AC 2009-445: A TEAM-BASED DESIGN COMPETITION FOR FRESHMAN ENGINEERING STUDENTS THAT EMPHASIZES SUSTAINABLE DESIGN

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Abstract

This paper discusses a design competition for freshman students in the School of Engineering at James Madison University. Our engineering program has a sustainability focus that is specifically related to sustainable design and sustainable systems analysis. Our philosophy of sustainable design incorporates technical, economic, environmental, and societal criteria. Our program includes a ten credit design course sequence in which development of tangible prototypes and models will be emphasized. The purpose of the freshman design competition is to introduce our freshmen to our philosophy of sustainable design, introduce our students to some of the tools available to them in our Engineering Design Studio, and to develop a sense of community in our freshmen.

Participants in the design competition are introduced to our philosophy of sustainable design via the competition rules and scoring formulas. Students in the competition are required to attend a training session in our Engineering Design Studio where they are introduced to basic construction tools, tool usage techniques, and layout techniques. The Engineering Design Studio also serves as the facility that students use to build their design competition entries. Students sign up for the competition in groups of three or four during the first two weeks of fall semester classes. Our program does not have a required engineering course until the spring semester of the freshman year so this is the first opportunity for our students to work together on an engineering activity.

This paper addresses the competition rules and scoring formula along with our rationale for each to facilitate transferability to others that are planning design competitions. We developed a formula to rate the student designs that incorporates scores from each of the four elements of our sustainable design philosophy. This formula and the underlying rationale are included in order to assist others who wish to assess student work using sustainable design criteria. We also present the competition results in order to share which aspects of the competition the students chose to prioritize. Post-competition feedback obtained from anonymous surveys of participants, faculty, and the external judges from local industries is given and discussed in order to show the aspects of the competition process that worked well, and those that may be modified.

Introduction

James Madison University (JMU), traditionally known as a liberal arts school, has recently created a School of Engineering which offers a single engineering degree: Bachelor of Science in Engineering. Our inaugural class of 120 students started as freshmen in the fall of 2008. The engineering program is designed to meet ABET accreditation criteria and to prepare our students to take the FE exam. The program has a sustainability focus, with particular attention paid to sustainable design and systems analysis. Our philosophy of sustainable design incorporates technical, financial, environmental, and societal criteria[1]. The backbone of our curriculum consists of a 10 credit sequence of design courses that extend through the entire sophomore, junior, and senior years. These courses are laboratory courses and contain significant project work as well as design instruction. Our approach to teaching design includes instruction in critical thinking practices such as the development of "intentional and directed intellectual processes and habits that foster effective thinking"[2]. This approach is complemented by projects that require students to physically construct their designs as part of the design iteration process. Our assertion is that critical thinking in combination with hands-on project experience inspires better design.

Although our students are required to take specific courses in their first semester to begin satisfying degree requirements, the introductory engineering course is not taught until the spring semester. We speculated that many of our students would be interested in participating voluntarily in an engineering school activity if given the opportunity. We decided to provide an extracurricular competition for our freshmen students as an innovative way to introduce the sustainability design content they will experience throughout the program and to develop a sense of community within the School of Engineering. The competition itself requires students to work in teams to design and build a device to launch a small projectile at a target. Teams are judged on demonstrated accuracy, cost, weight of materials and disposal plan, and level of collaboration. In this way the competition incorporates the technical, economic, environmental, and societal criteria of our sustainable design philosophy.

Motivation for Competition

Numerous design competitions exist for engineering students or prospective engineering students. Design competitions are often considered a means to generate a level of enthusiasm for academic material not typically observed in the classroom and can serve as an object lesson of the need for teamwork and communication[3,4]. Many of the most popular competitions are sponsored by national or international engineering societies and attract competitors from institutions around the globe. Other competitions may exist only at a single school, or even within a single course. All engineering competitions typically share the broad objective of promoting engineering academic objectives. Other specific objectives are reflected in the competition rules which sometimes reflect a desire to influence social behavior. For instance, in a situation where the retention of under-represented groups is an objective, competition rules require inclusion of a member of an under-represented group on each team[5]. In another case in which a regional high school competition was modeled after a national competition, additional requirements were added at the regional level in order to fulfill the local objective of promoting interdisciplinary work between technology education students and college prep students. Although the primary thrust of the national competition required welding and construction skills that are within the purview of the technology education students, the regional competition required teams to respond to questions of a scientific nature. It was noted that since the technology education students and college prep students rarely interacted academically, the additional requirements were one way to get the groups to communicate with each other[6].

