From Egg Drops to Gum Drops: Teaching Fourth Grade Students about Engineering

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Abstract
Students remember 80% of what they do and 20% of what they hear. With this premise in mind, the author developed an active approach to educating a classroom of fourth grade students in multiple areas of engineering. The intent is minimally, to increase interest in math and science in the young students. Optimally, the students will pursue engineering as a career. Hands-on activities were used to demonstrate six different areas of engineering over an academic year, such as launching rockets (Aerospace Engineering) and building bridges (Civil Engineering). A typical classroom session was comprised of a 10-15 minute introduction of the topic, 60 minutes of students constructing and testing a project, and 10-15 minutes discussing the results. The approach was applied to a fourth grade class of twenty students in Brighton, Michigan and was judged a success by faculty and students.

Introduction

> "I never knew engineering could be so fun. When I grow up, I'm either going to be an engineer or an actor. Sincerely, Maddy"

The motivations for the project include recent statistical trends in math, science, and engineering education. Recent studies have shown that many female elementary students diverge from interest in Math and Science at the fourth to fifth grade level [1,2]. Reasons for the divergence include implicit or explicit bias within the classroom, lack of role models, and subsequent decreased peer support.

In addition (and on a broader scale), the number of undergraduate degrees awarded in engineering has been steadily and consistently decreasing over the past decade [3]. Specifically, the percentage of degrees awarded in engineering and engineering technology decreased by 4 percent between 1990 and 1995, and an additional 7 percent between 1995 and 2000.

Finally, on a personal level, the author is both a practicing engineer (Mechanical and Computer Science) and the father of three daughters. Because of my background and lifelong interest in Math and Science, I would choose not to have the noted divergence occur in my home.

This project was intended to motivate young students (particularly, but not explicitly female) toward a potential career in engineering.

This paper discusses an approach to educating young students regarding six different areas of engineering over the period of an academic year. Specifically, this program introduced engineering to the fourth grade students in six different engineering disciplines: Civil, Industrial, Mechanical, Aeronautical, Aerospace, and Chemical Engineering.

A typical classroom session was comprised of a 10-15 minute introduction of the topic, 60 minutes of students constructing and testing a project, and 10-15 minutes discussing the results. Similarly, the discussions in this paper echo this basic cadence. The form of the discussions below for each area of engineering is:

- Introductory discussion: Information to introduce the area of engineering;
- Activity description: A specific discussion of the day's project;
- Materials required for activity: An itemized list of the materials needed for the activity; and
- Sample summary questions: Questions that were asked of the students to assist them in processing the activity

Finally, conclusions and recommendations are included near the end of the paper.

Engineering Discipline: Civil Engineering

"Thank you for teaching us about industrial engineering and bridges. I love the sandwich project and the bridge one too! It was fun to learn about different types of engineering. I like bridge engineering the best because you get to build bridges. Sincerely, Nathan"

Introduction

First, the job content of Civil Engineers was briefly discussed, including construction of large-scale projects, such as highways, dams, and bridges. Then, the construction of bridges was discussed more specifically. A website was found that described and had pictures of different types of bridges: arch, beam, and suspension [4]. Finally, some pictures of 'composite' bridges (those having characteristics of arch, beam, and/or suspension bridges) were shown and the students determined what properties of which bridge types were contained therein.

Activity

Students were divided into groups of 3-5 people. Each group constructed a bridge from gumdrops and toothpicks. The students were encouraged to use pictures that were displayed earlier for ideas regarding the structure of their bridges. Each student group had to build a bridge that spanned a six-inch gap between two desks. The bridge design had to allow for a small platform (e.g., top from a margarine container) to hold the load (pennies). Judges loaded pennies, one-at-a-time, onto each loading platform until failure. For reference, the first bridge failed after approximately 50 pennies, and the final bridge failed after approximately 100 pennies.

Materials

For each group:

- Bag of gumdrops;

- Box of round toothpicks;
- 12 inch ruler;
- 2 school desks;
- Approximately 100 pennies;
- Some platform to hold pennies during loading (such as a lid from a plastic margarine container).

