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Beverage engineers: Creative international STEM project

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Abstract
Students have an opportunity to participate in a creative engineering / international STEM project, prepared and facilitated by the authors. They are challenged to create their best tasting, nutritious fruit juice. In addition, they are asked to provide a catchy name and to design a special container for their drink. This project is an international collaboration between professors in the United States and Japan. It is a preliminary investigation and relates to various topics in education including chemistry and chemical engineering (the fruits, etc. contain various chemicals with different properties), materials science (students select a specific material such as glass or plastic for storing their drinks), and creative design (students design attractive containers for their beverages). In addition, this activity is an exercise in entrepreneurship, because it gives the participants a chance to invent and name a potential, new product for consumers.

Keywords: Creative education, multisensory approach, STEM, engineering education, teamwork, fruit juice, entrepreneurship.

Introduction
STEM education focuses on the teaching and learning of science, technology, engineering, and mathematics, STEM. (Kanematsu & Barry, 2016). This includes all grade levels from pre-school to post-doctorate positions (Chen, 2009; Gonzalez & Kuenzi, 2012). STEM education, especially when combined with creativity, is essential for all countries wanting to strengthen their power and status. World leading countries need a sufficient supply of qualified STEM graduates to creatively solve challenging problems and compete globally. Therefore, it is important to introduce students (of all ages) to the STEM components and motivate them to pursue studies in

these fields. For our purpose, we refer to creativity as the ability to produce original ideas, items, and services, and to combine existing ones in different ways for new purposes (Kozbelt et al., 2010). Creativity involves higher levels of thinking (like synthesis and evaluation in Bloom's Taxonomy) and is important for all areas of education (Bloom & Krathwohl, 1956; Hicks, 2015). Each field of study has problems to solve that rely on creative ideas for the possible solutions. Educators need to assist students in the processes of discovering and developing their creative potential in order to become the innovative scientists, engineers, and entrepreneurs of the future (Ward, 2004).

Barry initiated a program (in collaboration with Kanematsu) to promote creativity and combine it with STEM education at the international level (Barry & Kanematsu, 2006; 2007; 2008; 2010). The Creative Education program includes various teaching methods and activities for both the real and virtual world (Barry & Smith, 2008; Barry & Kanematsu, 2007; Kanematsu & Barry, 2011; Barry et al., 2009; Stimulating Interest in Science, 2009; Kanematsu et al., 2014; Barry et al., 2014; Barry et al., 2015; Dharmawansa et al., 2014; Barry et al., 2012) . One of the teaching methods is called the Multisensory Teaching Approach (Chemical Sensation Project), which was developed to meet the learning style needs of all students (Barry, 2003; Kanematsu et al., 2003; Barry et al., 2003; Barry et al., 2013). Some learn by seeing, while others learn by listening, or carrying out hands-on activities. This method requires instructors to incorporate the use of the senses (examples: seeing, smelling, tasting, and touching) into their science lessons and engineering design projects. To complement the Multisensory Teaching Approach, the authors prepared a STEM activity "Beverage Engineers," which was successfully carried out by students at Osaka University. Their work is presented and described.

Beverage activity begins

A variety of drinks are consumed each day by people throughout the world. Some, like milk and orange juice are nutritious, while others such as non-diet sodas contain sugar and lots of calories. This international, creative education activity provides students with a problem to solve, which is actually an opportunity for them to design their best tasting, nutritious fruit juice. The project is a preliminary investigation where the participants carry out research in a laboratory setting as they follow the steps of a typical Engineering Design Process. This process includes a problem to solve, data collection, design requirements, the generation and evaluation of possible solutions to the problem, etc. (Horenstein, 2006). Students (as Beverage Engineers) work in teams of two or three members and use a variety of fruits (five to ten different types) to prepare an innovative drink. Also each group is asked to write a name and recipe for their beverage and to design an attractive container for promoting it at the marketplace. This lesson encourages students to use their senses (examples: taste and smell) to analyze fruits and their juices in order to propose something new, a creative drink. It also nurtures communication skills and the planning capability of science and engineering students because they need to solve several problems as a group effort.

