An Outlook on the Future of Packaging: An engineering project based method for STEM education

Kim K. Smith[1] and David Tonjes[2]

[1]Department of Technology & Society
Stony Brook University, State University of New York (SUNY)
1424 (old) Computer Science Bldg.100 Nicolls Rd. Stony Brook, NY 11794-4404
Tel: +1 (516)-637-5119, Email: kim.k.smith@stonybrook.edu

[2]Department of Technology and Society
Stony Brook University, State University of New York (SUNY)
1424 (old) Computer Science Bldg.100 Nicolls Rd. Stony Brook, NY 11794-4404
Tel: +1 (631)-632-8518, Email: david.tonjes@stonybrook.edu

Abstract

The results of an experiential learning project in the field of solid waste and resource management are presented, as these relate to material recovery, recycling and reuse. A project-based learning method was employed in a course titled "Packaging Research" which was part of the school's Science and Technology Entry Program (STEP). The goal of this project was to introduce twenty-five (25) high school students in 9th and 10th grades, who met eligibility criteria coming from low income households in New York State, to the concepts of scientific discovery. The students, who self-selected to enroll in the course, had mathematical and scientific study deficits. The focus of the six Saturday class sessions was on issues associated with the accuracy and precision of measurements, using weights of packaging and materials in a variety of household products. Most of the products were chosen to parallel those used in a prior report published 25 years ago by the Office of Technology Assessment (OTA, 1989).

Keywords

Science and Technology Entry Program (STEP), solid waste, consumer packaging, source reduction, lightweight

Introduction

This study aims to investigate the learning perspective of the students of the Science and Technology Entry Program (STEP) by reporting a quantitative assessment of the course. Laboratory techniques, data management and class management were the activities used to achieve the goals. Initial results indicate that students' motivation to learn and apply the required mathematics and scientific discovery skills improved over the course of this particular class. Long-term effects on student achievement will be assessed upon review of future data.

In the United States, consumer packaging consists of 30% of total discarded waste, and is comprised of items purchased daily (USEPA, 2015). Decreasing the amount of packaging would also decrease the amount of waste disposed in the waste stream. Waste management costs money to accomplish, so decreasing the amount of garbage in the waste stream is in our financial interest. Sustainability is also linked to the total amount of waste disposed (Costi, Minciardi, Robba, Rovatti, & Sacile, 2004), as increases in packaging production also increases the exploitation of natural resources to make such products (USEPA, 2015). The extraction of natural resources is expected to increase from 85 to 186 billion tonnes over the next 34 years (UNEP, 2016). If the amount of raw materials used for packaging can be decreased and recycled materials can be substituted for new packaging, it is possible to create a more sustainable materials use system. Resources are lost when materials are discarded (McDaniel & Fiksel, 2000). From the perspective of society, taxpayers, and citizens, reducing waste enhances efficiency and is beneficial to the environment. From the perspective of industry, the effects may be ambiguous due to the extensive use of polymers in consumer products. In this work, the main focus is on the societal perspective. A reduction in the amount of packaging sent to landfills and incinerators decreases the amount of pollution associated with packaging management and the amount of carbon dioxide released into the environment, and thus leads to a diminished effect on global warming and climate change (Struijs, 2006).

The packaging resources course in STEP introduced the concepts of solid waste and consumer packaging to high school students. Using this educational environment to raise awareness provided students with information to inspire better purchasing decisions and to be conscious of how creating wastes affects the environment. In addition, the course developed some basic analytical skills for converting this information to practical knowledge and policy.

This approach is relatively unique, although research and engineering design teaching has been used to motivate students, by addressing key science content in packaging research. One packaging engineering class focused on deconstructing real packages as a means of introducing engineering (Snyder & Painter, 2014). Other Science, Technology, Engineering and Mathematics (STEM) educators have focused on the art and design education which involved an eight (8) step design process in their curriculum (Bequette & Bequette, 2012). Emphasis on pollution and the environment has also been the focus of elementary education in other studies (Bitting, 2012; Purzer, Duncan-Wiles, & Strobel, 2013).

Methodology

The class was offered in the spring semester of 2016 at Stony Brook University, Stony Brook, New York. Twenty-five 9th and 10th graders from the Long Island school districts of Brentwood, William Floyd and Longwood Central enrolled in "Packaging Research," a research project that focused on packaging and recycling. These self-selected participants had various reasons for enrolling in this course. In the US the educational process is competitive within high school classrooms and has brought sufficient attention to state policy (McGuinn, 2014). The program was also multifaceted since it involved efforts to enhance the participants' emotional health, cognitive skills, involvement of parent's interaction in students' education and academic performance. The research was tailored so that the participants could achieve higher grades than non-participants at the end of the school year. In this study, random selection of participants was not possible.

