



## Engagement in Practice: Developing a Sustainable K-12 Outreach STEM Program

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Dr. Katie Shannon is Associate Teaching Professor of Biological Sciences at Missouri University of Science and Technology. She earned her Bachelor of Arts degree in Biology with Honors from the University of North Carolina and her PhD in Cell and Developmental Biology from the Harvard Medical School. She has been active in biology education research since early in her career. She was a fellow in the Seeding Postdoctoral Innovators in Research and Education (SPIRE) as a Postdoc at UNC. In the SPIRE program Dr. Shannon was introduced to the fellowship of teaching and learning. In 2013, she participated in the American Society for Microbiology Biology Scholars Program Research Residency. During her research residency, she conducted research to determine if an assignment achieves the desired learning objectives. At Missouri S&T, she works closely with students on campus in many capacities. She has trained forty undergraduates in her lab, volunteered to run hands on activities for girls' summer camps, and advises pre-med students. She is also a co-advisor of the Missouri S&T iGEM, a synthetic biology student design team. Dr. Shannon's primary teaching role is Cell Biology (BioSci 2213). She used technology to improve the course, utilizing personal response systems (clickers) to increase student involvement and "flipping" one day a week by recording and editing online lectures to better utilize class time for problem solving.

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## *Introduction*

Currently there are several challenges for having a continued innovative workforce in science, technology, engineering and mathematic (STEM) fields. First of all, there is a need to attract a more diverse population of students into the field. Whether a surplus or shortage [1] of STEM workers exist to meet the future demands, it is clear that there is still a need to attract a more diverse group of students into these fields. Certainly, attracting a more diverse group of workers would help ensure that the pool includes the brightest and could ultimately lead to increased innovation in the workforce. Initially, STEM education was focused on the gifted students but integrating a STEM focus into the mainstream K-12 education can provide opportunities for students from many different backgrounds [2].

Second, there is a need to improve the quality of the STEM education at the K-12 level. Citing the need to keep the United States competitive with innovation, the National Academy of Science made recommendations for improvements in STEM education beginning in kindergarten [3]. According to the National Academy of Science, not only is there a shortage of highly qualified K-12 teachers, middle and high school mathematics and science teachers are more likely than not to teach outside their own fields of study. As stated in their text, “A US high school student has a 70% likelihood of being taught English by a teacher with a degree in English but about a 40% chance of studying chemistry with a teacher who was a chemistry major” [4].

One solution to increasing diversity and improving the quality of STEM education stated above could be the use of more project based active learning. Research suggests that student learning is improved when active learning is incorporated using integrated skills from multiple disciplines to solve problems [5],[6]. Improved learning should also result in increased student engagement. If these techniques are utilized systematically at lower levels, the education system would become more effective and more students would be engaged earlier in their education. There are now many existing programs, such as Project Lead the Way and Energy Projects in Community Service-Learning (EPICS) High that are designed to improve problem solving skills for students [7], but many of these programs are focused at the high school level.

Barriers still exist especially at the lower grades that prevent a systematic approach to STEM education. First, the fact that a majority of K-12 science and mathematics teachers are teaching outside their own fields, could explain why instead of utilizing active learning techniques, teachers often use worksheets or other methods of rote memorization. While worksheets can be effective tools for student engagement and directed learning during class, some research indicates that worksheets do not add much value to the learning process [8]. Completing worksheets in STEM related subjects might not be as engaging or useful for the development of critical skills as active learning such as project work. Burr-Alexander and coworkers propose another reason that more students are not interested in pursuing careers in STEM fields is that they are not exposed to relevant topics during their K-12 years [9]. Even if students in high school STEM related classes are exposed to relevant topics, many students have self-selected out

of those classes by that point in their education. And, if topics are relevant to only some of the students, then others might not be engaged because the projects do not fit with their prior knowledge.

### *Project Background and Goals*

Improvements to K-12 education will at best take time to implement and require funding. However there is a need now for more relevant STEM related projects in the classrooms for younger ages. Therefore, an outreach program was implemented to incorporate more project based learning in regional public schools. The middle school, which includes 4th through 6th grades in Rolla, Missouri (home of Missouri University of Science and Technology), was the initial target for this program. The intention was to send a team into the school during class time to introduce and aid the teachers with the implementation of STEM related projects. The program was intended to reach all students but especially those from the lower social economic sector who may have little support or encouragement from home to enter into STEM fields.

The goal was to partner with the teachers not only to demonstrate the effectiveness of project work, but also provide assistance in completing the tasks. The idea was to guide the teachers in the use of tools and techniques that could be successfully utilized to engage the students in STEM related topics and to also learn from them in order to develop best practices.