At Osaka University, eight teams (of two students each) were provided with five different fruits (oranges, bananas, seedless grapes, apples, and peaches). To start, they washed the fruit. Then the students carefully analyzed each type to determine its physical properties such as color, shape, size, smell, taste, surface texture, etc. See Figure 1. The information was recorded in the "Fruit's Physical Properties" section of their Data Chart. Their general observations showed that the orange was round and seedless, had an orange color and was not so sweet. It had more of a sour taste. The banana was mostly yellow with a curvy shape, had a strong smell, and was sweet if ripe. The grape was seedless and small, purple in color, had an oval to round shape, and tasted sweet. Each apple had a reddish/yellow color and the cut pieces quickly turned brown (oxidized) when exposed to air. The peach was mainly a red to pink color, with some yellow, and had a fuzzy skin. Both the peach and apple were somewhat sweet.

Figure 1: Students analyze various types of fruit.

The participants also used computers and iPads to find out the health benefits of each fruit. This information was recorded on the Data Chart. All of the fruits used in this activity are nutritious and contain vitamins. A brief statement is provided for each one. Oranges are rich in Vitamin C, which helps to strengthen our immune systems (Ware, November 18, 2015). Bananas are high in potassium and pectin, a form of fiber (Ware, January 11, 2016). Potassium helps regulate fluid balance in the body and controls the electrical activity of the heart and other muscles. On the other hand, fiber helps maintain bowel health. Grapes contain vitamins, minerals, and anthocyanins with antioxidants (Ware, January 9, 2016). The human body produces free radicals which cause illnesses, etc. Antioxidants counter the damaging effects of free radicals. Apples are high in fiber and Vitamin C (Nordqvist, 2016). Peaches are a good source of Vitamins A and C (Ware, February 9, 2016).Vitamin A is important for good vision.

Materials

Each team used the following materials to carry out this special drink project. They had 3 oranges, 1 banana, 1 bunch of seedless grapes, 2 apples, and 2 peaches to make a specific juice for each type of fruit. Other materials needed for this activity were 8 large cups (5 for each individual juice type and 3 for each potential best tasting, nutritious fruit drink), labels, plastic spoons, plastic knives, small paper cups for students and judges to use for sampling the juices, bottled water, paper towels, juicer & small bowl to hold the juice, blender, calibrated measuring cups, etc. computer, iPad, Data Chart, and Fruit Juice Combination Chart. The students also had a store bought container of juice to examine.

Fruit juice preparation procedures

In order to reduce the number of experimental variables, the teams used the same procedures (developed by the authors) to prepare a specific juice for each fruit. The fruit juice preparation procedures are provided.

Orange Juice: Use a plastic knife to cut 3 oranges in half. Then squeeze them using a juicer. Collect & save the juice in a labeled container.

Banana Juice: Remove the skin from a banana. Then put small pieces of 1 whole banana into a blender. Add 1 cup of water & blend one minute on a medium setting. Save & label the juice.
Grape Juice: Put 1 cup of seedless grapes and 0.5 cups of water into a blender. Blend for 1 minute. Save & label the juice.
Apple Juice: Remove the stem, core, and seeds from 2 apples. Put small apple pieces and 1 cup of water into a blender. Blend for 1 minute & save the juice in a labeled container. See Figure 2.
Peach Juice: Remove pits from 2 peaches. Put small pieces of each peach & 1 cup of water into a blender. Blend for 1 minute. Save & label the juice.

