation.	Device has some functionality, but with no usefulness for practical implementation.	Concept design and product show reasonable potential for real world implementation, but require significant modifications to be able to be used efficiently in a real-world setting	Complete system (both device and product), with slight modifications, has high potential for implementation in a real world setting.

Usability Testing

Consistent with our model of just-in-time instruction, the concept of usability testing was introduced as the students were drafting their final report. The students chose to conduct their first rounds of testing using themselves as test subjects. They first disassembled their device. Students familiar with the construction of the device then reassembled it, taking detailed notes about what steps were required. They developed a system for labelling the parts of the device. As seen below, all of the parts of the frame were labelled “F#”.

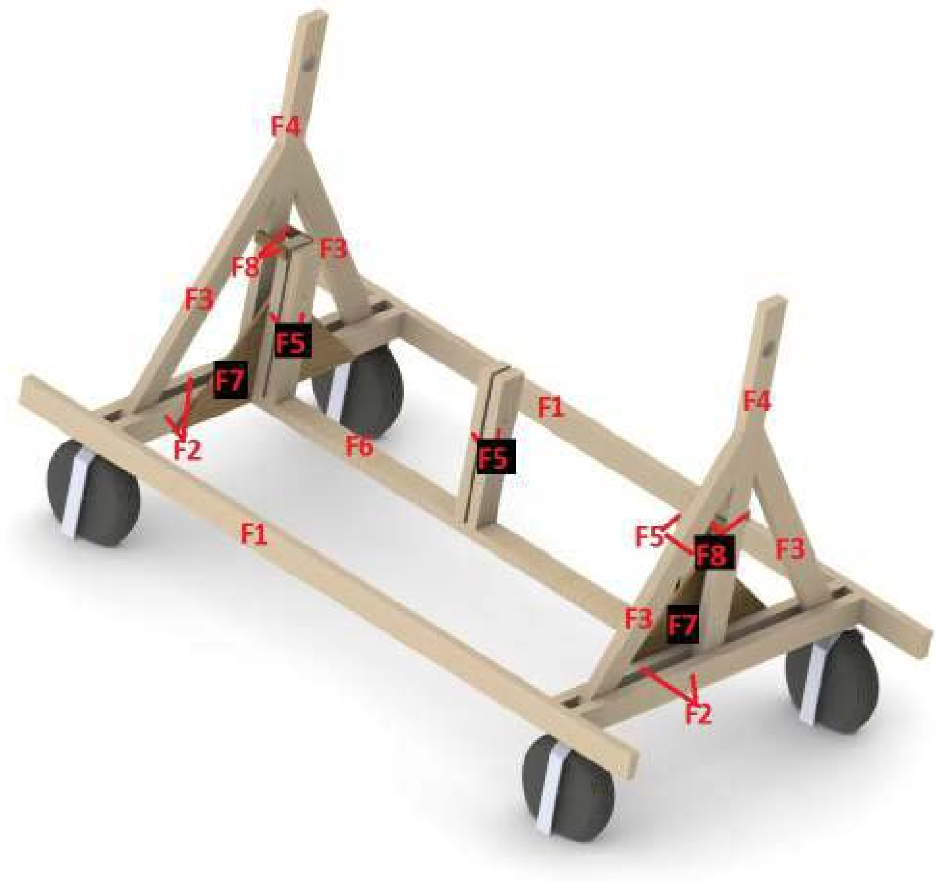

Figure 2: Drawing of the frame for the device, including labelling of parts as they will be included in the kit

Similarly, all of the trough parts begin with "T." Then they drafted assembly instructions, including some pictures and referring to the labelled parts. Following suggestions from the usability lecture, they incorporated caution statements and material lists. They then tested this early draft of the instructions on another set of team members less familiar with the device construction, exposing areas that needed improvement, such as ambiguity in some textual instructions and the need for better photographs. They improved not just the instructions, but also the kit, as they reconsidered for example which tools they should suggest the assembler have available for the construction process.

The next draft of the kit and instructions was then tested on us, the instructors as test subjects. There are benefits and drawbacks to this choice. The most ideal test subjects are the actual target users. When that is not possible, subjects as close to the target users as possible in demographics and relevant knowledge are usually considered the best choices. We were obviously more knowledgeable about the design than the ideal test subjects. However, we were very invested in providing good feedback, and so willing to take the time to painstakingly work through the instructions and expose flaws, playing the role of a less experienced user as needed to make a point about knowledge the students were taking for granted. Of course we were working from our own biases in doing so, and may have been limited in our ability to step into the role of the target user.

This round of testing resulted in the students changing the order in which different sections of the device are assembled. They also refined the labelling system for the parts, so that a part might have written on it not just T10A to indicate its part number, but also “Bottom” to help with orienting the alignment of the parts during the assembly process, as seen below.

