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Design it! Build it! A Summer Engineering Workshop for High School Students to Foster Creativity and Change Perceptions of Engineering (Work in Progress)

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Background

A survey of over 1,000 high school students conducted by Penn Schoen Berland found that students were more likely to consider engineering as a career if they had been exposed to engineering and better understood the role of engineers[1]. Additionally, students who had **not** been exposed to engineering were more likely to associate words like *smart* and *difficult* with engineers and engineering, whereas students who had been exposed to engineering were more likely to use words like *inventive* and *cool* [1].

Thirty-two high school students entering grades 10-12 attended a two-week pilot summer engineering workshop, *Design it! Build it!*, this past summer focused on designing and building engineering prototypes. The main goals of the workshop were to help students gain a better understanding of engineering and possibly change their perceptions about engineering such that they began to view engineering as a creative process. To that end we tried to design activities for the summer program that were inquiry-based and fostered creativity; instructors rated the activities to determine levels of inquiry-based learning and creativity each involved.

While many campuses offer engineering programs for K12 students[2,3,4,5,6] these programs often focus on a single type of engineering such as biomedical engineering[7] and few focus on engineering innovation and creativity (Johns Hopkins is one exception as they run an *Engineering Innovation* summer program for high school students). The Dartmouth *Design it! Build it! Summer Engineering Workshop* uses a design thinking and problem-solving framework to help students design and build engineering prototypes using an interdisciplinary approach. The goal is to show students that engineering can be an interdisciplinary, creative profession.

Objectives

Through the summer workshop, we hope that K-12 students will:

- View engineering as a creative and interdisciplinary profession;
- Begin to develop fundamental engineering skills such as problem-solving, design thinking and innovation, computer-aided design, and spatial reasoning;
- Increase interest in and perceptions of engineering;
- Design and build engineering prototypes.

Activities

Activities for the summer workshop were designed to meet the objectives of the workshop listed in the previous section; many activities were adapted from activities used in introductory college classes and curricula available online. To enhance understanding and change perceptions we focused on activities that were inquiry-based and were designed to foster creativity. Inquiry-based learning has been shown to increase student achievement and interest[8]. Using inquiry-based learning, students engage in scientifically-oriented questions, formulate explanations based on evidence, evaluate their explanations in light of alternative explanations, and communicate and justify their proposed explanations[9]. Creativity is fostered by exposing students to a wide range of ideas and experiences that allow them to make connections and create novel ideas[10].

While creativity is often associated with the arts, it is a critical element of engineering required in many aspects of the engineering process including the ability to reframe problems, interpret data, and create new processes and products[10]. By using inquiry-based approaches that foster creativity, we hope that K-12 student interest in and perceptions of engineering will increase.

During the first week of the summer workshop we included activities such as brainstorming, an improv session, sketching and computer-aided design tutorials. An engineering problem-solving session had the students re-defining problem statements and trying to come up with a variety of possible solutions. The K-12 students designed and built gliders, spinning tops, wind-turbine blades, 3D puzzles, pan-pipes and more using laser-cutters, lathes, and 3d printers. Math and science were used to explain the behavior of each of the prototypes that they built and students were often required to perform simple calculations. To help students see the breadth possible within engineering a variety of tours and short activities across different engineering disciplines were included: a visit to a biomedical laboratory, measurement of the power generated by solar panels, a visit to the heating plant on campus, and creation of a new chemical formula for slime. As a culminating experience, the students worked in small groups to design and build a project of their choice; students chose to build longboards, electric guitars, robots, and telescopes in this final week, learning about bending strength, music, programming, and optics along the way.

Activity Ratings

At the end of the workshop students were surveyed and asked to rate their enjoyment and learning for each of the main activities presented in the workshop on a scale of 1 to 10 with 1 indicating minimal enjoyment or learning and 10 indicating maximum enjoyment or learning. Results of the survey are presented in Table 1.

In addition, an instrument was developed to measure the level of inquiry and creativity associated with each of the different activities presented to the K-12 students; the instrument is included in the appendix and is based on an instrument developed by the National Research Council[9]. Instructors used the instrument to rate the level of inquiry (shaded green on the instrument) and creativity associated with the activities they developed and presented. 1 indicates a low level of inquiry, meaning the activity was more teacher-centered, and 10 indicates a high level of inquiry, meaning the students generated the questions and decided what ideas to explore. Three instructors rated the activities presented to the K-12 students and the averaged results for the three instructors on the different inquiry (shaded green) and creativity scales are given in the last two columns of Table 1. Some of the activities were not rated as indicated by a hyphen (-) since they were tour- or lecture-based rather than activity-based.