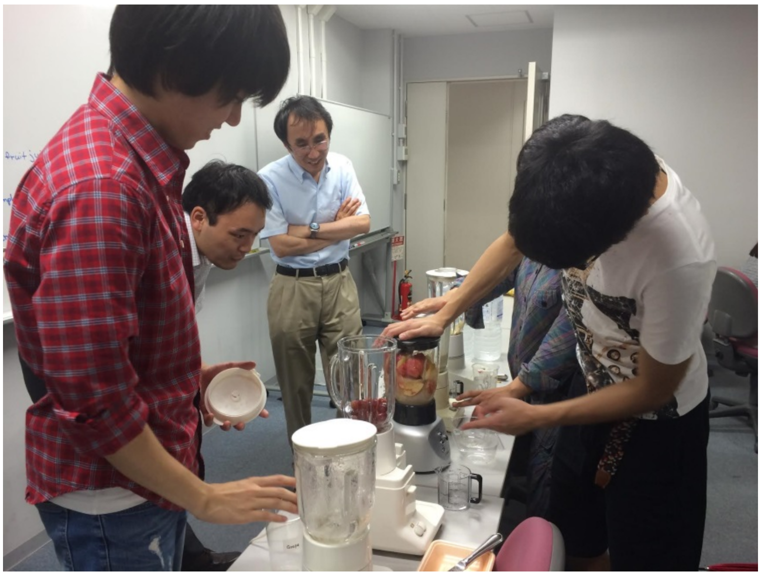

Figure 2: Students use blenders to make grape and apple juice.

After preparing all individual fruit juice types, the team members closely analyzed them to obtain information about their appearance, smell, taste, etc. Since this was a multisensory activity, the methodology (for evaluating both the fruits and fruit juices) focused on the use of our senses. In regards to taste, the bottled water did not really have any. Acidic fruits, like oranges and their juices, tended to have a sour taste. Fruit /juice like grape, tasted sweet because it contains sugar. Of course, the sense of taste depends on an individual's taste buds, etc. (Owen, 2015). Students used their eyes (sense of sight) to determine the attractiveness of a drink and their nose (sense of smell) to determine its aroma. Juice consumers make judgements using their senses too. All juice data was recorded in the Fruit Juice section of the Data Chart. General observations of the juices indicated that the banana, apple, and grape juices were foamy (mainly due to air bubbles). The orange juice was orange. The banana juice was an off white color and the grape juice was purple. The apple juice appeared thick and light brown in color. The peach juice was brown too. Also the banana juice and orange juice had a strong smell. NOTE: Students who used ripe fruit prepared sweet fruit juices. The degree of sweetness tends to increase with an increase in sugar content.

Students were encouraged to obtain more information about each juice by using simple equations and instruments available in their laboratories. For example, the density of each juice could be determined by using the following equation.

Density = Mass per unit Volume. $D = M/V$

One needs a clean, graduated cylinder to measure the volume of juice and a scale to determine the mass of that amount of juice.

Colorimetry is used to determine the concentration of colored compounds in solution (Colorimetry, 2016; Chen et al.2016). This technique may be useful for colorful fruit drinks. Take the food dye Allura Red as an example. Its concentration can be determined by measuring the absorption of light through the solution. The concentration of an unknown solution containing Allura Red is determined by measuring its absorbance with a colorimeter that has been calibrated for Allura Red. In order to do this, a stock solution must be prepared, from which four solutions of known concentration will be made. The absorbance of each is measured and then graphed versus concentration (x-axis) to give a calibration plot. The absorbance of the unknown sample is located on the y-axis of the graph. Its corresponding concentration can be found on the x-axis. Both concentration and solution length are allowed for in the Beer-Lambert Law (Clark, 2016).

An interesting article that relates to this work is titled “Peak Response Identification through Near-Infrared Spectroscopy Analysis on Aqueous Sucrose, Glucose, and Fructose Solution,” (Omar et al., 2012). It describes near infrared spectroscopy analysis for sugar solutions.

