Creating Interest in Middle School Students toward STEM Careers – Mechanical and Civil Engineering

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Abstract

In an effort to excite and inspire middle school students toward STEM careers, Baker College of Flint has been conducting summer camps regularly. Additionally, the college recently partnered with several local middle schools for hosting half-day outreach activities in engineering. During their visit to Baker College, students work on five to six hands-on activities that cover many areas of engineering and computers, each activity lasting for a duration of 20 minutes. This paper describes in detail the three activities in the areas of mechanical and civil engineering. They include- (1) identification of an unknown plastic specimen by performing simple tests, (2) setting yellow traffic light time by calculating reaction time and braking distance, and (3) creating models using 3D printing. It is hoped that the outreach activities, in addition to creating an interest in STEM careers, would also inspire students to attend our summer camps.

Introduction

It is well known and documented that there is a growing demand for STEM related jobs[1]. Additionally, there is also the need to make students proficient in the STEM area to continue to make the country competitive and innovative. It is not uncommon to find many colleges and universities offering on-campus STEM summer camps for high school and middle school students. Our institution, Baker College of Flint, has been offering[2] the "Explore Engineering and Technology" summer camp for high school students since 2013. The camp runs for two weeks with full day sessions. Students from the first week who are interested in earning college credit for the engineering course EGR105, "Introduction to Engineering and Design" of our curriculum will participate in the second week of the camp[3]. Our institution has also been offering Robotics summer camps for high school and middle school students since 2009 and 2010 respectively. The robotics high school camps better prepare students to participate in the FIRST Robotics competition.

Hirsch[4] et al. have discussed their summer enrichment program to introduce middle school students to engineering and engineering design process. An exposure to STEM for middle school students will stimulate an interest in STEM career pathways and also in high school summer camps. While most middle school camps run for a day or longer, our institution began half-day outreach activities in engineering in November 2014 through partnership with several local middle schools. Most students at Baker College have day-time jobs and take evening classes, and thus are classified as non-traditional students. Lately, through outreach activities, our institution is also attracting traditional students who continue their education immediately after high school, or even begin their college education during high school. Recently we hosted about 40 to 150 students from Carman-Ainsworth, Almont, and Beecher middle schools, and STEMM (science, technology, engineering, mathematics and medical) Academy in Lapeer for these half-day

activities. Students were grouped and they worked on five to six hands-on activities covering many areas of engineering and computers, with each activity lasting for a duration of 20 minutes. The activities are described in Table 1. This paper describes three activities in the areas of mechanical and civil engineering in detail- (1) identification of an unknown plastic specimen by performing simple tests, (2) setting traffic light time by calculating reaction time and braking distance, and (3) creating models using 3D printing.

Table 1. Schedule of half-day sessions

Time	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
9:15-9:40	3-D Printing	Material Science	Photonics	Civil Engineering	Programming	Cyber
9:45-10:10	Material Science	Photonics	Civil Engineering	Programming	Cyber	3-D Printing
10:15-10:40	Photonics	Civil Engineering	Programming	Cyber	3-D Printing	Material Science
10:45-11:10	Civil Engineering	Programming	Cyber	3-D Printing	Material Science	Photonics
11:15-11:40	Programming	Cyber	3-D Printing	Material Science	Photonics	Civil Engineering
11:45-12:10	Cyber	3-D Printing	Material Science	Photonics	Civil Engineering	Programming

Activity 1: Material Science- Identification of an unknown plastic specimen

In this experiment students will learn a technique to identify unknown plastic samples[5] using simple equipment like Tweezers, plastic samples, and candle, Figure 2. Students are first introduced to the seven most common types of plastics- PET, HDPE, PVC, LDPE, PP, PS, and OTHER. The procedure comprises of opacity, flexibility, and surface type tests, followed by a burn test. Students are given a worksheet shown in Figure 1 and the following steps are performed:

1. Opacity Test: Determine if the sample is transparent, translucent, or opaque. Transfer the corresponding numbers to Box A.
2. Flexibility: Bend the specimen and determine if it is flexible (rubber-like), semi-rigid (stiff), or rigid (breaks like glass). Transfer the corresponding numbers to Box B.
3. Compare the numbers in "A" and "B". Transfer any numbers appearing in both to Box D.
4. Surface Type: Feel the unknown specimen and determine if it has a hard glass like surface, a soft waxy feel that scratches easily, or a dull unpolished surface. Transfer the corresponding numbers to Box C.
5. Compare the numbers in "C" and "D". Transfer any numbers appearing in both to Box E.
6. Burn Test:
    i. Holding the specimen with tweezers, place over a flame and observe the following:
        - Does the specimen burn cleanly or does it give off a black sooty smoke?
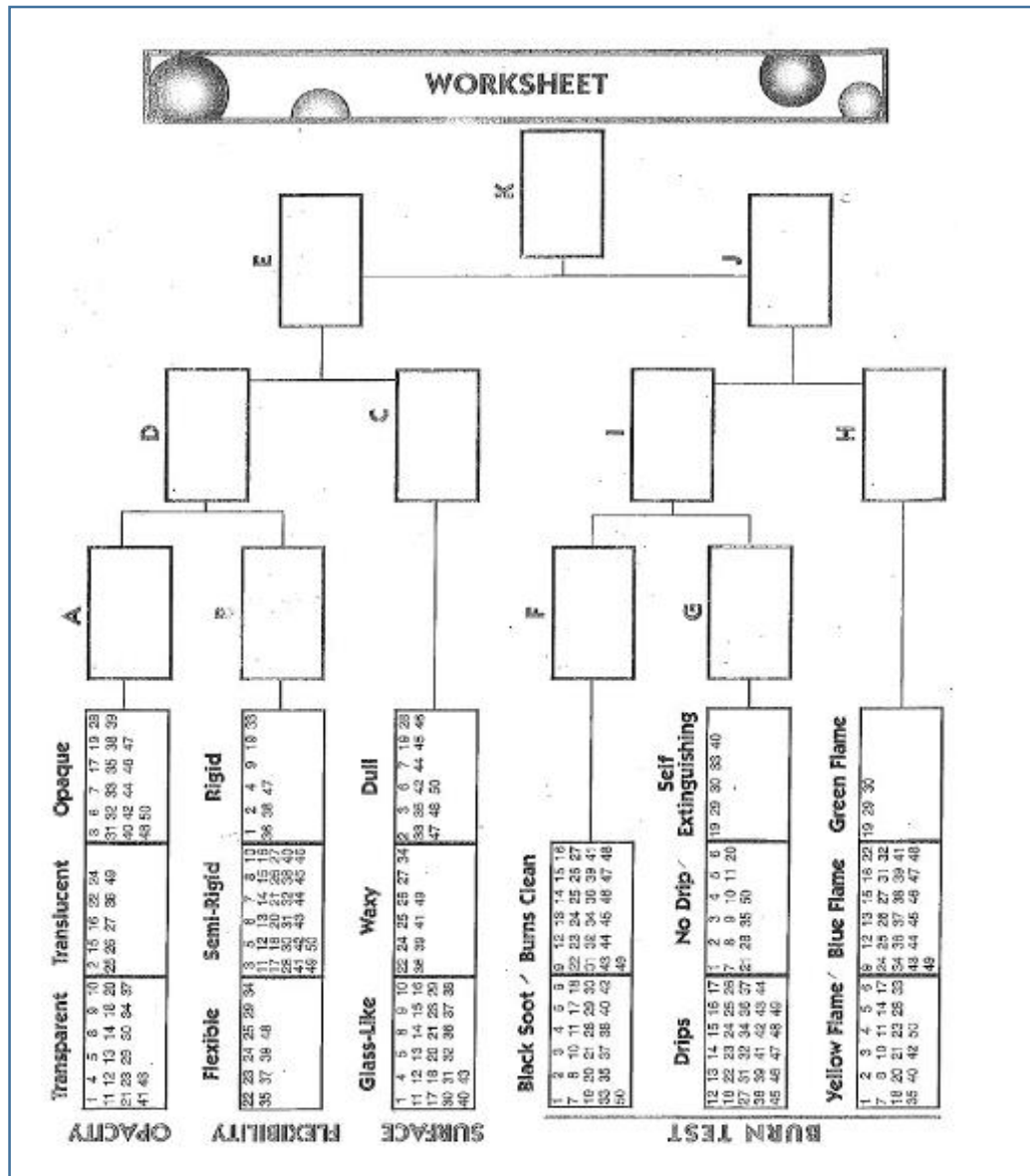
Figure 1. Worksheet for Identification of an unknown plastic specimen