Packaging research addressed the analysis of materials that enclose almost everything purchased. Packaging is used for protection, advertising, to provide products with recognition and to communicate the description of the contents. Packaging and branding play a role in a consumer's decision to purchase a product. Also, packaging reflects the manufacturer, the brand name, the price and the contents of an item. Most of us can give examples of things that have been bought where there seems to be too much packaging. This class discussed packaging in terms of its materials and amounts. During the class, the students were asked to carefully measure how much packaging was used in common, everyday products, using modern, state-of-the-art equipment to weigh packaging, and to determine the ratio of packaging to product. Also, they were asked to compare measurements with historical reports. These two activities helped to understand how materials usage has been changing over time, and provide a basis for understanding towards more sustainable materials. This class therefore helped students develop good measurement skills, and expanded their ability to critically analyze data sets across several dimensions. The course introduced students to technological issues in society. It explored underlying scientific and engineering concepts, ethical issues, and technological risks.

A pre-test was given to the students to evaluate their knowledge prior to taking the class. It was designed to understand their background knowledge, and how much they understood about the environment. Some of the questions were: define the scientific method; what was the largest anthropogenic greenhouse gas in the US; what is an experiment, and define scientific theory. Many of the students had a general idea of these concepts, very few were able to provide detailed explanations. When the questions were reviewed, many of the students asked for more information on group testing and lab activities reporting. The open discussion implied that they showed interest in the field and the course they signed up for.

Packaging is an element of solid waste. Therefore, the following four main topics were discussed; kinds of waste; waste generation; solid waste; and, management methods in solid waste. Overarching concepts included increases in global population, the rise in demand for food, and consumer spending responsible for increases in the amount of waste being generated daily. Waste that is not properly managed can result in health hazards and the spread of infectious diseases. The "5 R's" of waste management that were stressed: refuse, reduce, re-use, recycle and recover.

Central scientific topics were metric measurements and the basics of the scientific method. It was important to improve students' knowledge of scientific inquiry by using mathematical analysis and engineering design. The international system of measurement (metric system) was defined and the standard units for length, temperature, volume and mass were discussed. Prefix notation was also identified. The instruments used to measure these units were identified. Two simple experiments were developed and constructed so that the students had to make observations, construct hypotheses, make measurements, test hypotheses, and evaluate data.

i. Paper airplane engineering. The students were asked to construct an airplane and measure how far the plane flew. They were asked to construct and test the

hypothesis. In the computer lab, the students transcribed their results into a formal report that included their objectives, materials, procedure, data tabulation, plots, discussion and conclusion.

ii. Students were asked to measure their height and weight. Accuracy and precision were key tools. They were given a hypothesis and asked to test it. The hypothesis was: "Height in centimeters divided by weight in kilograms' equals 4 cm/kg." The reports similar to the first experiment also included their objectives, materials, procedure, data tabulation, plots, discussion and conclusion.

The second session was introduced by a multiple choice quiz. The questions covered methods in municipal solid waste, waste generation, landfilling and incineration, a partial review of the previous session. The focus of this session was on packing materials. These included textiles, metal, glass, plastic wrap, laminated plastic wrap, structured plastic, paper and cardboard. The goal was to introduce the advantages and disadvantages, chemical properties and physical properties associated with each material.

Two video clips were shown to the students: "Recycling for Kids with Waste Management's Mr. Cool Can" and "A Day in the Life of Your Garbage and Recyclables" (SunnyvaleRecycling, 2009; WasteManagement, 2009). The first recycling video depicted the lifespan of paper, plastic, glass and aluminum through the waste management material recovery facility. The second video showed the journey of trash and recyclables in the Sunnyvale Materials and Transfer Station in Sunnyvale, California. Emphasis was placed on manual and automatic sorting processes for recycling and waste disposal as well as landfill waste reduction.

Following this the design and function of food packaging was observed. This included keeping food clean, preventing physical and chemical changes of food and the marketing appeal of food. The students were asked to consider all that they have learned so far and come up with a potential list of items to be examined in a more comprehensive packaging study. The first introductory phase was introduced with a survey on disposable products and recycling around the community.