Having a class of middle schoolers complete activities in the classroom or lab would require more adult to student interaction when conducting some of the planned experiments, so a reliable pool of volunteers was needed. Partnering with Missouri University of Science and Technology (MS &T) students not only provides that pool of volunteers, but also gives the MS&T students an opportunity to give back to the community. For the first semester, volunteers were obtained by simply asking different student groups; several biology students were interested. Currently, a partnership with members of the MS&T track team has been formed. All student athletes at Missouri University of Science and Technology are required to complete community service every semester, a minimum of 1 hour each term. This partnership has indeed provided a source of interested students and will hopefully continue to do so in the future. Future plans include reaching out to other athletic teams in order to have a stream of volunteers regardless of which sport is in season.

Project goals include the following:

- Partner S&T instructors and students with the teachers and students in grades 4-6.
- Incorporate STEM projects into the curriculum and provide tools and supplies needed to complete the projects in a timely manner.
- Create a sustainable program with a stable pool of S&T student volunteers.
- Measure outcomes based on student attitudes toward STEM related topics.

### *Project Framework*

The plan was to work initially with one teacher conducting 1-2 projects each semester with that teacher's students. Each project was to be conducted over 4-6 weeks, using 1-3 hours per week

with the university team present only one hour per week. The work would be completed during class, rather than afterschool in order to reach all students.

Prior to embarking on this project, obtaining buy-in from the Middle School administration was deemed a necessity. The principal of the Rolla Middle School was contacted to discuss project ideas and determine possible options. She was interested in working with our university and made suggestions as to which teachers would be most open to piloting the project. Based on those recommendations, a teacher, who teaches both mathematics and science at the 6<sup>th</sup> grade level, was selected.

For the first semester, one project was chosen for the 6<sup>th</sup> grade students in the pilot class. The class consisted of 27 students. The initial project involved performing a bioassay using radish seeds [10]. Students germinated seeds after exposing the seeds to different dilutions of household bleach. Initially, several sets of seeds were placed in baggies on paper towels. Different bleach dilutions were made and then poured over the seeds. Water was used as the control. The seed growth was then measured over several days to determine the effect of exposure to bleach. The advantages of this project were low cost of supplies and timely germination of the seeds. Radish seeds germinate and grow over three days. After presenting the results of the first experiment, the students were able to decide which household chemical or item to test next. The 6<sup>th</sup> graders formulated a hypothesis and determined the dilutions to study. The process for creating the dilutions and saturating the seeds was repeated. A schedule was created for the university students to meet with the middle school students during class time for 1 hour a week for four consecutive weeks as shown in Table 1. The measurements of seed growth was completed during the school day by the 6<sup>th</sup> grade teacher and her students. Students also calculated the percent growth for the different dilutions, which followed lessons recently completed in mathematics. The university team consisted of two MS&T faculty and three or four student volunteers.

Table 1

| Baggie Bioassay Project Schedule |  |
|----------------------------------|--|
| Week 1                           | University team introduced lesson, discussed scientific method and supervised the making of bleach dilutions. Middle school students wrote their hypothesis. After which, 6 <sup>th</sup> graders measured seed growth for 3 consecutive days. |
| Week 2                           | University team discussed with 6 <sup>th</sup> graders the results of the initial experiments and worked with middle school students to determine which household chemical each team would test next.  |
| Week 3                           | Middle school students brought in the chemicals for testing and the university team aided in the creation of the dilutions. Middle school students then measured seed growth for 3 days.   |
| Week 4                           | The university team viewed the 6 <sup>th</sup> grade team presentations and provided guidance during a discussion about the original hypothesis.   |

During the second semester of the program, it was determined that two projects per semester (of length of 4-6 weeks each) were achievable. The radish bioassay was repeated for the initial project since the class was a new class of middle school students (26 students).

A second experiment was added which was obtained from Teach Engineering [11], an online teacher resource for K-12 students. The activity used was entitled “Does Your Chewing Gum Lose Its Sweetness?” The 6<sup>th</sup> graders formulated a hypothesis after a class discussion of the ingredients in chewing gum. The middle schoolers were required to measure the gum mass and then chew the gum for a specified amount of time. After which, the middle school students allowed the gum to dry in air for several days and then again measured the mass of the gum. This was a fairly simple experiment but was fun for the students and resulted in good discussion. After the initial results were shared with everyone, the university team then worked with the 6<sup>th</sup> graders to devise another experiment. Each team was able to design their own experiment which expanded on initial results. For example, one team wanted to measure sugar loss in several different gum brands. Middle students followed the procedures used previously and reported results. The schedule for the Chewing Gum activity only is shown in Table 2. The 6<sup>th</sup> grade teacher was then able to use the same project with another class (27 students). Middle school students calculated the percent loss of gum mass with each experiment.

