Using Mass Media to Bring Engineering Principles to Young Audiences to Inspire Interest and Pursuit of Future Engineering or Technologically Based Careers

by
Kimberly M. Straub
and
Deanna M. Lentz

Submitted to the Department of Mechanical Engineering in Partial Fulfillment of the Requirements for the Degree of

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Signatures of Authors: ____________________
Department of Mechanical Engineering
May 12th, 2006.

____
Department of Mechanical Engineering
May 12th, 2006.

Certified By: ____________________
Daniel Frey
Professor of Mechanical Engineering
Thesis Advisor

Accepted By: ____________________
John H. Lienhard V
Professor of Mechanical Engineering
Chairman, Undergraduate Thesis Committee

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ABSTRACT

In the progression of this thesis document, an idea for an episode of an educational and interactive television show has been explored and developed. The direction of this episode will fit into the aforementioned educational television show format (which will be further described and discussed in subsequent sections of this document). For our particular episode, the focus audience and main target demographic of the theme are young, middle-school aged girls. The theme of the show, which has to do with cooking a familiar and typically well-liked (by children) food by using an alternative energy source and engineering design principles. In this show, it is our goal that both the players and the viewing audience learn about the engineering concepts involved with basic optics and solar energy. In our investigation, a theme for the episode has been developed, and a sample solution has been worked out and tested. Based on the results of this trial run, suggestions and conclusions have been made regarding the future directions for this project.

Thesis Supervisor: Daniel Frey
Title: Professor of Mechanical Engineering

1. Background and Motivation

It is no secret that engineering and science professions have long been considered stereotypically dominated by men. While much has changed and numbers of women in engineering and technology professions are certainly on the rise, the inequalities are still present and very real. An unfortunate consequence of this inequality in the engineering profession is a general lack of awareness on the behalf of the general American public about the role and importance of engineers in society. While advancements in technology progress, an unfortunate result has been a general lack of need and motivation for society to understand how things work. In fact, as technology continues to make everyday tasks easier to complete, the general public is increasingly oblivious to the concepts behind these advances. Indeed, studies suggest that as technology advances, technological literacy will continue to drop. An unfortunate side effect of this drop is a decreasing inclination of qualified and intelligent members of society towards engineering professions.

In the fall of 1998, the National Academy of Engineering published the results of their survey of "American Perspectives on Engineers and Engineering" in response to these growing concerns. Among many findings, this survey revealed that the vast majority of Americans feel that engineers make positive contributions to society, but feel uninformed about engineers and engineering. The survey found that 45% of Americans feel that they are "not very well informed about engineers and engineering," while an additional 16% reported that they are "not at all well informed." Pointing out the further inequalities that exist in gender, women reported with 55% and 23% respectively on these questions. In addition, a shocking 53% of college graduates reported that they are "not very well informed about engineers and engineering."

In light of these disparities between technological use and technological understanding, coupled with the fact that the majority of information about technology reaches the general public via television and the internet, the academy advised working with the media to better portray and explain engineers and engineering. Results from the same survey showed that 69% of the general public gave ratings of "poor" or "fair" to the media coverage of science, technology, engineering, and medical discoveries. Even more shocking is the fact that 85% of college graduates and 80% of those with annual incomes over $75,000 gave the same "fair" and "poor" ratings. It is based on this advice and these statistics that the idea of an educational and interactive television show for middle school aged students was developed and created to better and more effectively bring engineering concepts to the general public.

Formation of a show such as this is further motivated by the decreasing numbers of engineering bachelor's degrees since 1987, which are down by 14%. Additionally, the need to increase the diversity in race and gender in the engineering profession is emphasized by the fact that although 53% of undergraduate students are female, only 19.4% of undergraduate engineering students are female. It is with the knowledge of these numbers that the episode developed by the authors of this thesis document was formulated.