- What types of products do you buy?
- How much of the product do you buy?
- Do you consider buying alternatives to disposable products?
- What do you do with disposable products when you are finished with them?
- Are you aware of opportunities for plastic recycling in your community?
- Are you aware of opportunities for glass recycling in your community?

The main project on the packaging research experiment was completed after multiple classroom sessions. The objective of this main experiment was to evaluate packaging trends over a period of time and to make a comparison of data collected by the Office of Technology Assessment from 1988. The materials for this experiment were divided into laboratory equipment and consumer/household products. They included the following:

- Brant Triple Beam balance
- Famili Digital Kitchen Food Scale (Electronic)

- Measuring cups and spoons – 2.5 ml ($\frac{1}{2} tsp.$), 5ml ($1\ tsp.$), 7.5ml ($\frac{1}{2} tbsp.$), 15ml (1 tbsp.), 30 ml ($\frac{1}{8}\ cup$), 60 ml ($\frac{1}{4} cup$), 125 ml ($\frac{1}{2} cup$), 250 ml (1 cup)
- Glass beakers – 50, 100, 250 ml
- Measuring cylinder – 3L
- Latex gloves

The items used in this experiment were as follows; Tropicana orange juice (8 oz.), Stop & Shop frozen concentrated juice (12 oz.), Bumble Bee Tuna (8 oz.), Birds Eye green beans ((10 oz.) microwaveable), Del Monte Can Green Beans (14.5 oz.), Dannon yogurt 4-pack (4-4 oz.), Pudding cup 4-pack (4-3.75 oz.), Mueller's Old Fashioned Egg Noodles (12 oz.), Tide laundry detergent (pods box 37 oz.), Tide laundry detergent (pods package 12 oz.), Milk 2% carton (1/2 gallon.)

The students were asked to first describe the item they were given by either taking a picture or writing a brief description of the item. Then they were asked to measure the gross product weight, product weight alone and packaging weight. Each measurement was done three times. Reporting requirements included:

- What was the gross weight of the product?
- What was the product weight alone?
- What was the packaging weight?
- Tabulate the readings.
- What item did you measure?
- What material was it made of?
- What problems did you face in the experiment?
- Is there any way you could have improved your experiment?
- What observations did you make from the experiment?
- Is there room for improvement in the design of the packaging?
- Would you design the product differently?
- Can you compare this item to any other item e.g. competitor, different packaging?
- Name a few other items you are interested in exploring?
- What did you learn from this experiment?

As part of the experiment the students were given a computer lab tutorial. The students were also introduced into a computer laboratory environment. The computer lab rules and policies were explained to the students at their individual stations. They were introduced to the Microsoft Office Suite. The discussion in the computer lab included lessons on how to write a scientific lab report using the paper airplane experiment as an example. Within the lab report, the students were asked to create a table and a plot.

The students were asked again to write up their final measurements of the packaging study and submit their reports to an online drive where all the material were stored. In the final assessment, the students were asked to write about what they learned and discuss their experiences.

Results and Discussion:

The students demonstrated growing interest in the course. They were enthusiastic about the experiments. They developed online skills such as tabulating, graphing and report writing. In their written evaluations about the experiments and research packaging experience, the outcome seemed rewarding. The following is a collection of their opinions and acquired information during the progression of the class.

A. Many students stated that they learned how to use a triple beam balance while others emphasized that the lessons on the units of measurement changed their way of thinking and also enhanced their knowledge. When asked about the packaging, many students observed that the packaging and containers of certain items appeared to be more efficient than others. An example of such finding included spices and grated cheese that had different packaging spout qualities. Others stated that excess and additional packaging is due to the outer casing of items. When considering the design of packaging, manufacturers should use materials that would be less harmful to the environment.

B. In another assessment, many students stated that they were aware of opportunities for plastic and glass recycling in their communities. When asked if the students considered buying alternatives to disposable products, they stated that using cloth towels instead of paper towels is one example. Others identified the use of re-usable Tupperware instead of paper products and the multiple re-use of Ziploc and brown bags.

C. The lessons were designed for the students to gain knowledge and how they applied this to their interaction with their environment. They were asked if they acknowledged anything new about packaging when they went home and how would they used this to teach their family and friends that are not taking the class about recycling, waste management and packaging. The results were positive and reflected a change in their awareness. One student stated that he acknowledged that his parents bought more fresh food and not as much canned items because of processing. Another stated that health plays a role in packaging. The experiments encouraged the students to read packaging labels. They acknowledged that some packaging material were a waste of raw materials. A clearer understanding of the effort that goes into packaging was noted. The students had a new perception of plastic water bottles and a new appreciation for reusable bottles. Composting is an alternative to disposing waste. Recycling is helpful tool to prevent us from wasting materials. Batteries and electronics need to be disposed of carefully. Recycling helps the amount of volume of trash deposited into landfills. Packaging materials weight less than the contents they are protecting. The more waste disposed, the more harm is done to the planet.

