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What's in the Soup? Auto-ethnograhies from an Engineer, a Physicist, and an English Professor Regarding a Successful Multidisciplinary Grand Challenge Program

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What's in the Soup? Reflections from an Engineer, a Physicist, and an English Professor on an Interdisciplinary Summer Grand Challenge Program

Introduction to the Summer Grand Challenge Program

Three professors with common interests and goals piloted in Summer 2013 a program focused on solving one of the fourteen Grand Challenges of the 21st Century identified by the National Academy of Engineering (NAE).[1] These challenges range from providing energy from fusion to engineering better medicines. The summer program was centered on making solar power cheaper and locally manufacturable in a less developed region. The program purposefully brought together humanities, science, and engineering into a single intensively focused experience. The program was profiled in local front page news coverage,[2] the headline story in ASEE *First Bell* publication,[3] and a *US News & World Report* article.[4] Following the teaching experience, the three faculty members sought to reflect on the experience in a structured way. We formulated questions to probe areas of interest for reflection based on Borrego and Newswander.[5] The questions were answered individually and independently, and then the answers were shared so that we could engage in shared reflection. After a brief overview of the nature of this program (objectives, structure, deliverables, assessment), this paper shares some of the notable points and insights that emerged from the reflection process, which we hope will be of interest to other engineering educators developing and/or teaching interdisciplinary programs. We follow Borrego and Newswander in using the term "interdisciplinary" when collaborators work together to create something new as opposed to a "multidisciplinary" collaboration where colleagues come together momentarily but then split apart "unchanged by the experience."[5]

Course objectives were outlined for the specific courses the program would encompass; Table 1 shows a list of objectives for each of three courses. Students earned twelve credit hours for the program (four in science, four in engineering, and four in technical writing and communication). Throughout this paper the word "program" refers to the full twelve credit experience.

Table 1- Course Objectives for the Summer Grand Challenge Program

RH330	• 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	• 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, in this case Kenyan
PH490	• Increase understanding of energy and mass principles • Understanding pressure-volume relationships • Utilizing heat flow for power conversion • Understanding energy efficiency and constraints • Exploring the relationships among heat, light, and electrical and mechanical energy

Although the objectives are distributed across three different courses in the table above, the courses were not taught separately but rather as part of a single program. The outcomes and milestones were overlaid upon a ten week duration, which helped to determine expected due dates in order to have functioning prototype at the end of the program. Students and all three faculty met four days per week, following a daily schedule of 9:00-11:30am, lunch break, 1:00-4:30 pm. As intended, this resulted in more class-time hours for faculty and students than would normally be expected for the number of credits. This extra time was leveraged so that most work was done during that scheduled time (rather than as independent homework, class preparation, and grading). The substantial lunch break of 1.5 hours was often used (by both students and faculty, sometimes together and other times apart) for less formal conversation while eating.

The major deliverables for the course are shown in Table 2. Student work was assessed using rubrics/assignment sheets, which can be found on the Summer Grand Challenge website.

Table 2- Major Deliverables for the Summer Grand Challenge Program

Deliverable Name	Communication Medium	Category
Energy Conversion Lab	Memo	Scientific Knowledge
Steam Engine Cutaway	Brochure	Scientific Knowledge
System Design Process Documentation	Memo	Teaming/Professionalism
Stirling and Steam Technical Sales Pitch	Oral Presentation	Scientific Knowledge
Peer Performance Evaluation	Memo	Teaming/Professionalism
Prototype Talk Invitation Email	Email	Teaming/Professionalism
Problem Description	Oral Presentation	Design Deliverable
Prototype Electronic Poster Presentation	Oral Presentation	Design Deliverable
Oral Exam 1	Oral Presentation	Scientific Knowledge
County Fair Writing	Written Reflections	Teaming/Professionalism
Press Conference	Oral Presentation	Design Deliverable
Proposal	Written Report	Design Deliverable
You-tube video	Instructional Video	Design Deliverable
Employment Project	Cover letter and Resume	Resume & Cover Letter

Each deliverable shown in Table 2 was assigned to a category with the grade distribution shown in Table 3. The design deliverable's grade for each student was individually scaled based on self and peer assessment of their teaming behavior using the online CATME software.[6] In addition, the teaming/professionalism category was also scaled based on our interactions with the student as well as observed behavior.