2. Show Progress and Direction to Date

As was already mentioned in the previous section, the authors of this thesis are working in collaboration with a group of researchers already working toward the formation of a television series geared toward getting young people interested and excited about engineering and engineering careers. These researchers include Dr. Daniel D. Frey, a Professor of Mechanical Engineering at the Massachusetts Institute of Technology, in conjunction with Marisa Wolsky of the WGBH Educational Foundation, a television producing company in Boston, Massachusetts. Previous studies had determined that the interest in engineering must be established before misconceptions about the profession are established in the minds of these impressionable young adults. In fact, the researchers cited that even by 8^{th} grade, less than 10% of students are aspiring to math and science careers, with considerably less interest on behalf of girls (less than one female for every two males). The show creators have also cited the following aims and goals for the television series:

- To foster a positive public image of engineering, especially among girls and minorities
- To emphasize the inherent rewards and enjoyment of creative, technical work
- To illustrate physical principles behind the engineering solutions
- To present role models exhibiting intelligence, persistence, teamwork, and gracious competition
- To illustrate effective skills for design, such as convergent and divergent questioning, estimation, planning and analysis of experiments

- To accommodate the variety of learning styles that are likely to be reflected in the viewing audience

Based on this knowledge and these goals, the series is being designed for a 9-12 year old audience, with "players" aged 14-17 years. Additionally, the episodes will feature players of a variety of ethnicities and both boys and girls to present role models in engineering roles for the audience to take example from.

So far, the formation and development of the series has taken several iterative steps. Prototype episodes have been created and critiqued by potential viewers and expert advisors to format the show accordingly. After three cycles of prototyping and critiquing, the first thirteen installments in the series are set to be filmed in the summer of 2006. Research into the potential popularity of the series has been conducted over 100 viewers, and has revealed popularity across ages *and* genders. Of particular note by those polled was the admirable skill and teamwork of the contestants involved (the players). Focus groups also revealed that those polled were adequately able to grasp the concepts and the scientific and technical ideas presented in the sample shows. However, these polls also revealed that some additional detail was desirable in some of the technical areas of the show. Based on these conclusions, the show creators have adapted and edited the show format accordingly. It is the goal of the authors of this document that the proposed episode idea fit into the schematic outlined by the researchers. The scientific concept on which we have chosen to focus the sample episode involves optics and alternative energy sources. These concepts will be presented in the form of a problem involving cooking, an idea which will hopefully appeal to both boys and girls equally.

3. Television Formatting Development

The projects that have already been filmed and edited for the proposed television show all have a competition based format, allowing two separate teams to attack an engineering design problem in order to come up with varying solutions. The hot dog cooker episode will follow this same basic format with a few variations. The beginning of the show will introduce the two host engineers and the two engineering teams made up of young high-school aged students. The two hosts will introduce the design challenge – to design an apparatus able to cook a hotdog and/or marshmallows without the aid of any outside man-produced power source. The two teams will then be allowed to separate and discuss the problem. The point of this discussion and deliberation period is to demonstrate how engineers deal with extremely vague and very open-ended problems with little instruction as to the "correct" way to solve the problem. This period will last for approximately thirty minutes real time, cut shorter when included in the final segment.

After the teams have put together a few ideas of how they would personally attack the problem, both teams will be brought together again. At this point of the show, the hosts will provide a little more guidance and instruction for the teams to work with in constructing their final projects. The hosts will describe the theory behind solar energy and efficient ways to harness and use it; they will in essence be giving a very basic and abridged lesson on optics and heat transfer to the two teams.

Following the mini-lecture on optics and energy, the hosts will then present the two teams with identical engineering kits with an assortment of materials and tools in order to be able to construct a hotdog cooking apparatus. The teams will then be instructed to have another thirty minute deliberation session, while the extreme importance of brainstorming, pre-planning, and analysis before any physical construction takes placed is stressed by the hosts.

After the second brainstorming session ends, the teams will then be allowed to start putting together their apparatuses based on the plans they have come up with. The show will focus on the fact that although coming up with a good plan prior to actual construction is the best way to achieve a successful final product; small adjustments usually have to be made in the process to account for unforeseen problems and obstacles.