Summary Questions
- Which bridge held the most pennies and why?
- Which bridge held the least pennies and why?
- What properties of an arch, beam, and/or suspension bridge did each group's design have?
- Did either aesthetics or symmetry provide a stronger bridge?

Engineering Discipline: Industrial Engineering

"Thank you for teaching us about industrial engineering. It was really cool. I never knew that there were so many kinds of engineering. I liked making sandwiches the most. It was very fun. The bologna, cheese, and lettuce were neat. My mom cut the cheese. It was really hard to label the sandwiches. We went way too fast, so we had to fumble around with the sandwiches trying to find out what they were. We also ran out of already torn saran wrap to wrap the sandwiches. It was hard, but fun. Thanks again! Sincerely, Eric"

Introduction
The job content of Industrial Engineers was briefly described, including ergonomics and production efficiency. The ease of doing simple/difficult tasks when the tasks are set up correctly was discussed, as was the difficulty of doing tasks when they are not. An assembly line was described, and how one cannot simply 'turn up the speed' in order to increase production was discussed.

Activity
There were two activities for Industrial Engineering. The first activity was related to assembly line speed. A central clock (person) kept beat with a four-beat rhythm. The students lined up in two rows, simulating two sides of an automobile assembly line. Each student had an assignment related to assembling an imaginary car, such as 'put on the door' or 'place the seat in' or 'must have four tires'. Note that each student assignment has four beats. The central clock (person) would speed up the beat when imaginary production increased, and slow down when imaginary production decreased. The first person on the assembly line to miss any beat in their respective four-beat task caused the entire assembly line to shut down.

The second activity involved assembling sandwiches. Once again, the class was divided into groups of 3-5 students. A sandwich was comprised of two slices of bread, and some combination of bologna, cheese, and lettuce. After the sandwich was assembled, each had to be wrapped in cellophane plastic and correctly labeled. The students were given a trial list of 5 sandwiches to define the group's process and a final list of 40 sandwiches for the actual production run. The objective was to build as many sandwiches as possible from the final list of 40 sandwiches in 5 minutes. For reference, the list below contains the first 10 sandwiches that were on the list:

1. Bologna, Cheese, and Lettuce
2. Bologna
3. Bologna
4. Bologna and Cheese
5. Cheese and Lettuce
6. Bologna, Cheese, and Lettuce
7. Bologna and Cheese
8. Bologna, Cheese, and Lettuce
9. Cheese and Lettuce
10. Bologna

Materials
For each group:
- 2-3 loaves of bread;
- Stack of brown felt circles, about the same diameter as a piece of bologna;
- Stack of yellow felt squares, about the same size as a slice of cheese;
- Plastic bag of green shredded paper, about the same consistency as shredded lettuce;
- Roll of plastic wrap;
- 2-3 sheets of labels;

Summary Questions
- Which group produced the most finished sandwiches and why?
- Which group produces the least finished sandwiches and why?
- Did more people in a group necessarily mean higher production?
- What was the single, most difficult task in creating sandwiches? That is, what was the bottleneck?
- Why did each group produce the sandwiches in the order assigned, rather than a more efficient order (e.g., all bologna sandwiches first, followed by all bologna and cheese, …)?

Engineering Discipline: Mechanical Engineering

"…Another experiment was the egg drop! Now that was awesome! It was really fun. I learned something from that too. I learned that a one way bumper is safer. Well, I hope to see you next year. Sincerely, Maddy"

Introduction
As always, the job function of a Mechanical Engineer was discussed. Specifically, Mechanical Engineering in the automotive industry was the focus. Further focus was on occupant protection and the importance of always wearing seatbelts in a moving vehicle. A wide variety of occupant protection devices were discussed, such as car seats, airbags, and crumple zones.

