The Regional Moonbuggy Competition: A Unique, Large-Scale Outreach Program to High Schools

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Introduction

The need for engineering outreach into the K-12 curricula has been well-documented in publications such as the Journal of Engineering Education and the ASEE Prism for several years. Engineering outreach into high schools is an important part of K-12 outreach as high school is a time when students make important curricular decisions in order to prepare themselves for post-secondary education. Consequently, engineering outreach activities that motivate students to choose college-preparatory courses appropriate for engineering such as physics and calculus while also developing decision making and teamwork skills are vital.

Multitudes of science and engineering outreach activities to K-12 are ongoing at universities throughout the US and abroad. The variety in these programs is astonishing and one could easily get lost in all of the literature on this topic when considering the implementation of a particular outreach activity. This paper accomplishes little in easing the confusion that the menagerie of outreach activities may create, but it does present a unique approach to K-12 outreach as the program is based on an existing national design competition which was adapted in order to meet the needs of the high school teachers and students in the authors' region of the country.

The West Kentucky Regional Moonbuggy Competition and Workshops, held throughout the 2004-2005 academic year, is the first-ever regional moonbuggy competition based on NASA Marshall Space Flight Center's Great Moonbuggy Race. In this unique program, high school students and faculty in math, science, engineering and engineering technology classes were challenged to design and build a human-powered vehicle that addressed a series of engineering problems similar to problems faced by the original designers of the rovers used on the Apollo missions. As a large-scale, year-long outreach activity, the moonbuggy competition is an effective approach that not only encourages students to consider engineering as a career but also enables students to work within an interdisciplinary and gender-inclusive team to solve an extremely challenging and realistic engineering design problem.

This paper describes the specifics of the event including publicity, fund-raising, and execution of the competition. The efficiency and effectiveness of this program is also discussed including assessment of specific learning outcomes through attitudinal surveys of the participating teachers.

Motivation and Learning Outcomes

As mentioned previously, a variety of outreach activities currently exist. The scope of each activity depends on the specific need that it is designed to meet. In some cases, the desire is to increase enrollments in engineering locally or nationally or to recruit underrepresented minorities into the engineering discipline. In other cases, the goal is to educate K-12 faculty and/or guidance counselors so that they are better equipped in preparing students for a post-secondary education in engineering. Still others attempt to change the culture of their community towards one that embraces technology and the need for higher education. The moonbuggy competition outreach program seeks to meet several of these goals including the last.

The authors' home institution, Murray State University, is a comprehensive, 4-year, regional university located in rural western Kentucky. Due to the general lack of technology in this area of the country, the high school students, and to some extent their parents and teachers, do not have a suitable grasp of what it means to be an engineer. Many feel that engineers only work on complex, large-scale projects that seem much too complicated for them to handle. Others fail to recognize the mathematical and analytical basis for engineering practice. Consequently, the motivation for this outreach program is to immerse these students in a realistic engineering design project in order to change their perspective towards engineering. Specifically, this project was designed to meet the following learning outcomes:

- Increase interest in engineering, engineering technology, mathematics, and science
- Encourage female students to consider engineering
- Interdisciplinary teamwork including students from physics, calculus and technology classes
- Increase awareness for space flight and exploration
- Introduce students and teachers to the engineering design process
- Build confidence through overcoming challenges during design and construction
- Outreach and support to high schools teachers in region

Since a goal of this project is a cultural shift in perspective and understanding, a simple, short-term activity is not suitable. Instead, the moonbuggy project is an in-depth, large-scale project that generally requires students and teachers to work throughout the academic year. During the year, they face many design choices each with pros and cons, and they also face and must overcome multiple difficulties throughout the design and construction phase. Advantages of a large-scale project like this one include an increased effectiveness in impacting the students and teachers in order to meet the learning outcomes. The project length also allows for a more realistic design problem with true engineering constraints and an open-ended solution space. Disadvantages of this program include higher costs and increased faculty time for both the high school and collegiate faculty. The ability to reach large numbers of students may be limited as well depending on how each high school manages their team; however, the depth of the impact made on each individual student makes up for the lack of breadth in the number of students involved.