The two teams will have three hours to complete the final cooking apparatus. After the three hour time segment, both teams' completed projects will be judged on the success of cooking a hotdog, the elegance of their design, and the efficiency of the cooker in cooking the hotdog and/or marshmallows – all important aspects of any engineering project.

After the judging of the two team projects, the hosts will show the apparatus that they worked to complete to solve the design problem – the apparatus described in the sample solution section below. They will stress the fact that their solution is not the only "correct" solution but is the one that they used to get the job done. They will also readdress the engineering design principles that are utilized by their particular apparatus. All successful projects will then be used to cook the hotdogs for the participants, and the show will end as everybody is enjoying some delicious solar barbequed food.

4. Project Concepts: Optics and Solar Energy

One of the main purposes of the proposed television show is to make the field of engineering more accessible to a wider audience; to give younger children a better understanding of what engineers are involved in. By providing the teams in the show with a short classroom session to explain the physics behind concepts that they are already familiar with, such as mirrors and solar energy, the hope is for the audience to make the connection that engineers apply physics, mathematics, and engineering principles, some of which the children might have already learned in school, in order to design a particular apparatus.

The lesson will begin with a very brief introduction to light energy and heat transfer. Most of the instruction will focus on optics, mirrors and magnifying glasses, as simple ways of harnessing solar energy. The lesson is intended to be very interactive with the teams applying background knowledge to answer questions and further their understanding of the aforementioned concepts. After going over physics concepts of energy and heat transfer, the lesson will then shift gears to look at the problem from a more mathematical standpoint. Applying what was just learned in the optics section, the hosts will then talk about how knowledge of parabolas can be applied to mirrors. Given this knowledge, the teams should have a firm foundation to attack the design problem given to them at the start of the program.

After the teams have built their separate apparatuses and both have been tested, the hosts will bring out their constructed cooker. They will explain the use of the parabolic shape in order to focus the energy of the sun onto the hotdog, as well as discuss the specific placement of the focal point, for the purpose of limiting the effects of the movement of the sun, and they will address the reason for the size of their apparatus as well as the materials they used.

In the construction of the solar powered cooker detailed below, the authors made use of some particular optical concepts. Because the sun is so far away from the earth, the rays can be approximated as parallel in their incidence with the earth's surface. Because of this fact, a parabolic shaped mirror was optimal for the design. A parabolic mirror would have the ability to reflect the sun's parallel rays to one focal point, thereby combining the solar power to cook the hot dog most efficiently.

However, there are an infinite number of parabola shapes and sizes. The dimensions and shape of this parabola were very specific, but this is not to say that another shape would not be as effective. The parabola shape chosen by the authors in the trial run detailed below has a deep curve. This allows for the focus of the parabola to be very close to the mirrored surface, which minimizes the distance that the focus moves as the sun moves.

Depending on the time of year, the sun has different power capabilities. By performing some simplified calculations, we can determine the amount of power we can expect from the arrangement detailed below. On average, we expect about 1000 Watts of power per 1 square meter of the earth's surface. Our mirror was hence designed with large dimensions (2 feet by 4 feet) to provide a large surface area to absorb the solar power from the sun. Our 8 square feet of mirrored surface is equivalent to about ¾ of a square meter. Because all of the power is reflected to one singular focal point, we can expect about 750 Watts of power to be output at the focal point of our solar powered cooker. This is approximately equivalent to the power output of a small electric stove.

5. Procedure and Trial Run: Conducted 3/30/2006

Below is a detailed sample solution that was tested on March 30th of 2006. Overall, the sample solution was a success, demonstrating that the use of solar energy at a concentrated focus of a parabola can provide sufficient heat for cooking.