Activity
The activity for Mechanical Engineering was an egg-drop competition. The idea was simply to protect a raw egg from breaking at increasing heights. The students groups were given a variety

of raw material from which to construct their egg-protection device (EPD). After completion of the EPD, the students were asked which EPD they thought would protect the egg from the greatest height and why. Interestingly, the EPD that failed the earliest appeared as if it would protect the egg the best. As a point of reference for the students, an egg was placed in a coffee can with no protection and dropped from the height of 2 feet. Naturally, the egg was crushed. The student-built EPDs were dropped from gradually increasing heights at approximately 2 foot increments until all eggs were broken. The first EPD failed at approximately 4 feet. The final EPD failed at approximately 40 feet. As a side note, the final EPD did not fail inside the building. In order to cause failure, the EPD had to be thrown into the air off of the gymnasium roof.

Materials

For each group:

- Plastic egg for design of prototype;
- Raw egg for final test;
- Coffee can;
- Packing Styrofoam;
- Bubble paper;
- Duct tape;
- Other moving/packing supplies.

Other materials:

- Ladder;
- Tape measure;
- Sheets of plastic to protect floor;
- Access to roof.

Summary Questions

- Which EPD do you think will fail first? Why?
- Which EPD do you think will fail last? Why?
- Which EPD actually failed first? Why?
- Which EPD actually failed last? Why?
- Did the egg break on primary impact or secondary impact?
- What happens to unconstrained egg in coffee can? How is this similar to passenger in car not wearing seatbelts?

Engineering Discipline: Aeronautical Engineering

"Thank you so much for coming in. I mean it. It was so fun doing rockets, sandwiches, airplanes, bridges, it was awesome! I hope that you can do it next year. I really appreciate it. Thanks! Sincerely, Brittanie"

Introduction

The job function of Aeronautical Engineers was briefly discussed, particularly related to airplane design. The fundamentals of thrust and lift were explained, and illustrated by a scene from the movie "Chicken Run" [5], in which a Scottish chicken is describing the theory of thrust to the other chickens. Various combinations of thrust and lift that are combined in the following devices:

prop-driven airplane, jet-driven airplane, helicopter, and rocket were debated by the class.

Activity
The students were divided into groups of 3-5. The objective was to build, decorate, and fly different paper airplanes. The planes could either be student-designed, or inspired from various books on paper airplane design [6]. Each group was given raw material, and asked to construct a set of airplanes that would: stay in the air for the longest amount of time; fly the longest straight-line distance from a throw; drop the truest straight-line path in a fall; and have aesthetic appeal.

Materials
For each group:
- 10-15 sheets of paper;
- 2-3 plastic straws;
- Several paper clips;
- Markers, crayons, etc.

Other materials:
- Tape measure;
- Stop watch;
- Margarine container top (for drop test);
- Paper airplane book(s) [6].

Summary Questions
- What design flew the greatest distance?
- What design stayed in the air the longest?
- Were the answers to the above two questions the same? Why or why not?
- What design dropped the most accurately? (*answer: a wadded up paper ball*)
- What design looked the best? Did it also fly the best? Worst?

Engineering Discipline: Aerospace Engineering

"Thank you very much for coming in and doing things with us. The rockets were fun to launch. I think that it is funny that only the girls' rockets came down in one piece. Thank you for helping us learn and have fun. Sincerely, Shannon"

Introduction
The discipline of Aerospace Engineering was introduced, including a discussion about space flight and different types of rockets. A volunteer from the community, who is also an owner of a newly opened hobby shop, came to the school playground to launch a variety of rockets. Approximately 15 different rockets were launched, including launching the same rocket with various size engines. Enough rockets were purchased from the business owner so that each student had his or her own rocket to construct.

Activity
As mentioned, the first activity was watching an expert from the community launch several rockets. Over the next month, the students assembled their own junior–level rockets. Note that

the rocket engines were kept separate from the rockets for safety reasons. On the appropriate day and in a controlled environment, the class launched their rockets from the school playground. The objective was both to construct rockets and to launch them such that they landed as close as possible to a designated target, such as a hula-hoop.

Materials
For each person:
- Junior-level rocket kit;
- 1-3 low thrust rocket engines;
- Glue, etc for assembly.

Other materials:
- 2-3 launch pads;
- 2-3 hula-hoops;
- Long piece of rope (to mark launch perimeter and keep students safe).