Table 3- Major Deliverables for the Summer Grand Challenge Program

Category Name	Weight Distribution
Teaming/Professionalism	25%
Scientific Knowledge	15%
Design Deliverables	50%
Resume and Cover Letter	10%

The program started with the class with 10 total students with rising sophomore to rising junior status with the following majors represented: Mechanical Engineering, Civil Engineering, Electrical Engineering, and Physics. The class was broken into small groups (three to four students per team) developing competing conceptual designs. The groups are assigned using an algorithm provided using the online CATME software program.[6] The first two weeks were allocated towards introduction to the topics required for the students to accomplish their task, including thermodynamic analysis and heat transfer. This initial period of the program included labs whose deliverable form varied from a technical memo to a sales brochure. In addition, students underwent an intensive problem definition phase, determining the target location and needs of the local customers. The next three weeks were devoted to developing concepts, building student design skills, and developing an initial design. The best design was then chosen (together by the instructors and students) and carried forward by the entire class for the remainder of the program. Thus, during the next four weeks smaller teams worked on individual subcomponents of the best design, which required the entire class to work together in order for their components to fit together into a fully functioning and tested device. The final week of the program was dedicated to their design presentation with the press, a written proposal to disseminate their idea, developing an instructional video for assembling the device, and building student résumés incorporating their summer experience and new skills acquired.

The expected institute outcomes of the Summer Grand Challenge program included the following: engage at-risk students, provide opportunities for advanced students, engage students in a meaningful cultural experience, and encourage students to explore the engineering Grand Challenges. These outcomes were accomplished by this program through the enrollment of students with different disciplines as well as varying degrees of academic success. In addition, collaboration with a Kenyan college student allowed students to explore the international dimension of their professions, becoming more aware of the roles engineers and scientists have in solving complex technological problems. The institute outcomes were far exceeded and the students ran their own press conference for their prototype.

Summaries of Reflections

As stated previously, three professor's participated in this program, each with various backgrounds. Dr. Anne Watt is a Full Professor in the Humanities and Social Sciences Department. She has been at Rose-Hulman for 14 years and is originally from Ohio. The courses that she typically teaches include Technical Communication, Rhetoric, and Literature courses. Dr. Scott Kirkpatrick is an Assistant Professor in the Physics and Optical Engineering Department and is originally from Pennsylvania. He previously worked at Rose-Hulman as a Researcher and a Visiting Assistant Professor prior to being hired into a tenure track position. Thus, he has been at Rose-Hulman for approximately 8 years and typically teaches MEMS and Nano courses. Dr. Ashley Bernal is an Assistant Professor in the Mechanical Engineering Department. She is an alumnus of Rose-Hulman and has been teaching at Rose for 2 years. She typically teaches classes in the design, manufacturing, and materials realm. The next few sections summarize our reflections.

Selecting Collaborators

Each summer in recent years, the institute has encouraged interested faculty members to participate in an innovation workshop, taking advantage of the summertime to explore new ideas and direct efforts. Last summer, we came together primarily due to our shared interest in the National Academy of Engineering's Grand Challenges and exploring ways to integrate the challenges into coursework. Unlike Borrego and Newswander's findings where typical cross-disciplinary collaborators often seek-out experts in another field with a specific purpose of a pre-conceived idea, this collaboration began more "by chance." As Kirkpatrick stated,

> "A group had been developed in previous years with an interest in the grand challenges. I was jealous, the grand challenges sound cool and I want to do them. So I walked over to that group. I was slightly surprised to find the group being represented by Humanities and Social Sciences faculty (but not too much-- I had friends who had degrees in English that could turn a wrench far better than I could)."

Model of Collaboration

The model of collaboration in the summer program was an interdisciplinary model.[5] Being a non-engineer, Watt was worried at the beginning that the program would be the "engineer's baby," which Borrego and Newswander pointed-out as one of the potential issues. However, Watt stated that she learned that "at least some of my colleagues are ready to welcome me in on equal ground, and won't just expect me to be a glorified grader if we co-teach." At the end of the program, each professor gained new ideas from the program development and implementation (see Learning and Satisfaction). We also developed a new way to teach and integrate several sets of class objectives simultaneously. In addition, this collaboration produced a new form of interdisciplinary education benefitting the students with a set of courses with a common goal and theme.

