Fun with Fluids: K-12 Outreach in Graduate Studies

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Abstract

An interactive lesson plan was delivered by an engineering graduate student at the experimental school at University of Florida in November 2017. The plan introduces molecules and bonds in the context of surface tension via interactive experiments and presents the work of a graduate student at the K-12 level. Experiments will address learning standard NGSS MS-PS1-2. Surface tension is introduced and demonstrated through several hands-on experiments and discussions. The aim of this project is to promote discussion with a researcher and popularize sciences in K-12. Evaluations for this work are carried out via a pre- and post- quiz for the students and input from the teacher.

Keywords

outreach, K12, fluid sciences, surface tension, chemical bonds

Background and Introduction

It is important to introduce STEM careers to young students prior to the career decision-making process that begins in high school. There is also an incentive to conceptualize a practical application of the subjects that students are learning in school to careers in the real world. For example, many students will learn about concepts involving chemical bonds, atoms, and reactions. However, it may be difficult to extend these concepts to real-world activities. Thus, a graduate researcher with background in industry and academia would be a valuable guest speaker and instructor for middle school students learning crucial science topics.

Lesson Plan and Implementation

The developmental research school at University of Florida was determined to be an appropriate location for this effort. A sixth-grade science teacher at the institution, was happy to accommodate a guest activity for her students. A corresponding lesson plan was developed to 1) engage the students in dialogue with a researcher, 2) complete experiments and explain concepts pertinent to class material addressing the performance expectation NGSS MS-PS1-2: "*Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred."*, and 3) evaluate activity effectiveness.

The 5E lesson plan model was used for this process, which stands for "Engage, Explore, Explain, Extend/Elaborate, Evaluate". Engagement began with the researcher showing a biographical presentation about research and background, followed by a discussion of current understanding of surface tension and molecular interactions. The experiments were then introduced, and each student was given materials and a worksheet which was filled out during the activity.

"Explore" and "Explain" took place in a series of three separate, but related experiments exploring surface tension. Each experiment was guided via the activity sheet and involved the student making a prediction, testing the prediction, and explaining what happened. The first experiment was "how many drops of water fit on the surface of the penny?". Students would take a plastic pipette and carefully find how many drops fit while noting the shape of the water on the penny. The second and third experiments involved testing what happens when soap interacts with water. In the second, pepper is sprinkled on a water-covered plate and soap is applied by a q-tip. The spreading of the pepper to the outside of the plate is observed. In the third, a paper "boat" is placed on the surface and students can propel it forward by placing soap behind the boat. While these activities took place, both teacher and research instructor monitored the students while they were conducting the activities, asking probing questions like "What is the shape of the water on the penny?" or "What happens to the paper boat?".

Figure 1. Students predict and test how many water drops fit on the surface of a penny, with surprising results.

Figure 2. Students propel a paper boat forward using soap.

"Extend/Elaborate" took place in a casual discussion with the entire class where surface tension was introduced to the class as molecules "holding hands" (explained to be a bond) at the surface of the liquid. Soap is introduced as a "surfactant", something that decreases this surface tension. Thus, each experiment was elaborated upon in detail to extend this concept to the behavior of the water. For example, the curvature of the water was due to the water molecules holding themselves together against gravity. The pepper moved to the outside of the plate because the stronger surface tension towards the outer edges of the plate were stronger than the weakened surface tension near the soap. Similarly, the boat moved forward because the water "pulled" it away from an area of low tension. This activity culminated with a video of a parabolic flight explaining that these effects can even be seen in microgravity.

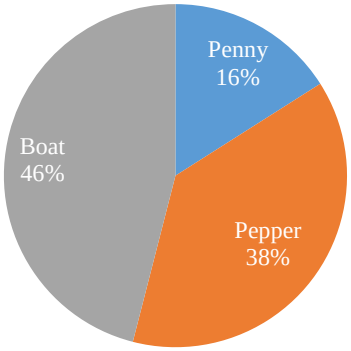
"Evaluation" was carried out via a quiz prior to and following the class activity. Both quizzes asked students to define surface tension and extend it to real-life scenarios (i.e. who would use this science in real life?). Evaluation also consisted of the teacher's impression of lesson effectiveness.

Results and Evaluations

Student Performance

It was clear, through both observation and student input from the activity worksheets (figure 3), that students enjoyed each experiment. Students would compete with how many drops they could fit on the pennies, shout out in amazement at the pepper experiment, and avidly explain what was happening.

Figure 3. What was your favorite experiment?



In the experimental activities, the students were asked to predict the number of drops of water that would fit on the surface of a penny. The average guess was 10 drops, compared to an average of 26 observed drops. The students were asked to comment on their observations, and many were surprised. Since these experiments took place in the "exploration" phase, the students were not yet introduced to surface tension and thus this result confirmed that students did not have much prior knowledge of this subject. They were also asked to draw what they saw, indicated in figure 4.

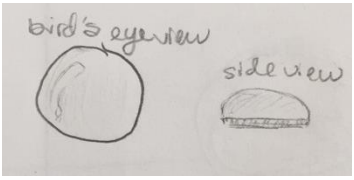


Figure 4. A student's illustration of water on the surface of a penny.

Similarly, in activities 2 and 3 (pepper and boat experiments), students were asked to predict and then comment on results. A "before" and "after" drawing was performed with satisfying results. Students frequently made surprising connections between what was seen on the penny and these experiments. In addition to expected behavior (pepper moving to sides, boat propelling forward), the students noticed unique, unexpected phenomena involving post-it notes curling up and began explaining the processes.