D. I. The videos were used to visualize the life cycle of solid waste and bring awareness to the landfills. The students stated that they have learned things that they would have not thought about or cared for before taking the class. Certain packaging materials are wasteful and unnecessary. They acknowledged that they should try to reuse materials such as water bottle, plastic bags and containers. They had a new understanding of where all garbage goes after it is disposed.

II. In the final assessment the students were asked to give an overview of the course and state what they had learned. Some of the responses were as follows:

I learned how waste is processed.
I learned how to recycle, reuse and reduce.
My favorite part of the class was the experiments.
I learnt things that I would have not thought of or cared for before I joined the program.
I learned how to write a report in a lab.
I learned if you want to get an accurate measurement, you need to do it 3 times.
I learned that certain packaging on products are really wasteful and unneeded.
I never thought about garbage and how much humans produce.
This course was super interesting and informative.
I remember the video when they said we should not throw out batteries, so when I was cleaning I remembered that and I put them to the side.

E. I. The students had several misconceptions during the course discussions. Some of those are listed below.

- Plastic was perceived as the greatest percentage of weight of solid waste.
- The best embodiment of qualities of a scientific theory was perceived as "students who study for their environmental science exams will perform better on those exams than those who do not." The correct answer for the best embodiment of qualities of a scientific theory was "all gases, liquids and solids consist of atoms."
- Carbon dioxide was thought to be the most abundant greenhouse gas. However, carbon dioxide is produced during the combustion of fossil fuels.
- In a controlled experiment, the researcher does not control the effects of only one variable, but the effects of all variables except one.
- Mass burn is a European concept that uses solid waste to generate electricity but not catalytic incineration.
- The largest source of anthropogenic greenhouse gases in the United States is electricity generation, followed by industry and not transportation.

II. Some of the problems students faced were creating a hypothesis. Some students failed to identify measurable variables. Others thought that a prediction of the end result is a hypothesis. Some students stated factors and variables that were not part of the experiment. Generally, the students started of the class by showing difficulty in creating a hypothesis.

III. When the students were asked to generate or prove the hypothesis after the lecture, it was found that the first experiment many had some trouble in understanding how to carry out the task. However, by the time they got to the second exercise on generating the hypothesis, they were able to easily do so. Therefore, the experiments they carried out helped in their understanding.

F. The items purchased from the grocery list were chosen based on similarities of the products found on the list compiled by the OTA (OTA, 1989). A list of data on products listed by the OTA and the items purchased for the project. The items collected by the OTA depicted weight measurements of total weight (ounces), product weight (ounces),

package weight (ounces), contents/package ratio, percentage packaging of contents, percentage packaging of total and total cost per ounce. Items on the list such as Minute Made Frozen concentrate and Del Monte microwaveable green beans appeared to be replaced by items in the supermarket such as Shop & Stop frozen concentrate and Birds Eye microwaveable beans. This data was collected in 1988 while the project data was collected in 2016. The need for the replacements could be attributed to consumer affinities over the 18 year period (de Boer & Schösler, 2016). Consumers need for convenient packaging could have also been the explanation for the changes in the products over the time (Welford, Hills, & Lam, 2006).

An example of such difference is Tide Laundry detergent, which came in a box in 1988 in the form of a powder where the percentage of packaging was 9.1. Even though it can still be purchased in a box, the Tide laundry detergent is available in a concentrated form as pods. The PODS are tossed directly into the wash where all parts of the packaging dissolve. In 2016, the percentage of packaging was calculated to be 12.73 percent. The difference in 2016 was that Tide came in a plastic container for protection of the dissolvable pods. The use of liquid Tide was not measured in this experiment. Even though the percentage of total packaging showed an increase in the use of a solid plastic container, the plastic bag showed that it only accounted for 4.17 percent of packaging. A trend from cardboard to plastic is observed.