Academic and social objectives both serve as motives for our design competition. Our academic objectives are to introduce freshman students to our philosophy of sustainable design and give them the opportunity to have a design/build experience. Sustainable design is the focus of our program, sustainability issues are often complex and as such may not be accessible to freshmen; we intend the design competition to introduce sustainability concepts at a basic level. Our programs' approach to design includes a significant hands-on component; we intend that the competition familiarize some of our students with our construction facilities and give them construction experience. From a social perspective we want to give our freshman students an opportunity to interact with each other and with the faculty and staff of the school of engineering in order to develop a sense of community. Our curriculum does not include an engineering course in the first semester; the competition is a way to allow students to identify each other and to begin the formation of social networks. Since the freshmen that took part in the first annual competition were also in our inaugural class, we wanted them to interact with the faculty and staff to develop their attachment to the program. We view the competition as an opportunity to influence our programs identity; a demonstration that we value collaborative work and extra-curricular learning activities.

Sponsorship

During the planning phase we were able to secure funding for the competition. A local company agreed to donate $1000 per year for five years to cover costs of construction materials and prizes as well as food served at the event. As the competition plan matured we were able to find members of local industry to assist with judging. The first event cost a total of $750.

Competition Description

The first competition occurred outdoors from 9 AM until noon on the Saturday of "Parents Weekend" (October 4th, 2008). The number of observers reached as many as 100 at one point and included several parents of students as well as representatives from the school and local newspapers. The object of the competition was to design, build, and deploy a device to launch a stuffed school mascot (Duke Dog) toward a specified target, we called the event "The Fling". Points were distributed based on performance, cost, environmental impact, and team collaboration. Students proceeded through judging stations for the cost, environmental impact, and team collaboration portions of the competition. Each judging station was staffed by a School of Engineering faculty member and a volunteer judge from industry. Performance was measured on the "Field of Play" which consisted of a 10' x 10' launch zone called the "batter's box", and a target that was positioned 50' from the batter's box. Teams were given a limited amount of time to set up their device and make five launches; performance scoring was based on cumulative accuracy. Figure 1 shows a team in the batter's box immediately after a launch; the launched Duke Dog is visible in the upper left corner of the photograph.

Figure 1: A team and their device in action at "The Fling"

Competition Timeline

A flyer with the competition rules and scoring was distributed at an orientation event on the Saturday before fall semester classes started. The competition was mentioned again at a School of Engineering freshman mixer during the second week of school; sign-up sheets were also provided at the mixer. The deadline for registration was at the end of the third week of class, and the competition itself occurred on the Saturday following the sixth week of class. Orientations to our student accessible construction facilities were run during the second, third, and fourth weeks of class.

Level of participation and demographics

At the beginning of the fall semester 2008, 120 students were registered as engineering students, 17% were female. Of these students, 47 (~40%) voluntarily signed up to participate in the competition in 12 teams, 21% of these students were female. Of the students that signed up, 46 participated in the required shop orientation session (boot camps). On the day of the competition 28 students (~23%) on 9 teams were still involved with the competition although 3 of these students had other obligations and could not be present. Of the 25 students present at the competition, 20% were female. As a whole, our program experienced a retention rate of 80% between the first and second semesters; 64% of the students who signed up for the competition and 71% of the students that were still involved on the day of the competition are still in the engineering program. This suggests that participation in the competition is not a good indicator of retention.

Competition Rules and Rationale

We established rules in an attempt to compel certain behaviors in our students as well as make operation of competition related activities manageable for us. For instance, we intend our students to work collaboratively in our design studio using construction tools and building assemblies; literally getting their hands dirty and working side by side. This led us to establish limits on propulsion techniques in order to direct students toward a mechanical design which we presumed would encourage use of the design studio. Our rule states:
No devices that require explosives/propellants/compressed gas/etc will be allowed. Human assisted propulsion will not be permitted (you may not throw the dog).

We intend our rules to be succinct in order to maximize participation rather than discourage would-be competitors with lengthy specifications. We also intend to keep design restrictions to a minimum to encourage creativity. With this in mind we developed the following rules to cover the launch, team makeup, and device construction.

<u>Launch Rules</u>

Our launch rules cover issues related to the amount of time each team would have to complete their launches, the size and extents of the launching device, the projectile itself, and the trigger mechanism.