Sharing the Workload

The workload for the program development took place in stages from the previous summer through the school year. At various points each of us found ourselves leading and then following through the ebb and flow of our available time and specific knowledge. All of us relied on the others and see the contributions the others have made. Each person gave what he or she could to further the program and fully appreciated the contribution of the others. The appreciation of others' contributions is exemplified in the following from Bernal: "I, myself, struggled to determine what my role was in the program." Conversely, Kirkpatrick states, "I saw Dr. Bernal's role as administrator as well as a great resource for a different point of view to similar concepts." We each saw the strengths in our colleagues and what a great contribution they provided.

Learning and satisfaction

We all agreed that what we learned from our colleagues ranged from observing effective teaching methods to principles in each other's discipline. As Watt states, "I can't list everything I learned from my colleagues; indeed, I'm sure I'm not even conscious of all that I learned." In terms of benefits of collaboration vs. teaching on one's own, we found reinforcement in our teaching approaches and expectations. For instance, we gained confidence in assigning grades, as more often than not we agreed within two percent. As Bernal stated, "It was great to make sure I was 'calibrated' with faculty member's expectations in other departments."

We also all agreed that one of the benefits for our students taking the program was their improved communication and teaming skills. We did diverge slightly, however, as to the other benefits for our students, which primarily seemed to stem from us being from different disciplines. For instance, Bernal's reflection also commented on the fact that "students became more cognizant of manufacturing difficulties when proposing ideas.…Prior to the program, the students didn't realize that caulking shouldn't be used for structural support." In addition, both Bernal and Kirkpatrick also hoped that students "were able to see firsthand how theoretical analysis should influence design decisions." Watt's reflection, however, focused on the ability of students to "see that professors from different disciplines share overlapping interest" and "[our modeling] of effective and pleasant teaming behaviors."

Keys to Faculty Developing an Interdisciplinary Program

After we pooled and read our individually-written reflections on this experience, common themes emerged about what factors may have contributed to making this a productive experience. We have grouped these ideas into three categories: Practicalities, Individual Traits, General Teaming Skills. In addition we will discuss Best Practices in Interdisciplinary Teaching.

Practicalities

As Borrego and Newswander also found, the institutional and logistical setting for our collaboration was key to the nature of our experience. As previously mentioned, the idea for this program emerged from the Summer Innovation Workshop offered for faculty at our college; in retrospect, we see the importance of providing such forums for innovation and collaboration. As Kirkpatrick wrote in his response, the Innovation Workshop created "one of those rare chances to interact with colleagues outside of our own department in a professional, yet relaxed environment, without some other task involved (standing committees)." We also noted that the summer timeframe aided us both in terms of generating the idea one summer, pursuing the necessary logistics to make it happen during the next school year, and then actually teaching the interdisciplinary program the second summer. By using the two summers for the bulk of our work, we were able to make our Summer Grand Challenge program our top priority, less distracted by competing obligations than is the case during the academic year.

The logistics pursued during the academic year included meeting with department heads and administrators to discuss our plans, both to help our own development of those plans and to build “buy-in” among the administrators. One key decision we made was to use existing course numbers for the credits students would earn for the program; thus, it was not necessary to shepherd approval for new course(s) through the Curriculum Committee or develop a description for the Course Catalog. We (the faculty teaching the course) and the involved administrators saw our program as an innovative program, and this led to several helpful effects: our sense of accountability was increased as this was the primary professional development focus and we strived to make the pilot a success in order to provide a pathway for future variations and iterations of the Summer Grand Challenge format.

However, as Bernal notes in her response to the reflection question about drawbacks of piloting the program, there was extra time required to setup the program and recruit students to participate (as they would need to pay summer tuition for twelve credit hours and relinquish other potential summer plans). In addition to the time investment was the financial investment: we had to work out the logistics of how the faculty would be paid, how to fund the purchase of lab equipment and supplies, and how to fund the Kenyan student to participate in part of the program.

Individual Traits

The three faculty collaborating have not only different academic disciplines but also different personalities, as may be evident in reading our reflections—both in what we say directly about each other, and perhaps in the style of our responses as we respond to the same set of prompts. Nevertheless, one can also see in reading our responses that our personalities meshed and we enjoyed working together. For example, we found that Kirkpatrick’s willingness to just dive into an experiment or build activity was a nice balance to Bernal’s emphasis on effective planning and preparation. Thus, we agree with Borrego and Newswander that “expertise alone is insufficient basis for successful cross-disciplinary collaborations” (i.e. personality must not be ignored when seeking collaborators).