Figure 1 shows a graph of the OTA data package weight plotted against the project data used in the course. The mean weight of package of the OTA products was less than that of the project data. The mean weight of the OTA data was 2.2 ounces while the mean weight of the project data was found to be 1.7 ounces. The packaging of items in the OTA data that were lighter than the project data included a half gallon milk carton, a Tide box, and a Minute Maid Juice carton. The packaging of items in the project data that were lighter than the OTA data included the Tropicana orange juice box 8 oz., Bumble Bee Tuna (8 oz.), Birds Eye Green Beans plastic packaging (10 oz.), Del Monte Can Green Beans (14.5 oz.), Dannon yogurt 4-pack (4-4 oz.), Pudding cup 4-pack (4-3.75 oz.), Mueller's Old Fashioned Egg Noodles (12 oz.), and Tide laundry detergent (pods package 12 oz.).

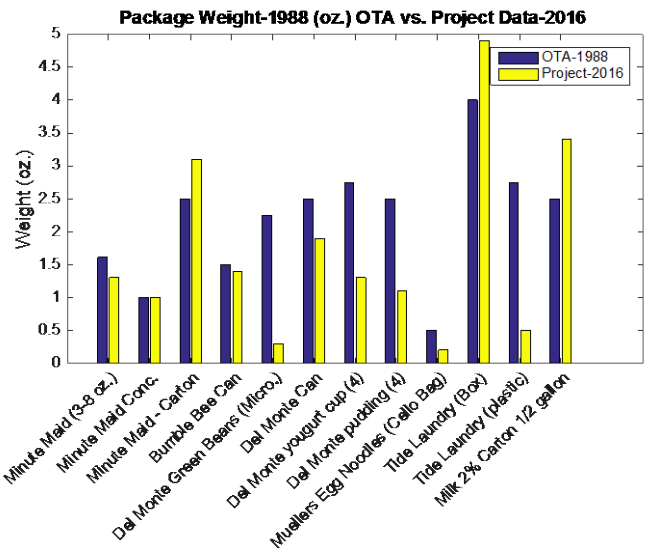

Figure 1: Comparison of Packaging Weight between the OTA (1988) and Project Data (2016)

The percentage of packaging of the total item is shown in Figure 2. The environmentally conscious consumer shows preference to packaging that is green and sustainable. After all, packaging satisfaction ends on the shelf. The data from the experiment shows that metal packaging such as the tuna can and the Del Monte can have had a greater percentage of packaging of the total. Paper and plastic reflect lesser percentages of packaging.

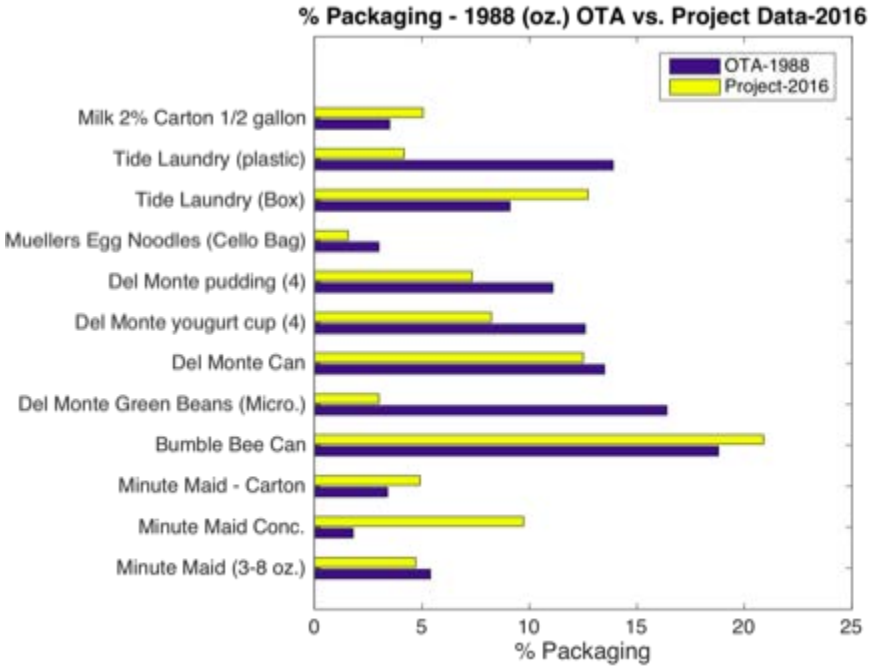

Figure 2: Comparison of Percentage of Packaging between the OTA (1988) and Project Data (2016)

Another noteworthy trend is the evolution of the packaging of Coca-Cola. Industry has shown the progression of the coke glass bottle started in 1915. The aluminum can (12 oz.) was introduced in 1960. The PET contour bottle (20 oz.) was introduced in 1993. In 2008, the aluminum bottle was introduced. Luckily, in 2009 a plant bottle was made of 100% recyclable where 30% was renewable (Ryan, 2015).