Table 2

| Chewing Gum Project Schedule |   |
|------------------------------|---|
| Week 1                       | University team introduced the project, and discussed the properties of chewing gum. The 6 <sup>th</sup> grade students weighted the gum and chewed for 15 minutes. |
| Week 2                       | 6 <sup>th</sup> grade students allowed the gum to dry and then with the help of the university team, measured the weight of the gum again.                          |
| Week 3                       | 6 <sup>th</sup> grade student teams calculate the percent change in the gum mass and discussed their results with the university team.                              |
| Week 4                       | University team and 6 <sup>th</sup> grade teams devised a second experiment. Each team created their own experiment.  |
| Week 5                       | Middle school teams again measured the weight of the gum before and after chewing with the aid of the university team. The gum was allowed to dry during the week.  |
| Week 6                       | 6 <sup>th</sup> grade student teams presented and discussed their results to the university team.   |

The program is currently in the third semester, and the same 6<sup>th</sup> graders from the second term are involved. Therefore, different projects were needed and the decision was made to include more engineering-type projects rather than science based projects. The first project was again based on an activity outlined in Teach Engineering [12]. This activity was entitled “Cool Puppy”. The 6<sup>th</sup> grade students were informed of having found a lost puppy (small stuffed puppy) that is in need of a dog house to protect it from the scorching heat. Students were be given a pretend allowance (\$12) which was be used to purchase materials from the in-house store in order to build their structure. The 6<sup>th</sup> grade teams then designed the dog house such that the inside temperature was suitable for a puppy (less than 32 C) when the outside structure is “out in the sun” (exposed to a heat lamp) for 30 minutes. Several different types of building materials were available for purchase for the students, including items such as cardboard, foil, foam core board, and other items. If students have completed a science section covering colors and their properties of absorbing or reflecting light (as have these middle schoolers), the project should reinforce that subject matter. A discussion on the concept of the flow of heat energy was also conducted prior to the project start. After the students tested their dog houses, they were given a chance to make design revisions based on their results. Students presented their results and ideas for design

changes to the class and the MS&T team. The project was conducted over a 5 week schedule with two class periods utilized for student teams to design and purchase materials for their structure, one class period for building and one for presenting their results and conclusions. For the second project in this semester, a more open ended project is planned where the students be asked what ideas would be of interest.

### *Lessons Learned to date*

Although the program has only recently begun, a list lessons learned to date has been formed as follows:

1. Work to ensure buy-in from the K-12 school administration before proceeding. Approach the process as a partnership, not as one where you are coming in to show them how to teach. Expect to learn from each other.
2. Begin with small projects that require little in terms of a time commitment. The work can be built on, but it is hard to recover and have continued buy-in if too much is taken on initially.
3. Choose projects initially that require little budget or supplies.
4. Select the teachers who are most open to change. Change is hard for all of us, and teachers are no exception. They are often overworked and their classrooms are too large. Some will be more open to trying new ideas or approaches.
5. Work with a team or group of university students to get volunteers. This provides a pool from which to choose and sustainable group as students graduate. Finding and scheduling volunteers can be time consuming otherwise.
6. Utilize only 1 hour per week for the project. This timeline is more doable for the university team and avoids burnout and dropouts.
7. Have fun and make it fun for all the students. Otherwise, why would the students we are trying to reach choose STEM or the university students continue to help?

### *Initial Results*

Although no data has been collected on attitudes about STEM topics, the students did seem to enjoy working on the projects. Initially, not all students participated at the same level, but by the end of the projects, all were actively engaged. The teacher stated that the course material had been reinforced and that it was a positive experience for the students. The middle school teams were able to articulate their findings on the effects of bleach on seed growth and sugar loss in gum after chewing. For the Cool Puppy projects, not all dog houses were successful within the project constraints but those teams were able to communicate reasonably why temperatures were outside the acceptable levels and discuss possible design changes.

### *Future Work*

Future plans include assessing the middle school student's attitudes about STEM careers and expanding the program. Assessing student attitudes both before and after working on these projects for 1 year is our preferred method. Our intention is to use a survey developed by Fabor and coworkers [13]. Expansion of our program, first into other 6th grade classes is desired and then into lower level classes as well. Another option for expansion is for the Middle School

teachers who have worked with us to provide training to their colleagues, which could reduce the need for more university faculty and result in better collaboration between teachers.

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