Figure 1: A Moonbuggy (left) is a human-powered vehicle that must fit or be collapsible to fit into a 4 foot cubic volume (right) and be carried 20 feet by its two drivers (1 male and 1 female).

What is a Moonbuggy?

As mentioned previously, this outreach activity is based on NASA Marshall Space Flight Center's (MSFC) Great Moonbuggy Race. The Great Moonbuggy Race, which is in its 12th year, challenges both high school and college teams to design, build, and test a human-powered vehicle like the one shown in Fig. 1. The 2005 Great Moonbuggy Race saw 44 high school and 28 college teams, including a team from Murray State University, compete at the US Space & Rocket Center in Huntsville, Alabama. The rules for the regional competition, which are consistent with those of NASA-MSFC so that participating teams can also travel to the national event with only minor adjustments, are detailed in the appendix. A key rule, which produces gender-inclusive teams, is the need for two drivers: one male and one female. The most challenging constraint is on the size of the moonbuggy as it must fit (or be collapsible to fit) within a 4-foot cubic volume. The moonbuggy must also be lightweight as the two drivers must be able to carry the vehicle a distance of 20 feet unassisted. Finally, the moonbuggy must be designed to be robust as it will need to traverse a hazardous course. Costs to build a moonbuggy vary significantly depending on funding for each team, but a realistic cost for building a competitive vehicle is between $1,000 and $1,500 US.

Due to the extensive welding required in constructing a moonbuggy, many high school teams are made up of mostly technical education students. In order to encourage interdisciplinary teams with students of different backgrounds and career aspirations, requirements that are not included in the rules for the national competition were added. These include the need to measure the average speed of the moonbuggy as it traverses the course and the measurement of the height of a building on campus. The main purpose of these additional tasks is to necessitate including students from physics and calculus or trigonometry courses. In many high schools across the nation, students in technical education almost never interact with students in college preparatory classes so by adding challenges that require principles from physics and trigonometry, these students must at least communicate and hopefully join forces on an interdisciplinary team.

The course for the regional moonbuggy competition was 0.6 miles long and twisted through the center of the Murray State University campus. The length and difficulty of the course is consistent with the national competition. Obstacles, like those shown in Fig. 2, simulating lunar

Figure 2: The course was 0.6 miles long and included obstacles made out of wood (left) and gravel (right) that simulated lunar terrain. The wooden obstacles were designed and constructed by freshman engineering physics students.

terrain including craters, rocks, inclines and loose soil were spaced throughout the course in order to test the robustness and reliability of the moonbuggy designs. In order to involve undergraduate engineering students in the activity, six of the obstacles, made of wood, tires, sand and other materials, were designed and constructed by freshmen. The remaining obstacles, which were most similar to those at the national event, consisted of gravel ridges and craters.

Publicity and Fundraising

Obviously for an outreach program to be successful, it must have participants. A primary concern with this large-scale, long-term project was the ability to recruit teachers interested in taking on such a time-consuming venture. However, interactions with local technical education teachers suggested a need for realistic design projects. In order to make these teachers aware of the program, a two-page letter detailing the event was mailed to approximately eighty schools in western Kentucky, western Tennessee and southern Illinois. For each school, a letter was sent to the superintendent, principal, and "science coordinator". Student recruitment programs of the university were also used to assist with recruiting as well as science and technology organizations and clubs.

Publicity for a first-time event can be difficult since many teachers may be skeptical of whether the event will truly come off as planned. However, now that a successful event has been held, word-of-mouth between teachers alone will grow the program for next year. Coupled with better promotional materials and new collaborations with some of this year's participating teachers, the number of participating schools is expected to grow substantially.

Another major need in putting on a large-scale event is funding. In this case, a natural funding source existed in the state. The Kentucky Space Grant Consortium (KSGC) is a NASA-based program whose mission includes increasing the number of people trained for the workforce in space-related fields and increasing public awareness of NASA and space-related research. The moonbuggy competition is a wonderful fit for this mission and was funded through a workshop grant providing $8,000 for the event. More than half of these funds were given directly to the participating schools in order to defray the costs of building their moonbuggy, and therefore,

Figure 3: Six high schools competed in the inaugural West Kentucky Regional Moonbuggy Competition

encouraging their participation. The remaining capital was spent on course construction including obstacles, t-shirts for participants and volunteers, and refreshments including lunch for all involved. These costs totaled around $3,000.

