Introducing Chemical Reactions Concepts In K-6 Through A Hands-On Food Spherification And Spaghetti–fication Experiment

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Abstract

Recruiting students in STEM majors to fill the gap in STEM workforce is a continued challenge, which can be addressed by introducing scientific principles through hand-on activities to the students at an early stage. This paper presents the design, implementation and assessment of a chemistry-related workshop for sixth grade students that were recruited through the local City School District program. The students were introduced to the concepts in chemical reactions through "food spherification and spaghetti–fication". The workshop included 1) pre- activity survey, 2) a short lecture on chemical reactions and the hands-on activity procedure, 3) hands-on activity to form spheres and spaghetti from fruit juice and, 4) post- activity survey. The participants included 15 female and 2 male students mostly from underrepresented communities. The long term goals of this program include 1) design and implementation of a safe, reproducible, economical scientific hands-on activity, and 2) increased participation of local middle school students in summer programs at the blinded university.

Introduction

There needs to be an increased enrollment and recruitment in Science, Technology, Engineering, and Mathematics (STEM) majors in order to address the needs of the future workforce. As a result, several programs have been developed in the recent years that focus on science and technology related hands-on workshops hosted by the local universities (Ronald et al., 2010, Rogers et al., 2005, Gupta, 2015). The intent of these programs are to familiarize the students to the university environment and combine STEM content with activity-based learning (Elam et al., 2012, Raines, 2012, Pecen et al., 2012, Nazier et al., 2014). Other school programs include in-class activities involving new tools, projects and demonstrations (Rivoli et al., 2009). It is imperative to plan the activities that concentrate on simple exercises to enforce the concepts and encourage exploration (Schmidt et al., 2012, Perrin, 2005, Rogers et al., 2005).

The STEM workforce plays a vital role for any country as STEM fields tend to provide the most innovations and allow for continued success in generating new jobs, technology, and opportunities for further improvements. The advances provided by the STEM workforce allow for continued competition on a global level and help to limit dependence on foreign technology for modern improvements. On a national level, promoting STEM education by mandating necessary classes for graduation and providing new equipment to help with STEM classes have been used in an attempt to raise interest in STEM programs (Atkinson et al., 2010). Individualized efforts to promote STEM interest seem to heavily focus on summer camps or workshops dedicated to activity-based learning for students. These then track the progress of students for following semesters (Elam et al., 2012, Raines, 2012, Pecen et al., 2012, Nazier et al., 2014). Projects run on a classroom scale have also been implemented, using special tools specifically built to encourage activity-based learning, concentrating especially on younger grades (Schmidt et al., 2012, Perrin, 2005, Rogers et al., 2005).

These methods are not perfect; enforcing more STEM classes on all students instead of allowing for selective participation often leads to boredom within classes, and those students who have a genuine interest are another face in the crowd instead of people that stand out. Additionally, concerns with demographic metrics and equal participation in STEM majors can lead to less applicants with no quality change and may even decrease the potential pool (Atkinson et al., 2010). For summer camps, availability of the programs is a problem in itself, but encouraging students to participate in these programs, giving them a new way to learn, and then sending them back to classes that provide the same scope of learning they previously experienced can prove to diminish their interest in the semester classes (Raines, 2012). Activity based learning is highly adaptable, and a variety of available experiments and tools can help increase the interest in students of all ages. Activities are used in many of the summer camps and encourage student participation. Many activities or tools can be explored at several different levels and brought back in subsequent years to help students connect new ideas with old knowledge.

The availability of low-cost STEM activities is especially important given the potential difficulty in access and equity for different regions of the country. Areas with economically disadvantaged people or rural areas with less students and therefore less funding have more difficulty accessing resources to increase interest or participation in STEM activities. They tend to see fewer students pursuing STEM majors or education past high school and need something to allow students to see the benefit of STEM projects (Elam et al., 2012). Low-cost activities increase the availability for economically disadvantaged areas. The more versatile the activities there are, the more they can useful because they can be reinforced and reused as knowledge base and can increase the ability to understand natural phenomenon. Additionally, low-cost activities that can be performed outside of school, could allow further exploration by interested students.