- Does the specimen drip while burning?
- Does the flame extinguish itself when the plastic is removed from the flame?
- What is the color of the flame (look at the base of the flame)
  NOTE: DO NOT BURN UP THE ENTIRE SAMPLE

ii. Transfer the corresponding numbers to boxes F, G, and H.
iii. Compare the numbers in "F" and "G". Transfer any numbers appearing in both to Box I.
iv. Compare the numbers in "I" and "H". Transfer any numbers appearing in both to Box J.

v.   Compare the numbers in "E" and "J". Transfer any numbers appearing in both to Box K.
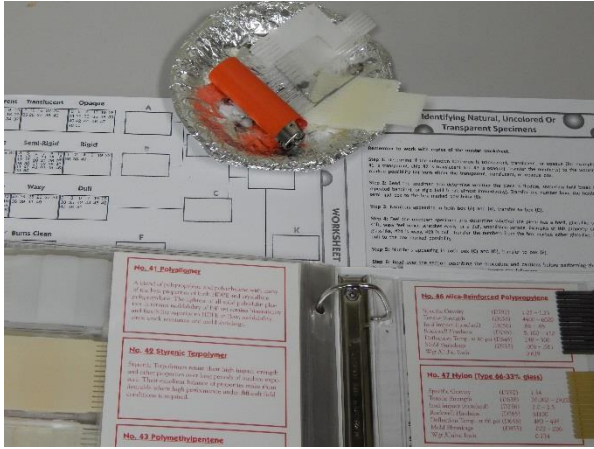vi.   Compare the numbers in BOX K with known plastic samples

Figure 2. Plastic sample identification

Figure 3. Setting yellow light time

Activity 2: Civil Engineering- Setting Yellow Light Time of Traffic Lights
Part (a): *Calculating Reaction Time-*
Here students roughly calculate their reaction time using linear motion equations[6]. A ruler is held above the student's open hand, released from rest, and stopped by the student closing the hand. The distance (x) travelled by the ruler is measured and recorded in Table 1.

Table 1. Reaction time

Student	Distance Ruler Dropped (*m*)			Average Dropped Distance (m)	Reaction Time (*s*)
	Trial 1	Trial 2	Trial 3	$\frac{\text{Trial1- Trial2- Trial3}}{3}$	
Person 1					
Person 2					
Person 3					
Person 4					

The distance equation for constant acceleration (acceleration due to gravity),

$$x = v_0 t + 0.5 (a) (t^2)$$ is solved for the reaction time, t.

The procedure is repeated three times and the reaction time is solved.

Part (b): *Calculating the Braking or Safe Stopping Distance*
The materials needed for this experiment consist of hot wheels track, two photo gates, computer, and hot wheels car. The equipment set up with the two photogates are shown in Figure 3. Students release the car from the starting point and collect the time data from the two photogates, enter the data in Table 2, and determine the initial (v_o) and final (v_f), velocities of the car.

Using linear motion equations, the deceleration and braking distance of the car are determined.