5.1 Sample Solution

- Materials Needed:

  2 pieces of plywood (1/2" thick, 2' by 4')

  2 pieces of scrap lumber (2x4) 1.5" thick, 3.5"x 8')

  Stiff steel wire (3' long)

  Plastic mirror (1/8" thick, 2' by 5.5')

- Tools:

  16 wood screws, 2" length

  92 small nails or wooden pegs, 1 inch length

  Drill with a bit that matches the 92 nails or pegs.

  Drill bit (1" or larger in diameter)

- Design Process/Procedure:

The first step is to drill the 92 holes for the wooden pegs or small nails into the plywood sheets. Because the plastic should lie flat on the pegs, the holes need to be drilled in the same location on each sheet of wood. In order to cook the hotdogs most efficiently and absorb the most solar energy from the sun, the holes should be drilled in a parabolic shape according to the following displacements given in Table 1.

Table 1: Hole locations for parabolic shape.

Inches(from left)	Inches (from bottom)
0	22.16
2	18.94
4	16
6	13.34
8	10.96
10	8.86
12	7.04
14	5.5
16	4.24
18	3.26
20	2.56
24	2
28	2.56
30	3.26
32	4.24
34	5.5
36	7.04
38	8.86
40	10.96
42	13.34
44	16
46	18.94
48	22.16

The best and most efficient way to drill the holes is to align the two sheets of plywood and drill through both simultaneously to ensure proper alignment of the holes (see Figure 1 on the following page).

Figure 1: Aligning two sheets of plywood makes drilling holes more efficient.

Next, we will need a row of holes that follows the same parabolic shape directly above the holes we have just drilled to hold the plastic sheet in place. With the two sheets of plywood still aligned, drill a hole about ½" above the holes you have just drilled.

Next ,the holes for the screws to hold the lumber stands in place need to be drilled (see the photograph in Figure 2 below). There should be eight holes at the following locations:

- Hole 1: ¾" from left, 15" from bottom
- Hole 2: ¾" from left, 13" from bottom
- Hole 3: ¾" from right, 15" from bottom

- Hole 4: ¾" from right, 13" from bottom
- Hole 5: ¾" from bottom, 12" from left
- Hole 6: ¾" from bottom, 10" from left
- Hole 7: ¾" from bottom, 36" from left
- Hole 8: ¾" from bottom, 38" from left

Figure 2: Hole placement for lumber braces.

Now a hole needed to be drilled at the focus of the parabola for the wire (on which the food will be held) to be threaded through. A drill bit was chosen that was about the same size or slightly larger than that of the stock wire that had been purchased. This hole should be drilled, again, through both of the pieces of plywood.

At this point in the assembly process, the two sheets of plywood were taken apart to drill a larger hole to accommodate whatever food would be placed on the feed wire. It was decided that the hole should be made oversized in order to accommodate other foods such as marshmallows or other things besides the hot dogs. Using a hole drill (a high torque drill with attachment parts to obtain holes of varying size), a hole of about 3 inches in diameter was drilled. The hole should be located so that the spit hole in one of the pieces of plywood is just below the edge of the hole. It is best if these two holes only overlap slightly, as is shown below in Figure 3 below, to allow the spit wire to have a place to be held when the frame is raised to different angles to match the sun.

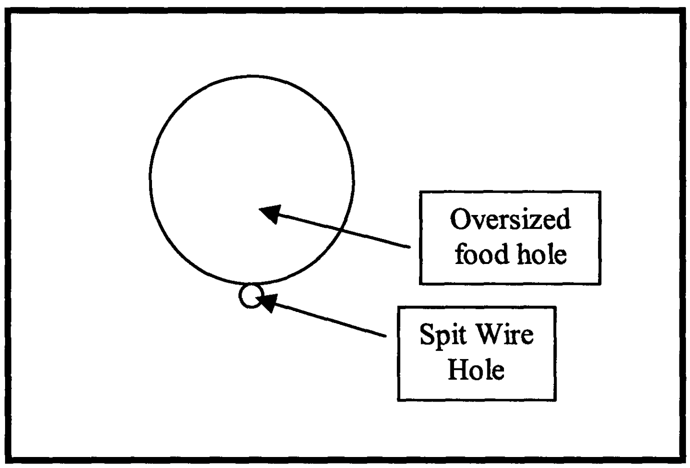

Figure 3: Relative Hole Placement for food and spit wire holes.