The novelty of this activity lies in the age group it is meant to capture. Introducing the concept of chemical reactions to a younger audience allows for greater initial understanding of a subject that often does not receive thorough illumination until later years, and can help clarify the subject when it becomes an essential topic of study. Additionally, clearing common misconceptions about what a chemical reaction is (e.g. water and vinegar instead of baking soda and vinegar) can help spur understanding of more complex chemical reactions. Encouraging interest in this subject at a younger age is also helpful in promoting further interest and exploration outside of the classroom.

Chemistry education is difficult at all levels of comprehension. Connecting macroscopic demonstrations or theoretical models with microscopic concepts, using language with colloquial meanings that differ from their scientific counterparts, introducing unfamiliar concepts, and enforcing memorization over understanding are all issues connected with teaching chemistry overall (Gabel, 1999). For younger children especially, like those in the K-6 set, connecting real-world or physical ideas that are already observed or understood allows for greater understanding among pupils and brings credence to the demonstration in their minds (Kelter et al., 1988). It is easier to understand concepts by relating them to past knowledge; therefore, having the students present the information they already know throughout the activity can help enforce the connections made during the demonstration.

Workshop Activities	Duration	Learning objective
Lab safety and introduction	20 mins	To Familiarize students with lab space including the locations of emergency exits, eye wash, spill kits, fire-extinguisher
Pre-activity survey	15 mins	Learning assessment
PowerPoint based lecture	20 mins	To introduce chemical reactions, factors affecting chemical reactions, and hands-on activity
Hands-on activity	40 mins	To use chemical reactions to form spheres and spaghetti from the juice by changing experimental parameter
Post-activity survey	25 mins	Learning assessment

Table 1. Summary of workshop activities and learning objectives

Rochester Institute of Technology (RIT) is a home to various K-12 programs that provide academic enrichment, pre-college STEM education, college preparation for Rochester's high school and middle school students from the local district public schools. The students participate in a variety of programs on campus and learn applications-based science, technology, engineering, mathematics, college and career exploration, and teamwork to broaden their perception of technology that may impact their career choices. Beyond 9.8 is one of such initiatives, held annually at the RIT for sixth-grade students from Theodore Roosevelt Elementary School. The student participants of this program have the opportunity to explore a variety of STEM topics through various engaging activities with RIT faculty.

This paper summarizes a food-science based Beyond 9.8 workshop activity that is simple, cost-effective, and safe with active learning assessment survey that can be adopted by school teachers to demonstrate the applications of chemical engineering in food science.

The main objectives of this workshop were to:

1. Introduce K-6 students to the application of chemical reactions in food science with a brief introduction to the factors that influence the rates of reaction
2. Demonstrate the importance of shape controlling factors in food manufacturing process (formation of spheres and spaghetti)