There are multiple traits that we all thought we shared. We believe we are all open-minded individuals. We all brought strong energy to the effort, and shared a predisposition to *do* something (not just consider it). An interesting difference we found in writing our reflections is that “doing something” was at the forefront of Watt’s mind, a more seasoned professor among us, who was aware of other groups she’d been involved with that never moved past the planning stage. Bernal, though--our newest faculty member and an engineer--took for granted that the program would come to fruition. While the seasoned communication professor was impressed that “we took the idea from inception to implementation in one year,” the new engineering professor hadn’t considered one year to be a particularly quick timeframe. A related key trait that all three share is accepting the need to do things “on the fly”; for instance, we agreed from the outset that we wanted most of our lecture material to emerge as it was needed by the students for the current or next stage in the project—a “just in time” instruction. A faculty member who feels he or she must have all of his lessons for the course slotted and planned in advance would have been a nervous wreck under this model.

Interdisciplinary Co-teaching as Good Teaming

Upon reflection, not only were individual traits important to our operation but also equally important is our capability to function as a productive team, following many of the same behaviors and practices that we teach our student teams. Emerging from all of our reflections is a strong sense of common goals--for addressing the Grand Challenges of engineering, for curricular innovation, for interdisciplinary teaching, and for student outcomes (as will be discussed further below). As we moved from those common goals towards actual decisions and implementations, everyone felt free to offer ideas and opinions with no fear of ridicule. Throughout our teaming process, no individual has "hogged the limelight"; conversely, it can be seen in our reflections that we tend to worry about our own contributions and to value our teammates' contributions more than our own, at least at some stages of the process. A related good teaming behavior that has been evident is that we frequently slip in brief praise and compliments for each other, to show that we value each other's talents and contributions.

<u>Keys to Students Experiencing an Interdisciplinary Program</u>

At the end of the Summer Grand Challenge Program, all ten students were asked to reflect upon the program and provide constructive feedback. When asked via a student survey whether or not a similar program should be offered (co-taught with one large challenge driving the direction of the class) all ten students that participated in the program agreed that the program was beneficial and should be taught again; however one student thought that having one teacher educate students is a better choice as students wouldn't have to cope with different teaching styles; however, nearly all other students thought that this was one of the benefits of the program. A few students also thought that part of the advantage of the program was the ability of the students to focus only on this program rather than other courses simultaneously that compete for the attention of the student. Thus, four students felt that the program should only be offered in the summer "so there can be more time and energy put into it."

In terms of the program structure, there wasn't a single overwhelming answer as to what they liked most about the program structure; however, several alluded to the fact that they enjoyed the seamless integration of all three topics (engineering, science, and technical communications) into one class. In addition, others enjoyed the working with people from different majors and the hands-on aspect of the program: "starting theoretical, to actuality."

In terms of what students liked least about the program structure, three students commented that they didn't like the lack of the direction during the second half of the program. As previously discussed, at the beginning of the program, the lectures were "canned" and each day was clearly specified in terms of the activities and the desired outcomes. During the second half of the program, the students were required to determine which tasks were necessary in order to complete deliverables on-time, thus requiring the students to be self-directive. It was clear that several students were uneasy with having to identify tasks and delegating work among all ten team members in order to develop a functioning prototype. One student stated, "I think explaining to the students beforehand that the program lacked structure would be useful…students were often wondering and looking for direction." Next year, we will definitely more clearly state this at the beginning of the program. It is encouraging, however, to note that some of the students thought this lack of structure was extremely beneficial. "Right now, there is no class that can help students to 'grow up' much like this." Another student commented that the "lack of structure was the best part of the program. Letting students figure out group work on their own for the most part was a great way of learning for me." Yet another, stated that "I enjoyed being able to freely learn what was necessary for proper construction and analysis of the project." Other students commented that what they liked least regarding the program's structure varied from "needing" another vacation during the middle of the program as he was getting "worn-out" to the hindrance of productivity due to "drama between students leading to inefficiency and general bitterness," to disliking writing the mandatory proposal at the end of the program.