Alternatives for the best tasting nutritious drink

It is essential for beverage engineers to exercise their critical and creative thinking skills. Therefore during this preliminary investigation, the student engineers carefully analyzed and evaluated the fruit and fruit juice information on their Data Charts. As a team, they discussed it and decided the desired properties (engineering design requirements) needed for their best tasting, nutritious drink. A particular color, smell, thickness, and degree of sweetness, etc. were selected for their beverage. Each group created plans (recipes) and used them to prepare three alternatives (possible solutions) for their best tasting, nutritious drink. If a drink was to be sweet, then appropriate juice(s) and their correct amounts needed to be combined in order to make the best tasting drink. Of course, various amounts of each added juice could be adjusted several times until the team was satisfied with the taste. A similar procedure was also used to produce the best final drink’s color, density, etc. Therefore, all changes and adjustments made to each alternative drink were incorporated into the final recipe for that drink. It is true that recipes for fruit drinks exist. However, many store-bought juices contain colored sugar water (Boulton et al. 2016). Osaka University students used their senses, items available in the laboratory, and their obtained fruit/juice information to combine fruit juices in a new way. They created drinks with a unique color, aroma, taste, etc.

The alternative drinks were closely analyzed and evaluated (taking into account the beverage’s engineering design requirements). This information was recorded on the Fruit Juice Combination Chart. Finally, each of the 8 teams selected their best tasting, nutritious drink (all of which contained orange juice). Since there were 8 best beverages, several instructors judged them to determine the best tasting, nutritious drink of all the participants. The winning drink was prepared by Team 5 and consisted of 40% orange juice, 30% apple juice, and 30% grape juice.

NOTE: The recipes for each team’s alternatives and best tasting, nutritious drink are provided on Table 1.

DATA CHART

Fruit	Physical Properties	Health Benefits	Fruit Juice Properties
Orange			
Banana			
Grape			
Apple			
Peach			

FRUIT JUICE COMBINATION CHART
(List Fruit Juices Combined and Amounts of Each. Also List other Information such as Appearance, Smell, Taste, etc.)

Alternative 1:

Alternative 2:

Alternative 3:

Solution to the Problem: List the best alternative.

TABLE 1: Team Alternatives & Best Tasting, Nutritious Drink

Team Number	Alternative #1	Alternative #2	Alternative #3	Best Drink
1	50% banana juice, 50% orange juice	50% banana juice, 50% peach juice	33 & 1/3 % of each: orange, grape, & banana juice	Alternative #3
2	33 & 1/3% of each: grape, orange, & apple juice	50% peach juice, 50% banana juice	50% orange juice, 50% apple juice	Alternative #3
3	30% orange juice, 30% peach juice, 30% grape juice, 5% apple juice, & 5% banana juice	30% grape juice, 25% peach juice, 20% orange juice, 15% apple juice, & 10 % banana juice	20% of each: grape, orange, apple, banana, & peach juice	Alternative #1
4	25% of each: apple, orange, grape & peach juice	33& 1/3 % of each: peach, grape, & orange juice	40% orange juice, 40% grape juice, & 20% banana juice	Alternative #1
5	50% orange juice, 50% grape juice	40% orange juice, 30% apple juice, & 30% grape juice	40% grape juice, 30% orange juice, & 30% banana juice	Alternative #2 **(Selected by Judges as best drink.)**
6	50% peach juice, 50% orange juice	50% orange juice, 50% grape juice	20% of each: peach, banana, orange, grape, & apple juice	Alternative #1
7	40% peach juice, 30% grape juice, & 10% of each: orange, banana, & apple juice	50% grape juice, 25% orange juice, & 25% banana juice	50% peach juice, 25% apple juice, & 25% orange juice	Alternative #1
8	25% of each: peach, grape, orange, & banana juice	33& 1/3 % of each: grape, apple, & orange juice	50% orange juice, & 50% grape juice	Alternative #3

Names and container designs for the best drinks

Students examined fruit juices purchased at the store. They noted the name, bottle design, and ingredients. A container of mango peach juice consisted mostly of sugar and water. It was only 5% juice. The backside of its plastic bottle was indented inward for an easy grip with one hand. A plastic container of cranberry juice was also analyzed. It was more nutritious than the mango peach juice. The drink contained cranberry juice, Vitamin C, potassium, etc. Its bottle had a narrow neck to provide an easy grip.