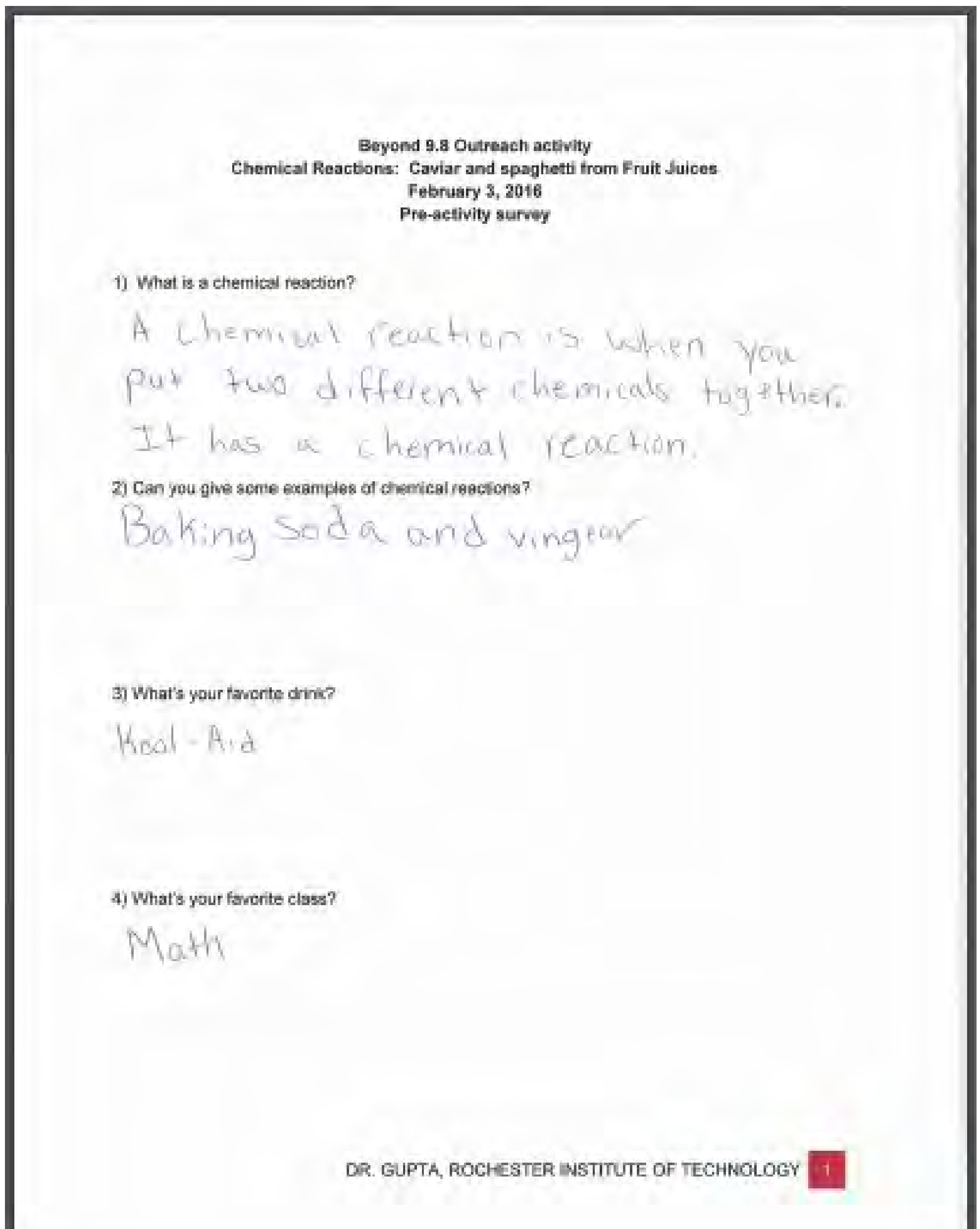
Workshop Activities and Learning Outcomes

This workshop was divided into three main components: brief lecture, hands-on activity, and pre and post-activity surveys. Table 1 summarized different activities, duration and their corresponding learning objectives.

The total duration of the workshop was 2 hours. The first 20 mins of the workshop was dedicated to lab safety familiarizing the students with the laboratory space and location of emergency exits, eye wash, shower, spill kits and fire extinguisher. The students were then given a set of pre-survey questions. Fig. 1 represents a sample pre-activity survey that demonstrates some level of understanding of chemical reactions of a K-6 student. The questions included- a) What is a chemical reaction? b) Can you give some examples of chemical reactions? c) What is your favorite drink? and d) What is your favorite class?

Table 2 summarizes the common responses to the definition of a chemical reaction and the examples. Based on the responses it was clear that the concept of chemical reactions was known to the students at a very basic level.

The next 20 mins involved a lecture on chemical reactions that included definition, visual real-life examples, visual classification of chemical reactions (combination of the reactions to form product, breaking down of the reactants, reactants changing the combinations) as shown in Fig 2 (left). The students were given a detailed description of the hands-on activity explaining the underlying chemical reaction that is taking place (Fig 2 center and right).
Figure 2: Summary of the lecture (left) classification of chemical reactions, (center) description of the hands-on


Beyond 9.8 Outreach activity
Chemical Reactions: Caviar and spaghetti from Fruit Juices
February 3, 2016
Pre-activity survey

1) What is a chemical reaction?

A chemical reaction is when you put two different chemicals together. It has a chemical reaction.

2) Can you give some examples of chemical reactions?