Braking distance calculation

$$v_f^2 = v_o^2 + 2ax$$

Deceleration, $a = (V_f^2 - v_o^2) / (2a)$

Braking distance $= - v_o^2 / 2a$

Table 2. Velocities and deceleration

	Initial and Final Velocities					Average Initial and Final Velocities		Deceleration
	Trial 1		Trial 2		Average of Trials 1 & 2		$V = \dfrac{length\ of\ block}{t}$	
	to	tf	to	tf	Avg (to)	Avg (tf)	Vo	Vf	a
Speed 1									
Speed 2									
Speed 3									

Part (c): *Calculating Yellow Light Timing*
Using the data and results from parts (a) and (b), students will determine the yellow light time and examine the yellow light time versus velocity using Table 3. Students realize from the braking distance equation that if the initial velocity is doubled, the braking distance will increase by 4 times.

Yellow light time = {(reaction time x v_0) – Braking distance – intersection length + avg. vehicle length} / v_0

Table 3. Yellow light period for different speeds

	Calculated Values				
Speed (mph)	Speed (*m/s*)	deleration (*m/s²*)	Braking Distance (*m*)	Reaction Time (*s*)	Yellow Light Period (*s*)
30					
35					
40					
45					
50					

Activity 3: Mechanical Engineering-3D Printing

The 3D printing session starts with a discussion asking students what they know about 3D printing. Students generally have examples they have heard about in the news, or have a parent or relative who has access to a 3D printer. Some students might have a printer at their home school. The role of 3D printing, from a prototyping tool twenty years ago to a disruptive technology now, is presented. Baker College has a Stratasys BST768, a Stratasys Dimension Elite, and two Makerbot Replicator 2 machines in our 3D printing lab. The difference between a breakaway support structure, a soluble support structure, and a material that builds its own supports is explored. Acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA) are presented as the base materials that we use for 3D printing and several samples of parts made from each material are on display in the lab along with filament rolls of each.
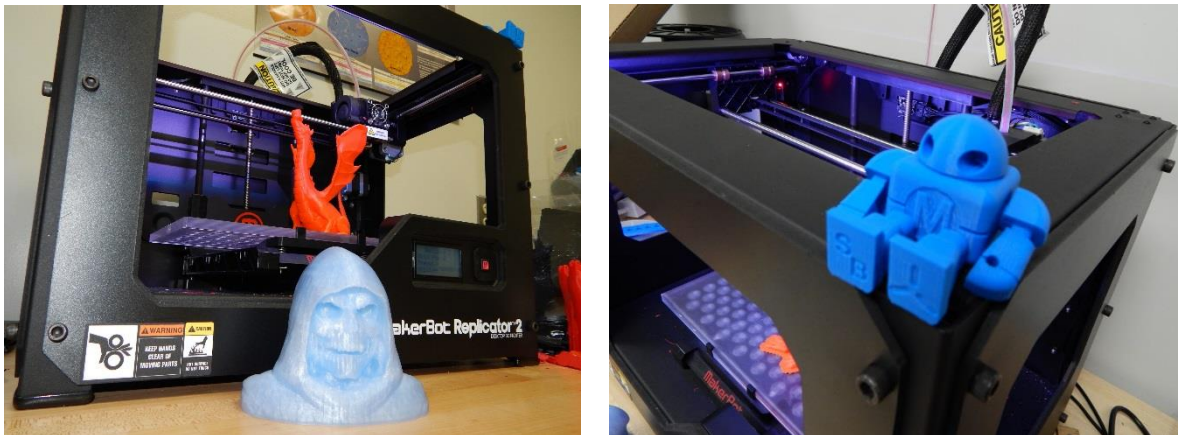

Figure 4. 3D printing

All of our printers have print heads that move in x and y directions and a build plate that starts at the top of the machine and then moves down in the z direction to create parts. Comparisons and

differences are made between the machines and the resolution to which they can print parts, from 0.013 inches down to 0.007 inches per layer. The Makerbot machine are generally running for the demonstration because the machines are open and the build is much more visual to explain to students. Students are able to watch as each layer of a part is printed and the build plate moves down to create the next layer. Sample parts are on the table in the lab to illustrate what the machines can build, showing the difference between parts built at low vs high resolution and the visual quality of the different build settings. Parts that have stopped in the middle of a build or built with misalignment are used to illustrate the honeycombed interior of the parts that uses fifteen percent of the component's volume but maintains strength of the parts

Activity: Manufacturing- Measurement instruments
We have sometimes included an activity in the manufacturing area, which provides students with an introduction to measurement instruments- scales and calipers used in manufacturing settings.