Workshops

In order to facilitate a meaningful learning experience for both the teachers and students, two workshops were held. The first, which was held in September, 2004, was attended by teachers from nine high schools. It introduced the teachers to the project through a seminar including pictures and video of past moonbuggies and a live demonstration of the MSU moonbuggy. The competition rules including necessary design constraints were covered in detail along with reasonable budget estimates. A discussion on vehicle design and analysis was also included. Following the workshop, each school was given the opportunity to write a short proposal to receive up to $500 to defray the costs of constructing the buggy. Seven of the nine schools who attended the first workshop submitted funding proposals and all of these were funded.

In January, 2004, the second workshop was held for the seven participating schools. Both teachers and students were invited to this workshop which concentrated on assisting the teams with any final design issues and on the fabrication, assembly and testing of their vehicles. Several questions concerning rules were discussed and clarified as well. While the context of this program is a competition, the teams were encouraged to share challenges and ideas throughout the workshops and competition in order to provide a deeper learning experience.

Results

On March 12, 2005, the inaugural West Kentucky Regional Moonbuggy Competition was held. As shown in Fig. 3, six high schools, including over 80 students, completed the task of constructing a moonbuggy and competed against each other. Each team was given two attempts to complete the course with a break in between to make repairs and improvements to their

Figure 4: Clockwise from Top-Left: Carlisle County pedals along the course; Obion County Central wins the inaugural race; Dyer County tackles an obstacle; Calloway County's design includes a unique sling seat design; the Pits were a busy place throughout the day; Graves County struggles over an obstacle.

vehicles. In a wonderful surprise, all teams improved on their first run performance in run two. From anecdotal comments from several teachers, these improvements had a significant impact on building the students' confidence and efficacy.

The inaugural event was an enormous success with no major issues. The course proved challenging, but as one can see in Fig. 4, the students rose to the occasion and inspired all those who attended the event. At the conclusion of the event, trophies were given to the top two teams, which from Fig. 5, were Obion County Central High School and Murray High School. Carlisle County High School was awarded the Spirit Award for the team that consistently displayed sportsmanship and team spirit.

2005 West Kentucky Regional Moonbuggy Competition

	Pre-Race Penalties						Run 1 Data					Run 2 Data						
	Assembly Time	Volume	Clearance	Width	20' Carry	Pre-Race Total	Run Time	Obstacle Penalties	Speed Meas. Penalty	Height Meas. Penalty	Run 1 Total	Run Time	Ht. Meas. Time/Penalty	Obstacle Penalties	Speed Meas. Penalty	Run 2 Total	Best Run	Standing
Calloway County	05:12	00:00	00:00	00:00	00:00	0:05:12	50:50	00:00	00:00	00:00	0:56:02	50:50	00:00	00:00	00:00	0:56:02	0:56:02	6
Carlisle County	01:28	00:00	00:00	00:00	00:00	0:01:28	08:55	08:00	00:44	00:04	0:19:11	07:45	00:53	05:00	00:24	0:15:30	0:15:30	3
Dyer County	00:12	00:00	00:00	00:00	00:00	0:00:12	23:23	13:00	00:59	00:12	0:37:46	14:15	00:34	12:00	00:20	0:27:21	0:27:21	5
Graves County	01:02	02:00	00:00	00:00	00:00	0:03:02	50:50	00:00	00:00	00:17	0:54:09	11:52	00:17	10:00	00:59	0:26:10	0:26:10	4
Marshall County	00:00	00:00	00:00	00:00	00:00	0:00:00	59:59	00:00	00:00	00:00	0:59:59	59:59	00:00	00:00	00:00	0:59:59	0:59:59	7
Murray High	00:51	00:00	00:00	00:00	00:00	0:00:51	13:03	06:00	00:36	00:09	0:20:39	06:57	00:34	06:00	00:11	0:14:33	0:14:33	2
Obion County Central	00:20	00:00	00:00	00:00	00:00	0:00:20	09:02	03:00	01:00	00:57	0:14:19	06:07	02:38	02:00	00:03	0:11:08	0:11:08	1

Official Scoring

Figure 5: Obion County Central High School won the inaugural competition while Murray High School placed 2nd. Carlisle County High School was awarded the Spirit Award.