Baking soda and vingear

3) What's your favorite drink?

Kool-Aid

4) What's your favorite class?

Math

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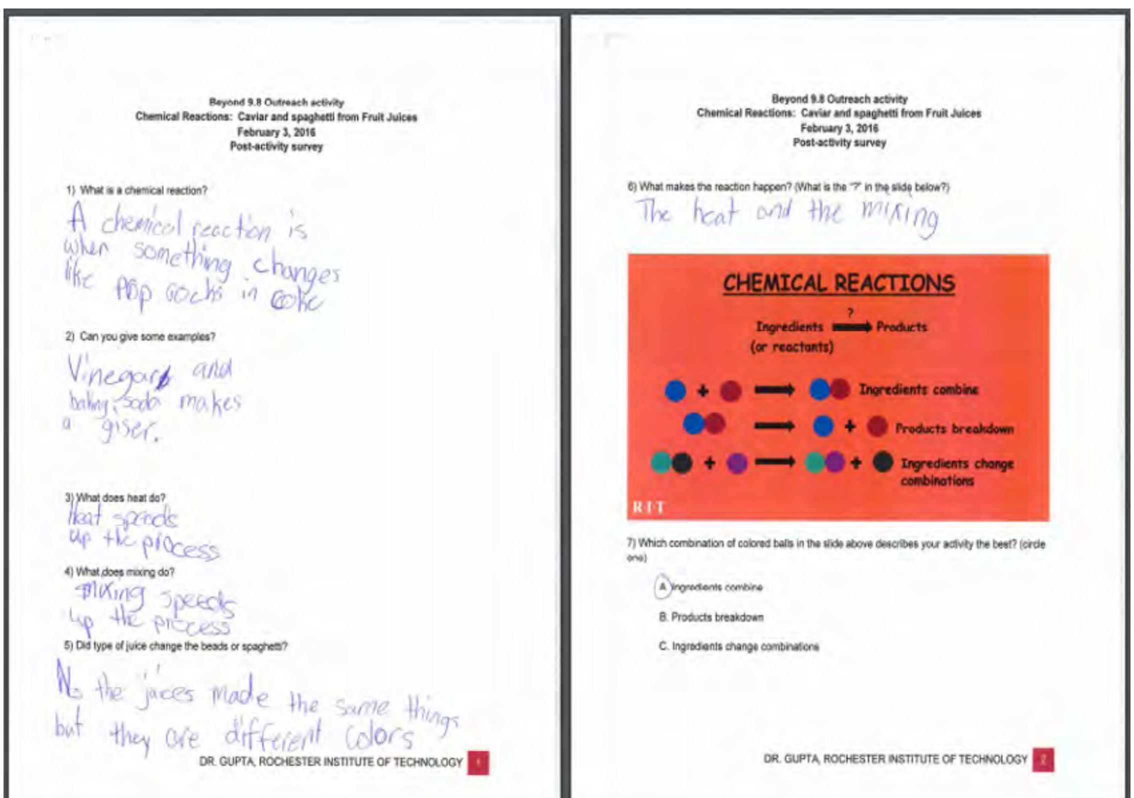
Figure 1. Sample of the pre-activity survey

Pre-Activity Survey Questions	What is a chemical reaction?	Examples of chemical reactions
Common Responses	*"A chemical reaction is when two things are mixed, when chemicals meet"*	*"Baking soda and vinegar", "borax with glue and water", "pop rocks and soda", "food coloring and liquid"*

Table 2. Common or repeat answers to the two primary questions on the pre-activity survey

Figure 2. Summary of the lecture (left) classification of chemical reactions, (center) description of the hands-on activity and (right) underlying chemical reaction of the hands-on activity

Figure 3. Hands-on activity pictures showing (left) student making calcium chloride stock solution, (center) addition of juice and alginate mixture to form spheres, and (right) juice and alginate mixture forming spaghetti



Beyond 9.8 Outreach activity
Chemical Reactions: Caviar and spaghetti from Fruit Juices
February 3, 2016
Post-activity survey