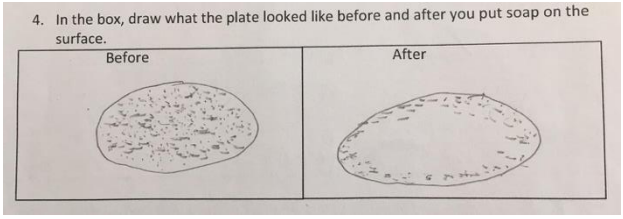
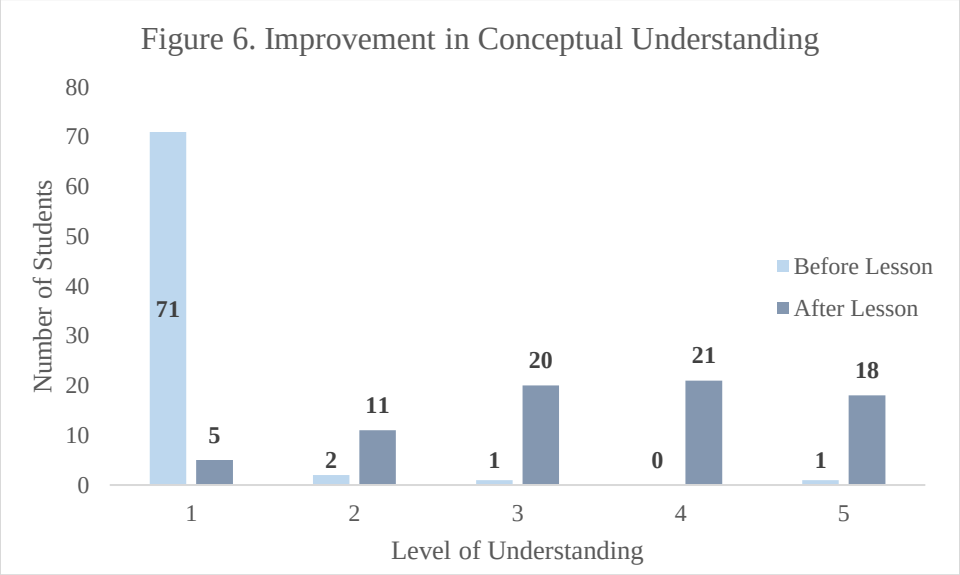


Figure 5. A student's illustration of the behavior of a pepper-covered water surface when soap is added.

The effectiveness of the lesson was determined by addressing the learning goal, "What is surface tension?" both prior to and after the activities and discussion (in the pre- and post- quiz). Student's responses were evaluated on a scale of 1-5, as described in the below table and shown in figure 6.

Rating	Level of Understanding

1	No concrete understanding of concept
2	Below average understanding; recognizes term “surface tension”. Knows it involves fluids.
3	Average understanding; mentions phenomena involving surface tension without defining
4	Adequate understanding, mentions interactions between molecules or “holding hands”
5	Excellent understanding, links interactions between molecules to tension at the surface and/or describes surfactants



These improvements, while slightly different for separate classes, demonstrated improvement or adequate introduction of surface tension as a scientific concept.

Teacher Evaluation

The teacher was very helpful in establishing areas of improvement in this lesson plan. A series of short-answer questions was given to the teacher, inquiring about 1) parts of the lesson that were more/less effective than expected, 2) appropriateness of topic and its explanation, 3) time issues, and 4) general areas of improvement.

The activities were determined to be effective, although time allotted was slightly too long and some distractions ensued. Prior to the activities, the research instructor presented a brief background of interesting phenomena surrounding surface tension. The teacher noticed this introduction was more effective than expected because students were making connections between the penny experiment and what they saw in the presented video of floating water droplets in space. The topic and the way in which the research instructor introduced it (water

molecules “holding hands” at the surface) was appropriate for the grade level. However, this could also be improved by including more scaffolding at the beginning of the lesson to introduce the learning goal.

The discussion was less effective than expected, as there was a lack of “formal discussion of the activities”. It is hypothesized that a formal discussion of these activities would positively affect student understanding and extension of activity concepts. Areas of improvement include an explanation portion of the activity worksheet and asking the students to explain a picture of a mosquito standing on a water surface in terms of surface tension, through small group and subsequent whole class discussions.

Summary / Plans for Improvement

In summary, the learning goal of “what is surface tension?” was adequately reached for five classes. Students actively engaged in both the introductory background presentation and the activity processes. However, there were clear weaknesses in the lesson plan, including a lack of thorough formal discussion, excess time during activities, and lack of preliminary introduction of the learning goal. The lesson plan demonstrates considerable potential for 1) introducing molecules and bonds in the context of surface tension and 2) engaging students in insightful conversation with a graduate researcher.

Nevin Brosius

Nevin Brosius is a second year PhD student in chemical engineering and teaching assistant for MEB at University of Florida. Since working as a math tutor at Penn State, he has held a heavy interest in STEM teaching. He has participated in Habitat for Humanity, Hugh O’Brien Youth (HOBY) and Alachua County Engineering & Science Fair. Since entering graduate school, he has led an outreach effort for Graduate Association of Chemical Engineers (GRACE) and has established an educational component as an integral part of his dissertation. In research, he has submitted work in the measurement of surface tension. He acknowledges funding from Florida Space Grant Consortium and UF Alumni Fellowship Program.

Mayra L. Cordero

Mayra L. Cordero has been a 6^{th} grade Science teacher for the past ten years. As a Hispanic female, she embraces cultural diversity and believes that each student has the potential to be successful once they have discovered their unique capabilities. She has worked in collaboration with other teachers in the state of Florida to reform science education in middle school utilizing an inquiry based approach. Her interests also include incorporating technology in her lessons to increase the engagement of underrepresented student populations in STEM related areas.