Table 1: Faculty Survey Results

Question	Response
Which of the following topic areas were addressed in your program?	
Physics	67%
Calculus and/or Trigonometry	50%
Engineering	50%
Technology	67%
This competition was effective in increasing interest in engineering, engineering technology, mathematics and science.	4.33
This competition was effective in encouraging female students to consider engineering as a career.	3.50
This competition was effective in creating interdisciplinary teamwork including students from physics, calculus and technology classes.	4.83
This competition was effective in increasing student awareness and interest in space flight and exploration.	3.67
This competition was effective in introducing faculty and students to the engineering design process.	4.50
This competition was effective in building students' confidence through overcoming challenges during design and construction.	5.00
This competition was effective in supporting you as a high school teacher.	4.83

*** 5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly Disagree ***

Assessment

While anecdotal evidence including conversations with teachers and spectators suggested the moonbuggy event was successful, quantitative data was taken through attitudinal surveys in order to assess how the program met the learning outcomes described previously. Surveys were given to all participating teachers and asked them to rate how the program met each of the learning outcomes by rating each from Strongly Agree (5) to Strongly Disagree (1). The results of the survey are given in Table 1.

Most of the survey results are positive as the program is sufficiently meeting most of the learning outcomes. However, a major concern is that the teachers in general do not agree that the program is effective in encouraging female students to consider engineering as a career. While the need for a female driver in the rules necessitates female team members, several of the teams were still male-dominated as many of the technical education programs have larger male populations. However, by injecting more science and mathematics into the program through further experiments similar to the average speed and height measurement, teams will be forced to involve physics, calculus and trigonometry classes which generally include a better population of female students. This change should also increase the percentages of physics and mathematics in the program content.

Conclusions

The inaugural West Kentucky Regional Moonbuggy Competition was an incredible success that involved a total of 6 high schools and over 80 students. As a large-scale, year-long outreach activity, this program is an effective approach to not only encourage students to consider engineering as a career but also enables the students to work within an interdisciplinary and gender-inclusive team to solve a challenging and realistic, yet fun, engineering design problem. By involving the teachers and students for the entire academic year, underlying misconceptions about science and engineering prevalent in this region of the country were deeply challenged and for some transformed.

Four of the participating schools took their experiences from the regional event and improved their vehicles in order to race in the national event, at the U.S. Space & Rocket Center, in Huntsville, Alabama where they gained further insight and motivation. Murray High School placed in the top ten at the national event.

Given the details of this K-12 outreach program, it is the authors' hope that the readers will be motivated to develop similar, large-scale outreach activities on their campuses. Whether you choose to organize a moonbuggy competition, collaborate with other national design challenges, or design their own activity, we hope that you are better equipped to fund, organize, and assess a large-scale outreach activity for K-12 students and faculty.

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Biographical Information

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APPENDIX

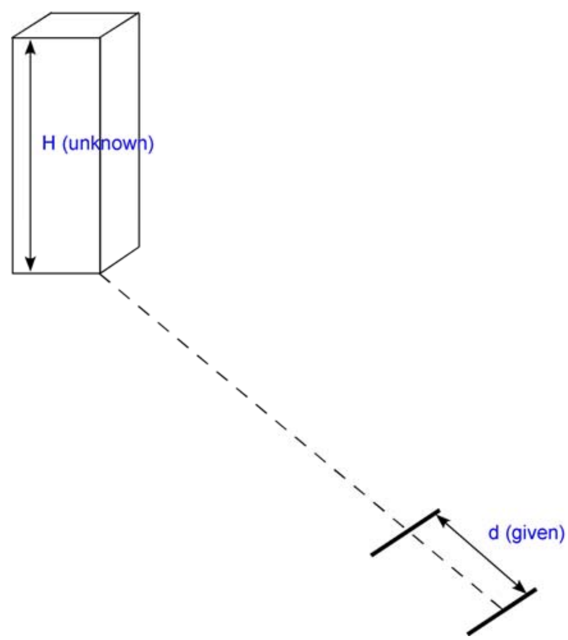
The following are the primary constraints for the Moonbuggy competition.