We chose to limit the amount of time that each team was allowed to occupy the batters' box primarily to keep the competition moving. We hoped to cycle teams through the performance portion of the competition in ten minute intervals in order to hold everyone's attention and to finish the competition before people drifted off to watch the football game. Another factor in our decision to limit time was to play up the competition aspect of the event by including a time crunch. Our rule states:
Each team is allowed eight minutes in the batters' box. The first three minutes are for setup, with five minutes allocated to launch five projectiles. Setup operations that extend past the three minute mark will result in reduced projectile launching time. Failure to launch five projectiles within the allotted time will result in a Performance score of 50 feet for any unlaunched projectiles.

In order to encourage reasonably sized devices as well as avoid long extension "slam dunk" solutions we required that the entire device stay within the confines of the batter's box during all stages of launch operations. Our rule states:
The entire device must be entirely contained within the batters' box during all stages of all five launch operations.

We intend our students to work within the given system parameters and not to attempt to change the parameters through gamesmanship. Our primary concern here is individual teams repackaging their projectile or adding mass to their projectile. Handling of the competition projectiles is restricted to judges and competition staff although sample projectiles were made available to teams for practice sessions. Our rules state:
All dogs will be supplied by the School of Engineering at the time of competition; team members shall not touch competition dogs. Practice dogs will be available for use in the on deck circle.

Example dogs are available for viewing in the School of Engineering main office and are available for purchase at the bookstore.

In order to reward thoughtful design as well as eliminate over-simplified solutions (e.g. three person surgical tubing slingshot) we require that each device be equipped with a trigger mechanism that can be actuated by a faculty member. This rule was designed to minimize any perceived faculty influence over the launch. Our rules states:
The launching device must include a trigger mechanism. When the team in the batters' box pronounces their device to be ready, [the School Director] will load a competition dog and actuate the trigger mechanism.

Many teams did not have an appropriate trigger device. Rather than disqualify teams, the faculty member involved in the launch made a best effort to not influence launches. In future competitions this rule will be elaborated with examples of acceptable and unacceptable triggering mechanisms.

Team Rules

The team rules were established to encourage collaboration and to help with competition management. Team rules covered issues related to team size, eligibility, and registration logistics.

We desire to get freshman students from the School of Engineering to interact with each other in order to encourage peer support networks for our students. This led us to choose small team sizes and to limit team membership to students registered in the School of Engineering. Our rules state:
Each team must consist of 3-4 players, all of whom must be enrolled in the School of Engineering.

In order to get teams to commit to the competition and get started, we employ a registration deadline approximately halfway between the original announcement and the competition itself. For the initial competition, the registration deadline occurred approximately three weeks before the competition. We recognize that in the fall semester some of our students will not realize which other students are also engineering majors. To facilitate teaming among these students we allow students to sign up individually or as a partial team; these smaller groups are then organized into full teams.

Construction Rules

Our approach to teaching construction is to start with the basics. We want our students to experience manual operations such as hand sawing as a means to introduce them to the properties of the materials they are working with. For the competition we require that all work be done using hand operated tools. We further require that all work be completed in the design studio and that the devices be stored in the design studio to discourage use of power tools or expertise available at other locations (e.g. home shop and parents). Our rules state:

All construction must take place in the Engineering Design Studio by team members using the provided hand tools (no power tools).
Devices will be housed in the design studio (devices will be allowed out of the Engineering Design Studio for on-campus testing purposes).

We recognize that students may or may not have experience working with tools. In order to level the playing field somewhat, and to encourage tools usage with inexperienced users, we require a shop orientation session of all participants. The sessions include a discussion of safety, demonstrations of tool usage, and student exercises using tools. Our rules state:
Students must successfully complete "studio boot camp" (a basic orientation to shop safety and hand tool usage) in order to work in the Engineering Design Studio.

In order to put a limit on material usage, and to introduce the idea of an operating budget, allowable material expenses are capped at $75. We also require that all materials be purchased rather than allow the use of "found" materials. Although we appreciate that finding use for waste materials is valuable, we want to avoid having to distinguish between "found" and "donated". We also require receipts for all materials; student teams are reimbursed up to $75 based on receipts. Our rules state:
Each team will be given a budget of $75 for construction materials. Teams will be reimbursed for material expenditures following the competition. Every part of the device must be included in the cost of materials.