As shown in Table 1, the SolidWorks-based activities (gliders, spinning tops, introductory SolidWorks tutorials, and 3D puzzles) were the most popular activities of the workshop with students rating their enjoyment (and for the most part their learning) very highly for these activities. SolidWorks is three-dimensional computer-aided design (CAD) software package. They rated the gliders activity most highly for enjoyment. For this activity the students first experimented with gliders, then drew a design in SolidWorks, and laser cut the gliders they had designed. The students enjoyed experimenting with the gliders and there was plenty of room for creativity in designing the wings and body of the glider. Instructors rated the level of inquiry and creativity at 5.8 and 7.8, respectively, as indicated in Table 1. The students did not, however, rate their learning in this activity very highly, which was a bit surprising but can probably be attributed to the complexity of our explanation of aerodynamics.

Table 1. Student ratings of Enjoyment and Learning on a scale of 1 (lowest) to 10 (highest); Instructor ratings of Inquiry and Creativity on a scale of 1 (lowest) to 10 (highest).

Topic	Enjoyment	Learning	Inquiry	Creativity
Glider	8.0	6.0	5.8	7.8
SolidWorks	7.6	8.5	6.2	8.3
Spinning Top	7.5	9.4	6.5	8.6
3D Puzzle	7.5	7.4	4.8	8.4
Wind Turbine	7.4	5.9	7.0	8.1
Energy	7.3	7.2	-	-
Machines	7.3	5.3	7.2	7.4
Design	7.1	6.7	6.8	7.7
Frequency	6.9	6.8	4.8	5.2
Heating Plant	6.5	6.5	-	-
Funicular	5.8	6.2	5.4	7.1
Problem-Solving	5.4	6.2	-	-
Arduino	5.3	5.8	4.8	5.8
Paper Engineering	5.3	3.9	4.4	4.7

The spinning top activity was rated highly for both enjoyment and learning (7.5 and 9.4). The spinning top activity was run similarly to the glider activity in that students first built prototypes of tops (out of cardboard and dowels) and then designed their own top in SolidWorks, finally machining their own tops out of stock aluminum using a computer-numerically-controlled (CNC) lathe. This activity was likely more successful learning-wise because the response of the tops was more controllable and the learning was more accessible to them.

At the other end of the spectrum, arduino and paper engineering were both rated fairly low with respect to both enjoyment and learning as shown in Table 1. Interestingly, instructors also rated these activities as less inquiry-based and less likely to foster creativity.

While the results are not conclusive since the number of students and instructors participating in the surveys and ratings was limited (32 K-12 students and 3 instructors) some trends emerged. Enjoyment and learning seem to be correlated to level of inquiry and level of creativity. Future studies will further evaluate this relationship and also look at persistance in engineering as it related to enjoyment and learning.

Understanding and Perceptions of Engineering

The main goals of the workshop were to help students gain a better understanding of engineering and possibly change their perceptions about engineering such that they began to view engineering as a creative process. To determine changes in perceptions and understanding of engineering we compared students' responses on their application to the question, "What is engineering?" with their responses to the same question on the post-workshop questionnaire. A wordle, which is a visual representation of the written responses where the frequency of different words is indicated by the size of the text, was produced for both the application responses and the post-workshop questionnaire responses. The application responses are depicted in Figure 1 and the post-workshop questionnaire responses are depicted in Figure 2.

Figure 1. K-12 student responses on the **application** to “What is engineering?”