It is crucial also that the food hole only be in one of the pieces of plywood to allow the wire a secure point of contact at one of the ends. The photograph below in Figure 4 shows the feed hole and spit wire hole alignment from further away.

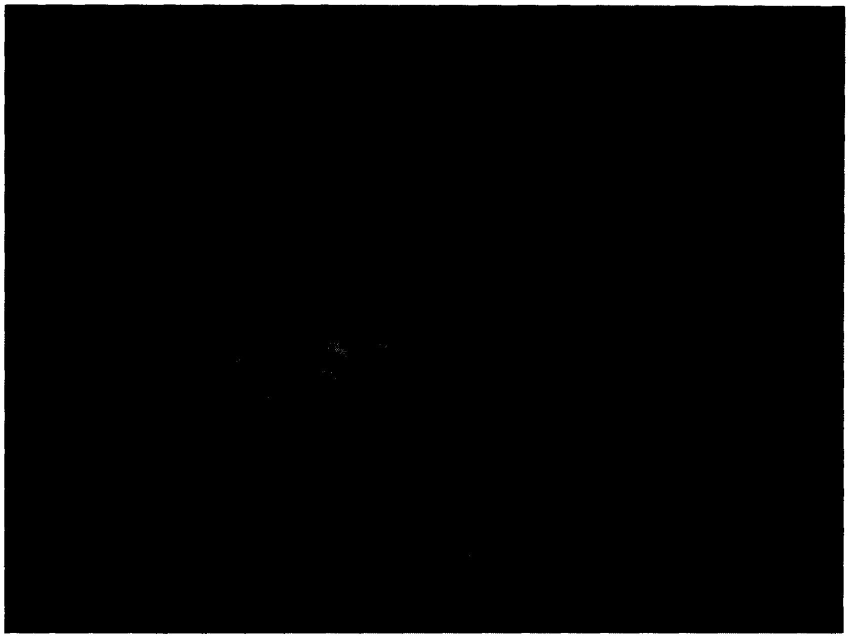

Figure 4: Feed hole and spit wire hole alignment.

After all of the holes had been drilled, the frame was ready to be assembled. One of the 2 x 4's was cut into 4 equal (2 foot length) pieces using a Mitre saw. Each piece was then aligned with one of the sets of two larger holes in the plywood. It was found to be the easiest to attach the 2 foot lengths of 2x4 to one sheet of plywood first and then maneuver them into alignment on the other sheet and attach them there.

The next step was to insert the bottom row of nails in the parabola shape on both pieces of plywood. The nails were inserted such that the points of the nails face towards each other, or so that the head is flat against the outside of the frame. In this trial run, it was found that the hole size chosen for the 92 holes was a little tight, so the nails had to be hammered into place.