A brief video discussing American manufacturing and the different jobs available in the manufacturing field is shown at the beginning of the session. The discussion centers around what manufacturing is, jobs in local industries, and the courses that students can take in high school and college to position themselves for jobs in the manufacturing field.

Four flat dogbone tensile test specimens made of different metals- 303 Stainless steel, 1020 Cold Rolled Steel, 6061 Aluminum, and 360 brass are used for the measurement exercise. Each student is given one tensile sample to conduct measurements. One half of the class uses digital calipers and the other uses rulers or scales. The length of the samples is 6.000 inches, the full extension of the caliper jaws 6.000 inches, the width 0.500 inches, and the thickness 0.125 inches.

Students who use the calipers are taught its basics as a measurement tool. Explanation is given on zeroing the calipers, manipulating the caliper jaws around a part, and reading the calipers in different measurement systems. Different system of units, when each is appropriate in industry, and converting between each system are also explained. The presence of both system of units on the scale, opposite to each other, is a great opportunity to discuss how many millimeters make an inch and the relative size of each.

Students first take the dogbone specimen and sketch its shape on the paper, and measure its length, width, and thickness. A diagram drawn on the whiteboard in the front of the class shows the proper way to create the sketch and dimension lines. After the students have taken the measurements and completed their drawings, the concept of manufacturing variation is introduced through the idea that these parts milled in our machine shop will not be exactly identical when many parts are made. Every student might have a slightly different measurement technique, their tools might have variation, and the parts themselves have manufacturing variation. Students then exchange their measurement tools so they have exposure to both rulers and digital calipers.

Conclusions:

The current paper demonstrates the successful partnership of Baker College of Flint with several local middle schools for hosting half-day outreach activities in engineering. Three hands-on activities in the areas of mechanical and civil engineering are described in detail. Students learned about the behavior different types of plastics by performing simple identification tests. They were able to determine the yellow light time for an intersection through basic principles of physics, and arrive at conclusions about how to time traffic lights. Students appreciated the learning of how successive layers of material are formed under computer control to create an object in 3D printing. It is hoped that the outreach activities, in addition to creating an interest in STEM careers, would also inspire students to attend our middle school and high school summer camps. We plan to continue this format with some enhancements to improve student learning and engagement.

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Biography

Dr. Pattabhi Sitaram is Associate Professor and Chair of the Department of Engineering at Baker College in Flint, Michigan. He worked in the automotive industry, primarily at General

Motors, for fifteen years as crashworthiness simulation and methods development engineer, and a Subject Matter Expert for plastics, composites and foam materials. He hast taught extensively at both undergraduate and graduate levels in Civil and Mechanical Engineering disciplines. His research interests include Finite Element Analysis & Design, Crashworthiness, Vibration, Structural Stability, and Plates & Shells.

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Mr. Tom Spendlove is an Assistant Professor in the Department of Engineering at Baker College in Flint, Michigan. He teaches Engineering, CAD, and machining courses. He moved to academia from industry after working for ten years in product design in the automotive field. His areas of interest and study are 3d printing, the design process, and engineering education.

Dr. Anca L. Sala is Professor and Dean of Engineering and Computer Technology at Baker College of Flint. In addition to her administrative role she continues to be involved with development of new engineering curriculum, improving teaching and assessment of student learning, assessment of program outcomes and objectives, and ABET accreditation. She is a founding member of Mi-Light Michigan Photonics Cluster, and is active in the ASEE, ASME, and OSA professional societies serving in various capacities.

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