In general, the overall outcome of any course is determined via the skills students learn. When asked about the area they felt they improved the most, an overwhelming response was their communication skills, both verbal and written. For instance a student stated, "I improved most upon communicating effectively with teammates about what was being accomplished and the next steps that had to be done to ensure that we were on task with whatever had to be completed that day." In addition, other students noted their improvement in interpersonal teaming skills. "I probably improved the most by learning more about how to deal with people. I wish that I had been more patient and a better listener...I also grew more through having my designs vetoed. It helped that the manager was also my friend, so now I have learned not to take these things personal." The students also stated the same was true in terms of improvements they saw in their classmates, noting that they "grew stronger in most all teaming/interpersonal attributes (communication, delegation, task management, accountability, planning, and requesting aid)" and after several weeks "[classmates] weren't afraid to voice their opinions and ideas."

Best Practices: How to Get the Most out of Interdisciplinary Teaching

Although we were largely making it up "on the fly" as we went, our reflections may hint at some best practices for interdisciplinary teaching.

- *Be Open-minded***:** We all came into the experience not only open-minded (or possessing what Spiro et al. call "cognitive flexibility"[7]), but also with appreciation for each other's disciplines and understanding that all three disciplines are important for our students.
- *Be United***:** We spent a lot of time together, not over-relying on the "divide and conquer method" of teaming. We worked together both outside and inside class. When students were working in their teams, we were also working in our faculty team, planning the next day's content or developing a grading rubric or doing the actual grading. We believe we benefitted tremendously from this time spent together, learning from each other, as well as indirectly modeling effective teaming for the students. This may not be the most efficient model, but we believe the short-term and long-term benefits are invaluable. Some of the benefits are more common ground being discovered and established, and each of us feeling more confident about that common ground. For example, a lab is not just a set of numbers, but also an analysis of the behavior. A quality lab report should

include both good data and well written analysis of the data, communicating the lab to others. By having all three professors represented, we could hold students to a higher standard as we were able to more readily know their capabilities in each area and have a better idea what they were taught previously in classes outside of our own discipline. As Kirkpatrick stated, "ownership of the whole thing is a big difference between what happens during a school year where I could consider writing skills or integration someone else's job to do, and that I should merely rely on the students to have picked it up from a set of nebulous classes outside my discipline." In terms of general pedagogical strategies, we learned new ones from each other, but also saw how others do some of the same things we do. For instance, the Socratic method works just as well in physics as in humanities. As has been posited in the *Journal of Engineering Education*, "the level of integration for a collaborative project can be a predictor of the quality of the final product."[8] In our summer program, we felt we modeled an interdisciplinary approach rather than a multdisciplinary approach as our interactions influenced the way we now teach our own individual courses, ranging from changes in the instructional method we use in class to the overall changes in course structure. For instance, Kirkpatrick has changed his slide design practice to utlize an assertion evidence approach, Bernal has incoroporated some Socratic methodology into her courses, and Watt has revised her teaching of design projects.

- *Trust Each Other***:** We also leverage each other as backup, a sort of "tag-teaming" in our interactions with administrators and students. For example, if a student approached just one of us in class, whenever possible we would turn to our faculty partners and draw them into the conversation as well, avoiding contradicting each other or seeming to have our own niche territories. It was clear that we all three decided and agreed upon, for example, what the content and structure of a given deliverable should be in order to have consistent expectations. In terms of administrators, we used each of our "contacts" to determine the most efficient way to "get something done."
- *Integrate***:** On all deliverables assigned to the students, we made sure each one integrated science, engineering, and communication elements such that the necessity and overlap of all three subject areas was further exemplified and was reflected on grading rubrics.
- *Be Purpose-Driven***:** We also avoided busywork for both the students and ourselves, with all material arising in the context of the larger class projects—while still meeting all of our original disciplinary goals. This allowed the students to be engaged in meaningful, applied research. As one student stated, "The structure of the program was great because we got a lot more hands on experience without the useless fluff that comes with typical courses."

In conclusion, the keys that we found to develop truly interdisciplinary program are to have a uniting purpose with certain character traits, mainly personality and attitudes that foster a good team working environment such as an open mind. This team also formed a united front when speaking to the students and developed an integrated set of deliverables for the program. This approach encouraged the whole team to take ownership of the entire project and kept everyone involved.

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