Conclusion:

The experiments helped students to observe how the daily use of recyclable and lightweight products would be in terms of efficiency and effectiveness. The results of the activities were evaluated according to students' satisfaction, comments, and a final laboratory report. The students were exposed to college life; learn the skills for writing lab reports, introduced to the scientific method, as well as about the process of solid waste.

Generally, the experiment went successfully though there were a few things that could have been improved. Pre and post experiment tasks could have been implemented including setting up measuring experimental material and thorough clean up afterwards. Instructor approval could have been given at the point of completion of the experiment. The students needed to provide a thorough

description of the items under study such as physical description and photograph for this experiment. Manufacturer history could have been explored during the computer lab hours. The experiments could have been timed. Demonstrations could have been given prior to the experiment.

The experiment conducted was preliminary work using preliminary data. This was a short, one time course to expose the students to the concept of scientific experimentation and all it encompasses. It would be interesting to follow up this group of students in their school performances, their report writings, and their logical discussions and understanding of the scientific concepts and compare them with other students who were not attending this course.

Further studies are recommended to take into consideration the above suggested improvements and a more controlled group of students who could be followed through the rest of their high school studies. These sets of planned studies will generate a portfolio that could very well be utilized in the educational establishments to improve the students' learning of the very important concept of environmental studies and the impact that each minor element in our daily lives could have on the climate change, global warming, and on a healthier environment for the future generations,

References:

Bequette, J. W., & Bequette, M. B. (2012). A Place for Art and Design Education in the STEM Conversation. *Art Education, 65*(2), 40-47.

Bitting, J. (2012). oh the thinks you can think. *Children's Technology & Engineering, 17*(1), 18.

Costi, P., Minciardi, R., Robba, M., Rovatti, M., & Sacile, R. (2004). An environmentally sustainable decision model for urban solid waste management. *Waste Management, 24*(3), 277-295. doi:http://dx.doi.org/10.1016/S0956-053X(03)00126-0

de Boer, J., & Schösler, H. (2016). Food and value motivation: Linking consumer affinities to different types of food products. *Appetite, 103*, 95-104. doi:10.1016/j.appet.2016.03.028

McDaniel, J. S., & Fiksel, J. (2000). *The lean and green supply chain [electronic resource] : a practical guide for materials managers and supply chain managers to reduce costs and improve environmental performance*: Washington, D.C. : United States Environmental Protection Agency, Office of Pollution Prevention and Toxics, [2000].

McGuinn, P. (2014). *Presidential Policymaking: Race to the Top, Executive Power, and the Obama Education Agenda.* Paper presented at the The Forum.

OTA. (1989). *Facing America's Trash: What Next for Municipal Solid Waste*. Washington, DC: Government Printing Office.

Purzer, Ş. s. p. e., Duncan-Wiles, D., & Strobel, J. (2013). COST or QUALITY? *Science & Children, 50*(5), 34-39.

Ryan, T. (2015). The Story of the Coca-Cola Bottle. Retrieved from http://www.coca-colacompany.com/stories/the-story-of-the-coca-cola-bottle

Snyder, M., & Painter, D. (2014). THINK INSIDE THE BOX package engineering. *Technology & Engineering Teacher, 73*(6), 32-39.

Struijs, J. (2006). Is cumulative fossil energy demand a useful indicator for the environmental performance of products? *Environmental Science and Technology*(3). doi:10.1021/es051689g

SunnyvaleRecycling (Producer). (2009). A Day in the Life of Your Garbage and Recyclables. Retrieved from https://www.youtube.com/watch?v=Prigs6dLLCQ

UNEP. (2016). *Resource Efficiency: Potential and Economic Implications*. Retrieved from

USEPA. (2015). *Advancing Sustainable Materials Management: 2013 Fact Sheet* (5306P). Retrieved from

WasteManagement (Producer). (2009). Recycling for Kids with Waste Management's Mr. Cool Can. Retrieved from https://www.youtube.com/watch?v=629clJ5VZFc

Welford, R., Hills, P., & Lam, J. (2006). Environmental Reform, Technology Policy and Transboundary Pollution in Hong Kong

Development and Change Volume 37, Issue 1. *Development and Change, 37*(1), 145-178. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.0012-155X.2006.00473.x/abstract