1) What is a chemical reaction?
A chemical reaction is when something changes like pop rocks in coke
2) Can you give some examples?
Vinegar and baking soda makes a giser.
3) What does heat do?
Heat speeds up the process
4) What does mixing do?
Mixing speeds up the process
5) Did type of juice change the beads or spaghetti?
No the juices made the same things but they are different colors

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Beyond 9.8 Outreach activity
Chemical Reactions: Caviar and spaghetti from Fruit Juices
February 3, 2016
Post-activity survey

6) What makes the reaction happen? (What is the "?" in the slide below?)
The heat and the mixing

CHEMICAL REACTIONS
Ingredients (or reactants) → Products
Ingredients combine
Products breakdown
Ingredients change combinations

7) Which combination of colored balls in the slide above describes your activity the best? (circle one)
A. Ingredients combine
B. Products breakdown
C. Ingredients change combinations

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Figure 4. Post-activity participant surveys.

activity and (right) underlying chemical reaction of the hands-on activity

The workshop activity designed for this workshop was food science based due to a) student's familiarity and daily-life experience of the subject, b) safety reasons, and c) most importantly, creating next generation workforce in a specific STEM field to fulfil the upstate New York's food and agriculture industry needs which is funded by the governor. According to the Rochester report Jan-Feb 2016 publication, \$500 million funding was awarded to a governor's regional initiative to support three areas including a) food and agriculture, b) phonics, imaging, and c) 3D printing, energy storage. 20% of the region comprises of farm land supporting 19,000 jobs in food and agriculture industries.

Food spherification was introduced and patented by W J S Peschardt in 1946 as a novel was to create artificial cherries which was adopted in early 2000s by the restaurants to create artificial caviar. The spheres or thermally irreversible solid gel are created from fruit juice in presence of calcium chloride salt and sodium alginate by replacement of sodium ions by calcium ions, which then form cross links with the alginate molecule. The chemical reaction between calcium chloride salt and sodium alginate produces sodium chloride-
$2NaAlg + CaCl_2 \rightarrow CaAlg_2 + 2NaCl$

The students were divided into groups of two at separate work stations. 0.5 g of sodium alginate was mixed in 100 g of Sunny D orange juice and Welch's grape juice in a household juice blender at the instructor's work station. The juice and sodium alginate mixtures were maintained at room temperature and at 40°C to demonstrate the effect of temperature on the reaction. The juices was chosen based on their distinct bright colors. Some students chose to mix the orange juice and grape juice to form different colors as shown in Fig 3. Stock solutions of calcium chloride were prepared by adding 1.25 g of calcium chloride in 250 g of deionized water in plastic cups (Fig 3 left). Each group was given four plastic cups for formation of spheres and spaghetti at room temperature and at 40°C. The juice alginate mixture was introduced into the calcium chloride bath with a syringe and a turkey baster held approximately 4 cm above the calcium chloride solution level as shown in Fig 3 center. The juice and

Post-Activity Survey Questions	Common Responses
What is a chemical reaction?	A chemical reaction is something that happens when ingredients are mixed, when something changes, things get combined and make something new
Examples of chemical reactions	The grape and orange juice with salt water, baking soda and vinegar, Mentos and soda, putting salt in water, shaking soda
What does heat do?	Makes it stir faster, makes the reaction process faster, speeds up the process, makes it work better
What does mixing do?	Mixing makes the reaction process faster, helps things combine, a slower way of heating
Did the type of juice change the beads or spaghetti?	The type of juice did not change the beads or spaghetti, changed the color, the grape juice made spaghetti and the orange juice made beads
What makes the reaction happen?	The heat, mixing, the salt, the sodium alginate
Which combination of colored balls in the slide above describes your activity the best?	Ingredients change combinations, ingredients combine

Table 3. Summary of student responses on the post-activity survey

alginate mixture was allowed to sit in the calcium chloride bath for 1 minute and the resultant spheres/spaghetti were scooped out using a slotted spoon. A 50 mL syringe yielded small spheres that looked like beads due to the small diameter of the tip. The turkey baster produced longer spaghetti like shapes owing to the large diameter tip that let out larger volumes of the juice alginate mixture. The 40°C solutions formed well defined shapes in less time.