1. *Moonbuggy Teams*: Each moonbuggy must be the work of a team comprised of students from a high school or group of high schools in collaboration.
2. *Propulsion:* Human powered (one or both passengers); energy storage devices, such as springs, flywheels or others, are not allowed.
3. *Unassembled Dimensions*: The unassembled vehicle must fit (or be collapsible to fit) in a volume of maximum dimension 4' x 4' x 4'.
4. *Weight*: The vehicle must be lifted and carried 20 feet by the two passengers, without aid of any sort (e.g., no wheels) in the unassembled 4'x 4'x 4' volume.
5. *Assembled Dimensions*: The maximum width of the assembled vehicle is four (4) feet, including wheels. No body part of either passenger may be closer than 15" to the flat surface on which the vehicle is supported.
6. *Construction:* Vehicles, or parts of vehicles not constructed by the entering team are not acceptable. **Students are expected to build their own buggies, and the course drivers, chosen from each team, must also be builders of the vehicle**.
7. *Wheels/Tracks:* No constraints are imposed in the means of contact between the buggy and the simulated lunar surface. We encourage creativity and participants are open to using wheels, belts, treads, etc.
8. *Turning Radius:* The vehicle must have a turning radius of 20 feet or less.
9. *Safety:* Each Moonbuggy must include a braking system capable of holding the vehicle still on a 30º slope. The center of gravity of the Moonbuggy should be low enough for the vehicle to climb a 30º slope. The Moonbuggy should also be free of any sharp edges.
10. *Spirit of the Rules*: Vehicles that do not satisfy the **intent** of the moonbuggy competition can be disqualified.
11. *Moonbuggy Passengers*: Two (2) student team members (one female and one male). The passengers must wear protective clothing including helmets, long pants, and gloves. Further, the passengers should avoid wearing baggy clothing that could get caught in rotating parts (Note: shoelaces must be covered with tape). No appendages such as stilts may be used on the feet of the moonbuggy passengers. Pushing the moonbuggy with a pole or other implement is not allowed. **Passengers must be belted into their seats at all times using an appropriate seat belt.**
12. *Roving Measurements*: On the first run, each team will be required to take two measurements that a lunar rover might be required to take. The first is the **average speed** of the Moonbuggy through the course. The second is the **height of a building** on campus to be specified the morning of the competition. See the diagram on the next page for the details for making this measurement.
13. *Winning Team*: The winning team will be the one having the shortest total time in assembling their moonbuggies, taking the required measurements and traversing the terrain course including all penalties. Each team is permitted two runs of the terrain course, and the shortest course time will be added to the assembly time and time to perform the height measurement for the final total event time.
14. *Alcohol*: The consumption of alcoholic beverages or controlled substances by any team member at any time during the event is strictly prohibited and is grounds for disqualification of the team.
15. *Budget:* Teams are *encouraged* not to spend more than $1500 on their vehicle.
16. *Penalties:* See the following table for the list of time penalties.

Infraction	Time Penalty (min:sec)
Carry requirement	2:00
4’ X 4’ X 4’ volume requirement	2:00
15” clearance requirement (measured before and after run)	2:00
Assembled width of 4’ requirement	2:00
Contacting edge (ropes) of obstacle (1 penalty per obstacle)	1:00
Ground contact by driver on obstacle (1 penalty per obstacle)	1:00
Error in height measurement	Up to 1:00 (see formula)
Error in average speed measurement	Up to 1:00 (see formula)
Passenger requirement (1 male, 1 female)	Disqualification
Missing or not attempting an obstacle	Disqualification
Unsafe vehicle (judges discretion)	Disqualification
Late start (10 minutes after being called to the start)	Disqualification

Formula for time penalties for measurement errors

$$\text{Penalty} = \frac{|\text{Measured Value} - \text{Actual Value}|}{\text{Actual Value}} \times 60 \text{ sec}.$$



Schematic of Height Measurement: Two points on the course will be clearly marked. These points will be co-linear with the object whose height is to be measured. The distance between the points will be given. This measurement will only be taken on the first run. Therefore, each team will be timed as they take this measurement and this time will be included in the time of the second run.