Figure 3: Photograph showing revised labelling of parts for device construction kit

Components are handled similarly throughout manufacturing. Diodes always have a black line on one side to indicate the cathode. Boxes state which end should be up. Tents always have poles of vastly different lengths to prevent confusion during setup. The usability testing our students conducted resulted in similar pragmatic revisions.

The students also refined the photographs where needed to express important concepts to novice users, such as how to optimally align the solar collector with the sun during operation of the device, as seen in the following page from the manual.

5 Operation of Device

1. Align device towards the sun such that there is no shadow created on trough by the plywood pieces. The shadow created by the device on the ground should be exactly behind the device as shown in Figure 37. After orienting the device, secure the wheels to prevent it from rolling.

(a) Incorrect alignment

(b) Correct alignment

Figure 4: A page from the manual written by the students, depicting how the shadow of the device must be directly behind the device

Another set of additions made to the instructions based on usability testing were notes that provided advance warning to the audience of mistakes likely to be made, such as the following:

> 27. Insert aluminum sheets lengthwise one at a time starting from the top
> of the parabola. Note: make sure not to pull too far on one side or the

aluminum sheet will slide out of other T10 piece.

When the test subjects (we) committed such errors, the students would then add such proactive notes to prevent their target users from making the same mistakes.

Outcomes

The assembly process developed and instructions written by the students in 2015 were much more detailed that those produced in previous years, when we did not include usability testing among our expectations for the students' project. We speculate that they wrote much more detailed instructions than in prior years even in the first draft because they knew they would be expected to test the instructions: they knew they would be going through the process of building the device again using only these instructions. Then, the testing itself revealed other potential user pitfalls, requiring yet more explanation. We believe that the changes the students made to the kit and the instructions for assembly and operation were nicely substantive, especially given the limited amount of time that they knew they had available to make changes before their time on the project ran out (a matter of a few days); if usability testing was introduced sooner in the project timeline (assuming a prototype was ready earlier), even more substantive improvements might be made.

And in fact, we saw students introduce those further improvements inspired by the usability testing after the summer was over. One of us teaches an engineering capstone design course, and one of our summer students is a member of that course (taking place during the regular academic year). The carry-over student is part of a capstone design project team that continues to work with our non-profit client on refinements to the design developed over the summer. The poster found below shows the team's current thoughts about the design.