Summary Questions
- How is trajectory predicted based upon weather conditions? That is, what should be taken into consideration to get the rockets to land as close as possible to the target area?
- How do different types of rocket engines affect flight of same rocket?
- How does the same type of rocket engine affect flight of different rockets?
- What are safety considerations for each and every launch?

Engineering Discipline: Chemical Engineering

"Thank you for teaching us about engineering. Also, thank you for the pizza party. You are a really nice person for all you have done. Your classes that we attended were very informational and fun. I hope you come back next year. Sincerely, Brian"

Introduction
The job function of Chemical Engineers was briefly discussed. Specifically, chemical reactions that involve combinations of materials and either the addition or removal of heat were pondered. The students understood that the kitchen in their home is a virtual wonderland of Chemical Engineering, and that every meal is an experiment in chemistry. The students described various methods of increasing and decreasing temperature that are readily available at home.

Activity
In truth, this activity was as much social as educational. Pizza was ordered from a local pizzeria and the students discussed all of the chemical engineering that occurs in a pizza. Specifically, focus was given to the tomato sauce on the pizza and the processes that a raw tomato must go through on its path to becoming a pizza. Also, students helped make 'mud', which is a combination of chocolate pudding and crushed Oreo cookies.

Materials
- Pudding mix;
- Crushed cookies;

- Handheld mixer to make pudding;
- Pizza (delivered);
- Serving plates, napkins, utensils.

Summary Questions

- Why does a powder and liquid make something in between? Will that always be the case?
- What type of processing goes into pizza sauce?
- Why are things heated to create a chemical reaction? That is, why to we use ovens, stoves, and microwaves to cook food?
- Why must things be cooled to slow a chemical reaction? That is, why do we use a refrigerator?
- What chemical processes take place daily in each household?

Conclusions and Recommendations

"Thank you for teaching our class about engineering. I loved every last bit of the activities you planned. They were all fun and they're inspiring me to be an engineer. Thank you for your cooperation. Sincerely, Nate"

The overall goal of this project was to introduce fourth-grade elementary students to an exciting variety of career choices in engineering. Through hands-on experiments, the students obtained a snapshot of what a Civil, Industrial, Mechanical, Aeronautical, Aerospace, and Chemical engineer might do on a daily basis. The students embraced the tasks with exceptional enthusiasm and learned about engineering as a potential career. The student quotes indicate the level of enthusiasm that the students shared.

In addition to the explicit objectives mentioned above, there were many implied lessons. The students leaned a great deal regarding working in groups to obtain mutually beneficial goals. They learned how to cooperate within a group, while competing between groups. Hopefully, the students enhanced their ability to process the results of their experiments into meaningful knowledge.

The paper was written in a form such that the methodologies could easily be adopted by other interested parties. Existing activities and the materials required were inexpensive. Alternative activities might be introduced as long as they are consistent with the theme of the engineering discipline.

"Dear dad, Thank you for coming in and teaching us about many different kinds of engineering. I really enjoyed it! Thank you so much for coming. Sincerely, Mairin"

Bibliography

[1] National Center for Education Statistics. *Findings from the Condition of Education 1997: Women in Mathematics and Science*, 1997. U.S. Department of Education, Washington D.C. http://www.ed.gov/NCES.

[2] The National Science Foundation. *Women, Minorities, and People with Disabilities in Science and Engineering*: 1994. NSF 94-333, 1994.

[3] National Center for Education Statistics. Digest of Education Statistics, 2001. U.S. Department of Education, Washington D.C. http://nces.ed.gov/pubs2002/digest2001.

[4] Great Buildings Online. http://www.greatbuildings.com.

[5] *Chicken Run*, Dreamworks Home Entertainment, 2000 Dreamworks LLC, Aardman Chicken Run Limited and Pathe Image, 100 Universal City Plaza, CA.

[6] Ken Blackburn and Jeff Lammers, *The World Record Paper Airplane Book*, Workman Publishing, New York, New York, 1994, ISBN 1 56305 631 3.

Biographical Information

David R. Chesney received his PhD in Computer Science from Michigan State University. In addition, he has degrees in Mechanical Engineering. He is very fortunate to have three daughters, and thus, is particularly interested in Math and Science education of female students.