Competition scoring and rationale

Our philosophy of sustainable engineering design is that a sustainable design addresses the technical, financial, environmental, and societal aspects of an engineering problem. In order to introduce this philosophy to our students, we overtly include all four aspects in our scoring formula as individual categories. Each scoring category includes an objective and a scoring formula. We intend the scoring formulas to be transparent and to allow students to consider "what-if" scenarios and to make intelligent tradeoffs between categories; for instance "heavy and cheap" versus "light and expensive". Scoring in the Performance and Financial categories is entirely objective, in the Environment category the score contains objective and subjective components, and in the societal category the scoring is entirely subjective. The scoring formulae are intended to weight each of the four categories equally.

Performance Score

When considering performance parameters preference is given to those that can be quickly measured. Although projectile distance initially seemed useful as a performance metric, we ultimately selected accuracy to discourage a "bigger is better" approach to construction. We determined an appropriate distance from the batters' box to the target by measuring the distance that the projectile can be thrown by hand; it is our intent that the relatively short target distance encourages students to focus on repeatability and control. Our rules state:
Objective: Minimize distance between dog and target

Score: **50 – sum of distances** *where* **sum of distances** *is the total distance (in feet) from the target to the final locations of each of the five launched projectiles. Negative scores are possible.*

In general it was clear that students prioritized this aspect of the competition above all others. The vast majority of time was spent designing and building the device with many teams minimizing consideration of the remaining aspects. Scores in this category ranged from -183 points to +30 points with an average of -29 points. Five out of nine teams had negative scores indicating an average error of more than 10 feet per launch.

Financial Score

In this category we want to reward intelligent use of materials and working within a budget, as well as encourage project management skills. Our scoring formula simply rewards minimization of cost although we also value the ability to track costs within a project. We require a table to summarize materials used and their costs. Our rules state:

Objective: Minimize cost

Score: **75 – amount spent** *(in dollars). This score will be based on a one page financial sheet that details the cost of all materials in a table format. Receipts for ALL materials must be attached to the financial sheet (all materials must be purchased new or provided by the School of Engineering at cost). Teams with material expenses in excess of $75 will be disqualified.*

Note that although we are willing to "sell" students hardware from our own limited stocks, our intent is to get them to travel to local hardware stores and lumber yards to browse, select their materials, and manage their receipts. The local Home Depot and Lowes franchises are within walking distance from campus which is fortunate since freshman students are not allowed cars on campus. We assume that teams are able and willing to spend $75 on their projects if they knew they will be reimbursed.

Student response to this category included teams arriving with only a handful of receipts or perhaps a brief summary of their receipts on a sheet of notebook paper prepared while in line although some teams did provide the required financial sheet. Judges for this category requested that future scoring include a way to deduct points for sloppy or nonexistent bookkeeping since the scoring formula was based solely on cost. Team expenses ranged from $34 (41 points) to $64 (11 points) with an average expense of $45 (30 points). This suggests that the $75 limit was appropriate.

Environmental Score

In this category we want to encourage students to consider the life cycle of their chosen construction materials through the introduction of the *Reduce, Reuse, Recycle, Recover, Remove* hierarchy. We initially considered an entirely objective formula that scored each individual component of a device based on component weight and its' place in the above hierarchy. Although this approach may have merit we consider it too arduous for our purposes. We chose instead to score based on total device weight (broad emphasis on Reduce) and a written description of what will happen to the materials after competition. Note that although we

encourage reuse of competition materials we do not allow use of reused materials in the competition. Our rules state:
Objective: Use as little material as possible (by weight). Give preference to reusable or recyclable components. Points will be lost for components that must be discarded. Remember: Reduce, Reuse, Recycle, Recover, Remove (in that order).
Score: score is based on two components: Weight and Written
Weight: **50 – device weight** *(in pounds). Negative scores are possible.*
Written: up to **15 points** *will be awarded for a 1-page written description of the materials used and the planned post-competition disposition of the device.*

Student responses to the written portion of this component fell into three categories: minimal attempt, a generalized discussion of a mode of disposition for materials similar to those used in the project (e.g. "the scrap wood can be used in a wood-fired power plant"), or a specific discussion of the disposition of the actual components in their device (e.g. "I will use the surgical tubing for my rehabilitation exercises"). We were not anticipating the specific discussions and found them interesting. The device weights ranged from 5 pounds to 55 pounds with an average of 35 pounds. The written scores ranged from 6 to 13 points with an average of 9 points. The resulting combined scores ranged from 6 to 51 points with an average of 24 points.