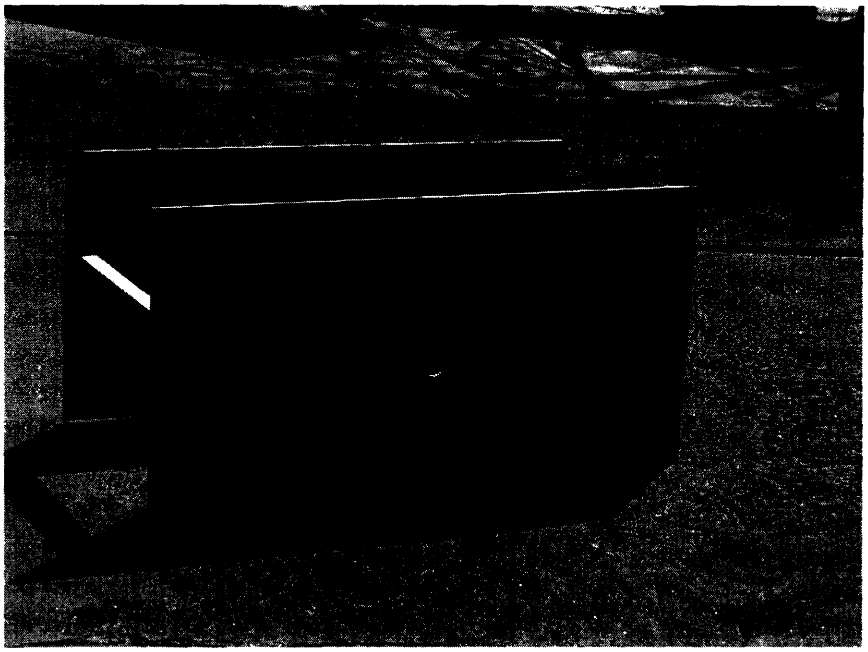

Figure 5: Fully assembled frame.

At this point, the mirror piece could be inserted into the frame, but first it had to be prepared. Because in this trial a plastic mirror could not be located and purchased, as was recommended, instead a thin piece of hardwood that was flexible enough to be bent into the parabola shape was used. Spray adhesive was used to glue extra wide (36 inch) sheets of aluminum foil to the hardwood. After allowing it to dry for the recommended hour, it was ready to be bent into the frame. Because the frame was tight on either side of the "mirror" it was relatively easy to push the piece into the shape without a lot of resistance and springback, even without the top row of nails in place. Starting with the middle hole, and working outwards, all of the nails were subsequently inserted into place in the top row of holes. Once all of them had been hammered in, the frame was completed!

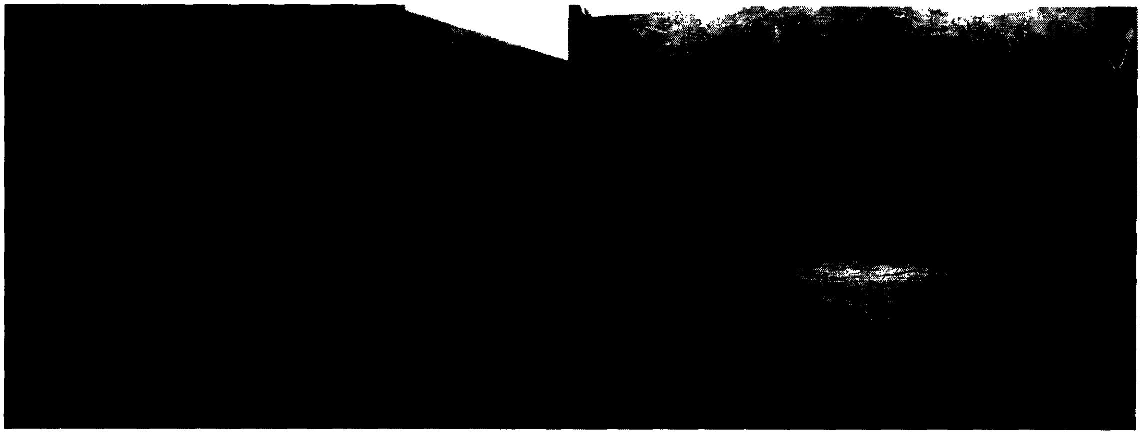

Figure 6: Completed frame with "mirror" in place.

Now it was time to test the design of the cooker. Luckily, it was a sunny afternoon and almost 11 am, so the sun was relatively intense for the time of year. A hot dog was fed onto the spit wire (after sterilizing it in hot water) and the wire was placed into the frame. In this trial, the hot dog was placed into the center of the wire and into the center of the frame as much as possible to optimize the light intensity. Hanging a hot dog bun on the spit wire to see if it would be "toasted" in the sun was also attempted in this trial. The frame was lifted up at an angle by one of the ends until the shadow of the wire was aligned with the middle nail in the parabola. This would ensure the proper angle with the sun.

Figure 7: Propped up frame to cook hot dog and bun.