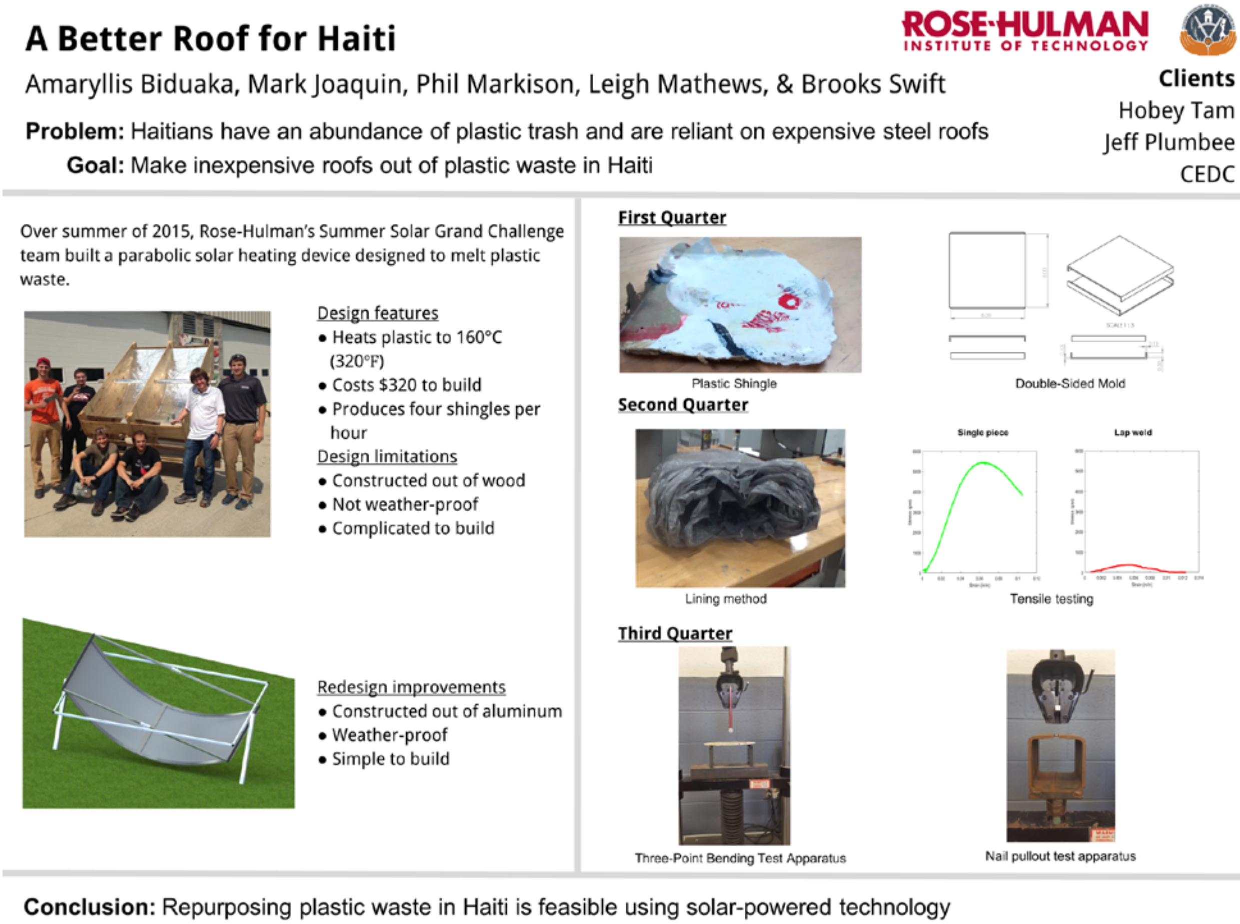

Figure 5: Poster from 2015-2016 capstone design team that continues to work on the project

Looking under "Design limitations" on the left-hand side of the poster, one can see some of the drawbacks noted by the summer students during their usability testing, especially that the device was "Complicated to build"; the capstone design team then notes the improvements they have subsequently introduced, including simplifying the build.

The general principles and process of usability testing that we recommend might be summarized as follows:

1. Test design prototypes and draft documentation (manuals, instructions, procedures), when possible, on test subjects representative of the target audience, as well as on those familiar with the technology.
2. Engage in multiple iterations of testing, possibly testing just portions of the documentation at a time.
3. Include quantitative and qualitative tests.
4. Observe results and record notes throughout the testing.
5. Based on testing, consider changes to the technology itself and/or the recommended procedures for constructing and/or operating it.

6. Revise documentation based on the results of the testing, striving to provide a positive experience for the target user.

Conducting usability testing with this basic process in an interdisciplinary design project that includes emphasis on effective documentation yielded positive results.

Conclusions

Overall, introducing usability testing processes into our interdisciplinary project has led to a better design and smoother assembly process as well as improved documentation—all desirable outcomes for our student engineers as well as their client. Comparing the usability testing completed in this Grand Challenge project to that completed in the Technical Communication course one of us teaches, we see that students feeling ownership of the design leads to more serious and extensive testing and revision. For example, in the Technical Communication course Watt had the students develop instructions for donning and doffing PPE—and having good instructions for that procedure for a given audience is very important. But the students did not feel the same amount of buy-in or investment (ownership) as they do when they are working with instructions for how to assemble their own device, especially when they believe that device may really be used and make a difference in people's lives. This illustrates one more advantage of a team-taught multidisciplinary project course.

Bibliography

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[1] Sarah Summers and Anneliese Watt, "Quick and Dirty Usability Testing in the Technical Communication Classroom," *ProComm 2015 Conference Proceedings* (IEEE Professional Communication Society), Limerick, Ireland.

[2] See for example S. Ludi, "Providing Students with Usability Testing Experience: Bringing Home the Lesson "The User Is Not Like You," 35th ASEE/IEEE Frontiers in Education Conference, Indianapolis, 2005; and M.A. Atlas, "The User Edit: Making Manuals Easier to Use," *IEEE Transactions on Professional Communication*, vol. 24, no.1, pp. 28-29, March 1981.

[3] For discussions of usability pedagogy, see Summers and Watt (above), as well as L.M. Kastman Breuch, M. Zachry, and C. Spinuzzi, "Usability Instruction in Technical Communication Programs: New Directions in Curriculum Development, " *Journal of Business and Technical Communication*, vol. 15, pp. 223-240, Apr. 2001; and S. Schneider, "Usable Pedagogies: Usability, Rhetoric, and Sociocultural Pedagogy in the Technical Writing Classroom," *Technical Communication Quarterly*, vol. 14, no.4, pp. 447-467, 2005.

[4] Descriptions of our summer Grand Challenges course structure, objectives, interdisciplinary teaching, and design projects are available in the following publications: Ashley Bernal, Scott Kirkpatrick, and Anneliese Watt, "What's in the Soup? Auto-ethnographies from an Engineer, a Physicist, and an English Professor Regarding a Successful Multidisciplinary Grand Challenge Program," *Proceedings of the 2014 American Society for Engineering Education Annual Conference and Exposition*; Ashley Bernal, Scott Kirkpatrick, and Anneliese Watt, "Border-Crossing with Competition then Collaboration in a Challenge-Driven Design and Communication Experience for Engineering and Science Students," *Proceedings of the IEEE International Professional Communication Conference, 2013.*