<u>Collaboration Score</u>

We use team collaboration to measure the societal component of our design philosophy. We consider a truly collaborative team effort to be such that each team member is familiar with all phases of the project and makes significant contributions to the project. This approach can be contrasted with an approach in which each team member specializes in one aspect of a project and has minimal knowledge of other aspects. Our intent is to encourage teams to take this approach to working together as practice for what they will encounter in their engineering courses. This component is scored in an interview session where team members are asked about their designs and their team experience. Our rules state:
Objective: Work together to design and construct the device. This means that each team member is intimately familiar with all aspects of the device design and construction.
Score: A maximum of **30 points** *will be awarded based on a team interview with Collaboration judges. Judges will assess the level of teamwork and collaboration in the design and construction of the device.*

Judging in this category consists of a team interview in which team members are asked about their process from conceptualization to construction as well as questions related to their overall experience. Teams that incorporate an inclusive process in which the input from multiple team members is considered during a well defined concept phase should score well in this category. Scores ranged from 15 to 30 points with an average score of 23 points. The lowest scoring team was the only team that indicated they would not participate again if given the opportunity.

Prizes are awarded for top finishers in each category in the form of bookstore vouchers. Overall scores are calculated as the sum of the scores in each of the categories; prizes are awarded for the top three overall scores. Teams may only be awarded one prize, if a team earns multiple prizes the lesser prize is awarded to the next runner up.

The scoring formulae were based on our initial estimates that a typical team will miss the target by five feet each launch, spend 50 dollars, construct a 35 pound device, be awarded 10 points for their description of post-competition disposition, and be awarded 25 points for collaboration. The actual average scores in the first competition corresponded to missing the target by 16 feet per launch, spending $45, constructing a 35 pound device, being awarded 9 points for the description of post-competition disposition, and scoring 23 points for collaboration. Although the initial estimates were proved incorrect they did give us a starting point that intended to balance scores between categories.

In the first competition, the rank of absolute scores was in the order of financial, performance, environmental impact, and collaboration. After the competition a variety of ways to equalize the weights between the individual categories were discussed. Three of the approaches are summarized here:

- Normalize each score to the maximum possible score in the category
- Normalize each score to the maximum score achieved in the category
- Use results of the initial event to modify existing formulae

None of these are perfect; the first two reduce the transparency of tradeoffs between categories, the last option assumes that the next event will score similar to the initial event. Other scoring changes for consideration include assessing penalties for non-compliance. For instance adding costs in the financial judging station for items missing from financial sheet ($2 per missing item, plus 2 times the approximate value of the item), or lack of appropriate financial sheet ($10). Another example would be to assess a weight penalty of 10 pounds if the post-competition material disposition plan is not typewritten, and a 2 pound penalty for any items not accounted for, plus 2 times the approximate weight of the missing item.

Construction Facility

We require that all construction activities occur in the Engineering Design Studio in order to discourage outside construction help and to control the use of tools. The Engineering Design Studio is a purpose-built facility that includes 1200 ft^2 of instructional space and 600 ft^2 of construction space. The instructional space includes 15 large laboratory benches and can be used for assembly tasks. The construction space contains workbenches, tools, and materials for construction.

Boot Camp

Although our program includes a significant hands-on construction component, we do not assume that our students arrive with the required skills. In order to prepare students for the competition we offer sessions of shop orientation and introduction to the construction space. These sessions, or “studio boot camps,” have three components; safety and procedural rules, tool usage instruction, and tool usage exercises. Our shop safety rules are typical of laboratory safety rules. Tool usage instruction is presented as a series of demonstrations which are followed by exercises in which each student must copy the demonstrated operation. Figure 2 shows a group of students performing hacksaw cuts through steel bar stock.

Figure 2: Students in the Engineering Design Studio learning hands-on skills

In preparation for the first competition, all of the faculty and one staff member participated in boot camp instruction. The number of students and instructors in a given boot camp session varied from four students with one instructor to nine students with one instructor. Some of the sessions included eight students and two instructors. Feedback from instructors suggests that four to six students per instructor is appropriate. In the case of two instructors, the number of students was limited to eight due to tool and workspace availability. 46 students participated in the sessions.