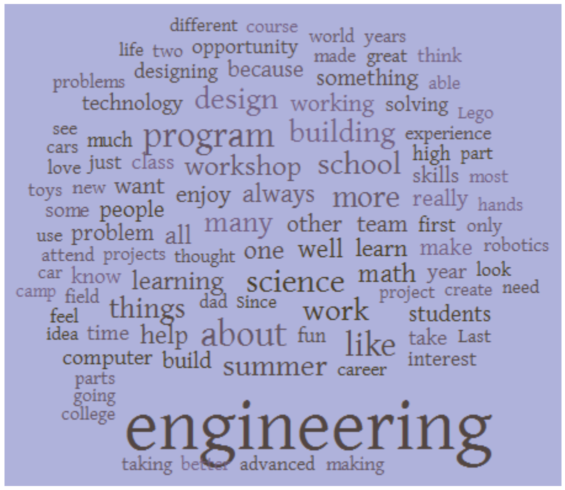
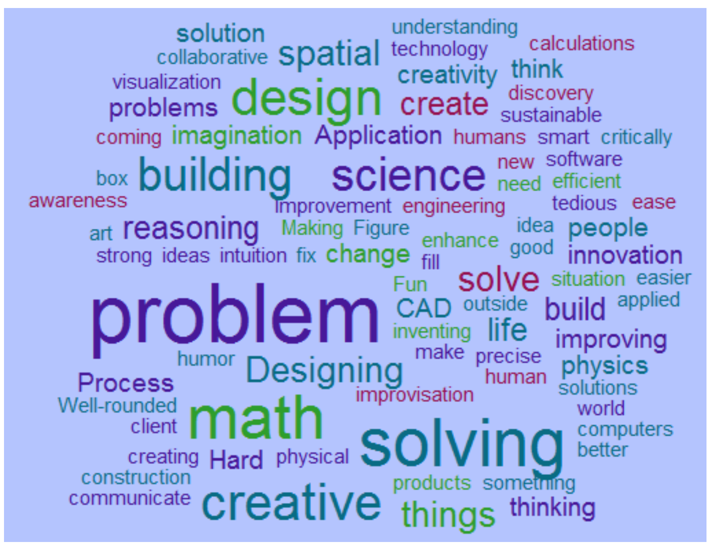


Figure 2. K-12 student responses on the post-workshop survey to “What is engineering?”



Comparing the two wordles depicted in Figures 1 and 2 we can see K-12 student responses to the question ‘what is engineering?’ on their applications (or pre-workshop) weren’t very focused, with ‘engineering’ appearing most often and other words somewhat evenly distributed. As shown in Figure 2, based on the Post-Workshop Survey students were more focused in their responses, with many words standing out such as ‘create,’ ‘creative,’ ‘problem solving,’ ‘design’ and ‘build.’ While the sample size is fairly small, the results do indicate a shift toward viewing engineering as a more creative process (one of the goals of the workshop). By classifying and counting words in students’ pre and post workshop responses to ‘what is engineering?’ we confirmed that words associated with creativity (create, design, invent) were found more frequently in post-workshop essays. We are currently analyzing the responses to determine changes in understanding of engineering.

Interviews with the K-12 students also indicate that they viewed engineering as a creative process after the workshop. Informal interviews were conducted with each of the participants during the last few days of the workshop; participants were asked about the program, how it might be improved, what they gained from the program, and how they viewed engineering. Many students reported finding engineering to be much more creative than they expected. A video highlighting some of the interviews is available at: http://engineering.dartmouth.edu/summer-workshop/overview.html.

Conclusions and Future Steps

We plan to offer two sessions of the *Design it! Build it! Summer Engineering Workshop* at Dartmouth this summer, a residential and a day program. This summer we are targeting women and minorities by working with the Admissions Office at Dartmouth to advertise to schools and guidance counselors in New England. We plan to improve activities by making them more inquiry-based and designed to foster creativity and work on correlating enjoyment and learning with level of inquiry and creativity, further correlating participation in these activities with changes in creativity and interest in engineering.

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Appendix

Fostering Creativity and Inquiry

Assessment of Classroom Activities

Activity:____

Circle a number from 1 (more learner-centered) to 10 (less learner-centered).

Less Learner Self-Direction **More Teacher-Direction**		**More Learner Self-Direction** **Less Teacher Direction**
Activity is focused on content	1 2 3 4 5 6 7 8 9 10	Activity is focused on questions
Teacher provides the questions	1 2 3 4 5 6 7 8 9 10	Learner poses the questions
Learner given data and told how to analyze it	1 2 3 4 5 6 7 8 9 10	Leaner determines what constitutes evidence and decides how to collect it
Teacher provides connections	1 2 3 4 5 6 7 8 9 10	Learner independently determines connections between evidence and scientific explanations
Activity is prescribed	1 2 3 4 5 6 7 8 9 10	Learner given opportunities for creativity
Learner focuses on a single, 'right' solution	1 2 3 4 5 6 7 8 9 10	Learner is encouraged to generate multiple solutions
A single set of materials and approaches are provided	1 2 3 4 5 6 7 8 9 10	Learner may choose different materials and approaches
Failure is discouraged	1 2 3 4 5 6 7 8 9 10	Learner is encouraged to try different approaches even if some of the approaches fail
Conventional solutions are encouraged	1 2 3 4 5 6 7 8 9 10	Learner is encouraged to come up with a unique or crazy solution

Comments and Observations:

Adapted from an instrument developed by the: National Research Council (NRC). *Inquiry and the National Science Education Standards.* Washington, DC: National Academy Press, 2000.