The workshop was concluded by a post-activity survey to assess the learning outcomes of the activity (Fig 4). First two questions- What is a chemical reaction, and Can you give some examples of chemical reactions, were repeated on the post-activity survey as measures of the effectiveness of the activity and lecture as a whole.

The final section of the demonstration was the post-activity survey, designed to test the effectiveness of the demonstration in teaching the concept of chemical reactions. The first two questions from the pre-activity survey were repeated, and additional questions, 'What does heat do?', 'What does mixing do?', 'Did type of juice change the spheres or spaghetti?', 'What makes the reaction happen?', and 'Which combination of colored balls in the slide above describes your activity best?', were asked to guide students in the desired learning objectives of the demonstration. Figure 4 shows a couple of participant responses for the post-activity survey.

The surveys were designed with three components in mind: repetition of key concepts or ideas, guided questions to reinforce ideas presented, and comfortability of students answering. The pre-survey presented two main ideas that related to the activity as a whole (what is a chemical reaction and what are some examples of chemical reactions) and two additional questions designed to make the students feel more comfortable filling out the survey (favorite class and favorite drink). The pre-survey introduced the key takeaway concept without pushing the idea too hard so the students could understand what they were expected to concentrate on for the presentation and activity. The post-survey reinforced the importance of ideas shown on the pre-survey, in the presentation, and in the demonstration and outlined additional points demonstrated by the activity that the pre-survey did not touch.

The surveys were anonymous (no names) but handwriting was matched as best as possible in an attempt to track the effectiveness of the exercise. There was no formal scoring, but comparing the repeated survey questions did demonstrate a key concept: students tended to repeat or reword ideas that they previously emphasized. Those with a good initial answer tended to keep their original ideas but incorporate the newer concepts into their work; those with initial answers that were not as accurate tended to have a harder time producing an accurate answer in the post-survey. This demonstrates an essential idea behind teaching: it is harder to unlearn a wrong lesson than learn a right one. Key misconceptions need to be identified and corrected before they can permanently seed in a student's mind and simple activities such as the one presented in this paper are good ways of finding these misconceptions.

There were a total of sixteen participating students, and we analyzed the data in two ways: we searched for common, repeated answers present in the pre- and post- surveys and used those to develop the table. We also matched pre- and post- surveys as best as we could with handwriting to be able to make a direct comparison between the two. We found that students tried to include ideas that they heard in the presentation regardless of relevance: they tried to say something about the ideas presented but did not necessarily make the connections we wanted them to make. A good number of students used examples in the post-survey that we presented or that other students had used before and we had specified as correct. Most often, a student would present a concept of a chemical reaction in the post-survey very similar to the one presented in the pre-survey. Table 3 summarized the common responses to each answer for the post-activity survey. The students were handed recipe cards with describing the lab activity.

Conclusion

This workshop – a) introduced K-6 students to the application of chemical reactions in food science with a brief introduction to the factors that influence the rates of reaction and b) demonstrated the importance of shape controlling factors in food manufacturing process (formation of spheres and spaghetti). The students were also introduced to basic lab safety principles to the students. Overall, the students were successful in a) demonstrating their understanding of the lecture on chemical reactions, and b) follow a lab procedure to evaluate the effectiveness of factors that influence a chemical reaction. While the students were greatly enthusiastic and able to grasp the new concepts easily overall, their initial willingness to participate was low, and they had trouble recognizing and casting aside the misconceptions of chemical reactions they previously had. This activity is an effective low-cost activity that can prove fun for children, but would likely work better integrated into a longer chemistry lesson where the students learn about a chemical reaction, review more on it to cement the idea, and then participate in the activity. As previously mentioned, students learn better with ideas that they are familiar with or can connect to concepts they understand; the reinforcing technique utilized in this activity would be better utilized in a unit with a longer time span.

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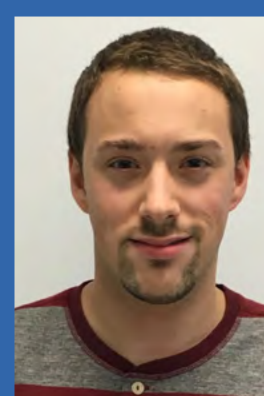

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