Feedback from Stakeholders

Because this was our first attempt at a student competition within our program, there were many unknowns and many decisions that were based on estimates. We surveyed three groups of stakeholders immediately after the competition to inform changes for subsequent events. The groups surveyed were: student competitors, external judges, and School of Engineering faculty/staff. In addition, student feedback on the experience was gathered during the collaboration interviews at the societal judging station. Student surveys were conducted by a third party and were blinded.

Students

The 25 students at the competition were surveyed in order to learn their perceptions of the event. The survey included Likert scale questions, and open ended questions.

The students were asked to respond to statements related to the competition based on a Likert scale. The statements broadly addressed competition access, the competition experience, and their own perceptions of their design abilities and understanding of sustainable design. Table 1 shows the questions, and the percentage of students responding at each level.

Table 1: Student responses (in percent of students) to competition questions

In this section, indicate your level of agreement with the statements below	**Strongly Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Strongly Agree**
	1	**2**	**3**	**4**	**5**
I was able to understand the device requirements by reading the Pamphlet	0	0	17	29	54
I was able to understand the scoring system by reading the Pamphlet	0	4	0	52	44
Finding a team to join was easy	0	8	13	21	58
Scheduling a “boot camp” session (hand tool training) was easy	4	12	8	20	56
“Boot camp” increased my confidence in the use of hand tools	11	4	30	19	37
"Boot camp" helped bring my team together	9	9	57	17	9
I felt more connected to the Engineering program after boot camp	6	3	18	32	41
The hours that the studio was available for construction activities were convenient	4	16	8	16	56
We had enough time to complete our build the way we wanted to	0	4	8	36	52
Because I needed to build a device that I had designed, my ability to design has improved	0	0	4	68	28
On the day of competition it was clear what station I needed to be at and what to do	0	4	16	48	32
By participating in this competition, I gained a better understanding of what JMU Engineering means by “Sustainable Design”	0	0	24	48	28

The above results suggest that to a large degree, students found the competition and surrounding activities to be accessible. Furthermore, most students felt more connected to the program, felt that they had become better designers, and felt they had a better understanding of our programs definition of “sustainable design” after participating in the competition. In general, questions related to the “boot camp” experience received lower responses than the rest of the competition. We were uncertain what the benefit of boot camp would be since we teach tool use at a basic level. It is interesting to observe that nearly 40% of students indicated strong agreement that boot camp increased their confidence in hand tool usage.

Students were asked to rate four segments of their experience as well as their overall experience on a ten level Likert scale (1-10). Table 2 shows the questions, and the percentage of students responding at each level.

Table 2: Student responses (in percent of students) to competition experience questions

On a scale of 1-10, rate the following experiences:											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	Avg
Boot camp	0	9	0	0	4	9	13	35	17	13	**7.5**
Design Process	0	0	0	0	0	4	16	16	40	24	**8.6**
Build Process	0	0	0	0	0	4	4	28	36	28	**8.8**
Competition Day	0	0	0	4	0	4	4	20	24	44	**8.8**
Overall Experience	0	0	0	0	0	0	8	24	24	44	**9**

The results in table 2 indicate that for the most part students rated their experiences highly; only boot camp was rated below an 8.5.

Students were asked three questions to help us quantify social networking and effort levels. Table 3 shows the questions and the ranges of the responses.

Table 3: Student responses to competition questions related to social networking and effort

Provide Your Best Estimate of the Following				
Number of Members of my team I knew before the day we signed up **(0,1,2,3)**	**0**	**1**	**2**	**3**
	7	7	8	3
Approximate number of hours spent with team (for any reason) BEFORE boot camp? ___**hours**	**0**	**0.5-3**	**more than 3**	
	9	10	6	
Approximate number of hours spent designing and building device ___**hours**	**0-9**	**10-19**	**20 or more**	
	8	9	8	

The results in table 3 suggest that the competition did facilitate social networking, and that boot camp served as a "project kickoff" point for team members. The number of hours spent indicates that a majority of students took the event seriously.

Additional student feedback was solicited in the interviews that took place during the judging of the societal component of the competition. Students were asked about their design process; responses were widely varied. Three of the teams did not have a well-defined design conceptualization phase but moved directly to the construction phase. Of the six of the teams that did have a well-defined design conceptualization phase, at least three developed multiple concepts and one team reported performing calculations. Two of the teams also identified specific elements of their design that they would change, two other teams indicated that they would spend more time in research. Of the nine teams that participated in the competition, eight indicated that they would do it again. Figure 3 shows the student participants and several of the devices. Survey results and anecdotal evidence supports that nearly all participants had a positive experience

Figure 3: Student participants at the conclusion of the competition

External Judges

Each of the four external judges responded to a survey immediately after the event. Each judge was associated with a different scoring category so that their experiences did vary. The judge survey consisted of Likert scale responses and open-ended responses.