Next, each team was asked to create a name and design an attractive container to promote their drink to consumers. They also selected a material (such as glass or plastic, etc.) for their container. Results for two student teams are displayed in Figures 3 and 4. In Figure 3, a student shares the plastic container design for the best drink of Team 3. See Table 1. The bottle is shaped like a leaf and has a unique cap. This drink is called Nafreco. It has color, is fresh, and comes from nature. The name was derived from the following words.

Nature + **Fre**sh + **Co**lor = Nafreco

Figure 3: A student describes the container design for the best tasting, nutritious drink (called Nafreco) of Team 3.

Figure 4 contains the design for the plastic container to hold the best tasting, nutritious drink of Team 5 (selected as overall winner for best drink of the 8 teams). See Table 1. This container holds 3 different juices, with each in a separate section. A slurry is at the bottom of each section. Such a versatile container allows consumers to drink individual juices (orange, apple, or grape) or to combine them by shaking the bottle. This special drink is called Shaking Fruit.

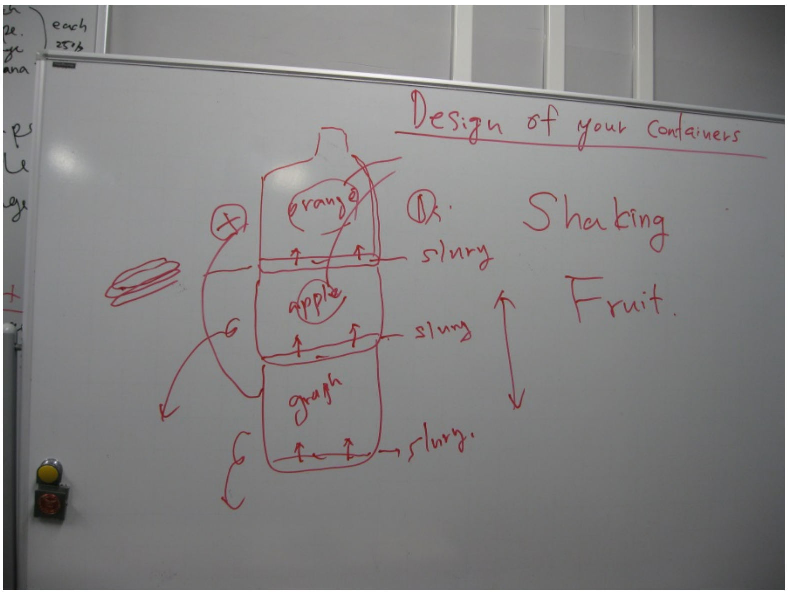

Figure 4: This is the container design for the best tasting, nutritious drink for Team 5. It is versatile and allows consumers to drink individual juices (orange, apple, or grape) or to combine them by shaking the bottle.

Conclusion

This educational project, which complements Barry's and Kanematsu's international program in Creative Education, was between professors in the United States and Japan. It provided students at Osaka University with an opportunity to create their best tasting, nutritious fruit juice. They (as Beverage Engineers) worked in teams of two members and used a variety of fruits (five different types) to prepare an innovative drink. Also each group wrote a name and recipe for their beverage and designed an attractive container for promoting it at the marketplace. This lesson encouraged them to use their senses (examples: taste and smell) to analyze fruits and fruit juices in order to propose something new, a creative drink. It also nurtured their communication skills and planning capability because they needed to solve several problems as a team effort.

This is an excellent activity for engineering education /STEM (science, technology, engineering, and mathematics). Also it is a great exercise in entrepreneurship, because it gives the students a chance to invent and name a potential, new product for consumers.

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