After about 2-3 minutes, the outside of the hotdog began to appear cracked as the steam forced its way out of the center. Eventually the hot dog began steaming observably. The spit wire was continually rotated for about 10 minutes, in hopes of seeing a charring effect as would be seen in grilling, but in this trial charring was never observed. However, upon removing the hot dog, it was noticeably hot and tasting it proved that it had been cooked. The bun experiment actually did work, although it seemed more dried out than toasted.

Figure 8: Cooking hot dog and preparation to taste test.

The lack of charring on the hot dog can be attributed to a variety of factors. First of all, the time of year that the experiment was performed does not have optimal sun intensity, so it is possible that such results could never have been achieved. Another issue is the imperfect mirror issue. The aluminum had been adhered to the hardwood while it was still flat, and bending the mirror had caused air bubbles and ridges in the mirrored surface. These impurities would inhibit the intensity of the light to be reflected onto the apex of the parabola. Finally, it is a bit difficult to determine if the frame is in proper alignment because looking at the shadow location on the mirrored surface is very hard on the naked eye. Perhaps some sort of shaded goggles could be provided in a show taping.

Overall the experiment returned some interesting results. It would definitely be interesting to perform it again in the summertime when the sun is more intense to see if better cooking results could be obtained.

6. Conclusions and Future Directions

The results of the preliminary experiments with the construction of the solar powered cooking mechanism demonstrate that this project would be of feasible and reasonable scope for an episode of the television series. While this project is relatively simple to construct, it demonstrates clearly the concepts of optics and the capabilities of solar energy to be used for power. These ideas are presented in such a manner that they could easily be grasped by the target audience and would still provide an entertaining spin on engineering theories. It is the hope of the authors of this document that the formulation of this episode of the television show will aid in the creation of a television series that will have the capacity to engage young children in engineering before they develop stereotypes possessed by many youths today about science and technology careers. Even though these results are fairly preliminary, the authors feel that they show great promise for use in an episode of this series, with some small modifications. The next steps for this project would include performing a trial run of the experiment and show format with a group of high school aged students, to simulate the filming of the episode. Much like the previous trials, a focus group consisting of potential viewing audience members and a team of expert advisors would be used to critique the episode's effectiveness and interest level. Depending on the outcome of such prototyping, further prototyping could be done or the show theme could undergo some simple modifications to make it more appropriate for the scope of the television series.

References and Bibliography

1. "Experimental Projects." PEI Science and Technology Awareness Site. October 9, 1999. Science and Technology Awareness Group. 5 Jan. 2006 http://stas.edu.pe.cu/english/sub.cfm

2. Field, Simon Quellen. "Science Toys You Can Make with Your Kids." December 1, 2003. Gonzo Gizmos. 5 Jan. 2006 <http://www.sci-toys.com/bibliography.html>

3. Frey, Daniel D. and Wolsky, Marisa. "Engaging Children in Engineering Design through Popular Media." 12 December 2006.

4. "Harris Poll Reveals Public Perceptions of Engineering." National Academy of Engineering Website. September 1, 1998. National Academy of Engineering. 5 April 2006 http://www.nae.edu/NAE/naehome.nsf/

5. "Science and Engineering Room." Young Engineers' Club. July 2004. USACE. 7 January 2006 http://education.usace.army.mil/clubhouse/science/

6. "The United States in a Changing World." Science and Engineering Indicators 2004. May 2004. National Science Board. 7 April 2006 http://www.nsf.gov/statistics/seindo4/c0/c0s1.htm

7. Dym, C. L., A. M. Agogino, O. Eris, D. D. Frey, and L. J. Leifer, "Engineering Design Thinking, Teaching, and Learning," *ASEE Journal of Engineering Education* Vol. 94, No. 1, 2005, pp. 103-120

8. Felder, R. M., and R. Brent, "Understanding Student Differences," *ASEE Journal of Engineering Education*, Vol. 94, No. 1, 2005, pp. 57-72.