We asked questions related to the judges' comfort with procedure, their opinion of the value of the event, and we asked them to rate their experience. Their responses are shown in Tables 4 and 5.

Table 4: External judge responses (in percent) to competition questions regarding procedure and value

In this section, indicate your level of agreement with the statements below	**Strongly Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Strongly Agree**
	1	**2**	**3**	**4**	**5**
Once I got to the competition it was clear what station I needed to be at and what to do				25	75
I had a clear understanding of the judging criteria for my station				50	50
I had a clear understanding of how to assign scores to entries at my station			75		25

Students at the competition appeared engaged in the event				100	
The criteria used to judge competition entries emphasize qualities that are relevant to industry					100
I consider contact with JMU engineering students and faculty to be worth the time required to judge the competition					100

Table 5: External judge responses (in percent) to competition questions

On a scale of 1-10, rate the following experiences:											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Avg**
Competition							25	25	25	25	**8.5**
Overall Experience								25	50	25	**9**

Tables 4 and 5 suggest that the judges' experiences were largely positive, although there was a learning curve related to scoring the competition. Open ended responses indicated that student contact was the primary draw for the judges.

SOE Faculty and Staff

Faculty and staff from the School of Engineering were involved in the event in a variety of ways including competition planning, event planning and promotion, management of registration and boot camp sign up, boot camp instruction, and judging. The faculty/staff survey consisted of Likert scale responses and open-ended responses.

We asked the faculty and staff questions related to the event procedure, and the perceived value of the entire event process. We also asked faculty and staff to rate their experience. Their responses are shown in Tables 6 and 7.

Table 6: SOE faculty and staff responses (in percent) to competition questions

In this section, indicate your level of agreement with the statements below	**Strongly Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Strongly Agree**
	1	**2**	**3**	**4**	**5**
I was aware of what information needed to be conveyed during bootcamp			20		80
Being a bootcamp instructor provided me with quality "facetime" with students			40	40	20
bootcamp increased my students confidence in the use of hand tools				100	
At the competition it was clear what station I needed to be at and what to do					100

Students at the competition appeared engaged in the event				20	80
The total design competition experience (preparation, bootcamp, competition) was a worthwhile effort					100
The judging criteria are well matched to the SOE vision of sustainability				33	67
The competition provided the students with a good introduction to the JMU Engineering vision of "Sustainable Design"			17	33	50

Table 7: SOE faculty and staff responses (in percent) to competition questions

On a scale of 1-10, rate the following experiences:											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Avg**
Competition							20	80			**7.8**
Overall Experience								33	33	33	**9**

The overall value of the event received high ratings from the SOE faculty and staff. Areas that show room for improvement for next year include reinforcing our vision of sustainability through the rules or through discussion of the rules.

Faculty and staff responses to open ended questions strongly indicated that community building was considered to be the most valuable part of the experience. Most did not indicate a "least valuable" part of the experience although boot camp tardiness was cited once. Ideas for improvement included the rules and scoring changes discussed previously, as well as event scheduling changes, and ways to increase event visibility.

We are considering extending the event into two days; the first day would include judging of the financial, environmental, and collaborative elements in the evening, followed by a dinner that would allow increased interaction between industry volunteers, faculty, and students. The following morning would be dedicated to the performance element. This approach would also allow us to accommodate more student teams.

Since we are a new program, visibility is important to us; to increase visibility for the event and for our program we intend to solicit greater media coverage. This can also be considered to reflect our confidence that our students can put on a good "show".

Conclusions

We have established an annual freshman design competition within our engineering program. The competition rules and scoring reflect our philosophy that a sustainable design incorporates technical, financial, environmental, and societal criteria. A benefit to students who participate is that they are introduced to construction tools and the work area that they will use in courses throughout our program. The competition also allows first semester freshmen to identify others in their major thus facilitating the formation of social networks. Our program as a whole benefits from the opportunity to demonstrate the value we place on collaborative work and extra-curricular learning.

We consider our first design competition to be a success based on the number of student participants and their demeanor during the competition. The competition also proved to be a venue to foster relationships with industrial partners and has the potential to raise our profile both on campus and in the regional media.

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