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Extension - A novel approach to inquiry learning with the 5E's

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Extension – A novel approach to inquiry learning with the 5E’s

Introduction

The 5E's, as described by Roger Bybee, include five instructional phases that support inquiry and learning in the classroom: engagement, exploration, explanation, elaboration, and evaluation (Bybee et al., 2006). Integrated Science Education Outreach (InSciEd Out), a collaborative science education and research program run through Mayo Clinic in Rochester, Minnesota, also utilizes a sixth 'E', extension. While there are many examples of other educators using an extension phase (Jobrack, 2011; NASA eClips, 2017), we believe what they describe is actually a retitled elaboration phase. In contrast, InSciEd Out's extension experience is an adaption of the elaboration phase of the 5E's that engages students in novel scientific inquiry with a goal of creating authentic scientific products that contribute to scientific knowledge (Pierret et al., 2012; Yang, LaBounty, Ekker, & Pierret, 2016). We seek to describe how the process of extension was developed, what it looks like in the classroom, and why it can be a valuable tool for both educators and scientists.

Integrated Science Education Outreach (InSciEd Out)

InSciEd Out works with teachers to increase the science literacy and proficiency of students through a unique partnership model with a vision of achieving excellence in science education in public schools. This partnership model involves scientists, pedagogical experts, and k-12 teachers and students who work together for the mutual benefit of all involved. InSciEd Out employs innovative methods to enrich teacher and student understanding, with a strong emphasis on the Nature of Science. All teachers in a single school are brought in for an internship to experience cutting edge science as well as current pedagogical methods. During this internship, the teachers produce new curriculum that directly addresses opportunities for improvement at their own school. (Pierret et al., 2012)

Part of the teacher training provided by InSciEd Out involves a pedagogical shift towards inquiry-based instruction and the associated skills necessary to write curriculum in that space. This training has utilized Understanding by Design and the 5E Instructional Model as primary models for developing inquiry-based curriculum. As a part of the training, teachers are instructed in the use of the 5E’s and are required to incorporate them throughout the curriculum they write.

The Creation of Extension

The cooperative work of professional scientists with K-12 educators uncovered some differences in the perception of the scientific experience for younger learners. Scientists leaned toward “new to the world” science, working with students and/or classrooms to address authentic novelty in their field. Educators leaned toward “new to the learner” science, a process that allowed them to teach through inquiry, but with the added safety of an endpoint that was known to them. This difference was drawn into many discussions in the early days of InSciEd Out.

Both educators and scientists hoped to deliver authentic science, but this core difference divided the group. One model of classroom inquiry drew the team together. Roger Bybee’s 5E model for the delivery of science inquiry (Bybee et al., 2006) provided the space and place for the planned science research with its alternative 5th E - extend. The team spent a great deal of time determining working definitions of elaborate versus extend, finally landing on extend with a specific focus on extension through synthesis (as a Bloom's Taxonomy verb) (Bloom, 1956). In short, it was determined that learners could be expected to add to what is known (as held by the scientists) through a progressive process supported by educational theory. However, this required some support for the classroom educator, as it was not reasonable to expect the educator to have working knowledge of all fields of science and the threshold to novelty. The extension process was borne of that realization. Educators had the relationship with their classroom to lead students through inquiry. Scientists became the safety net, to reveal the cutting-edge of science and support classroom projects to achieve novelty.

The Classroom Experience of Extension

The extension process emerged from the elaboration phase of the 5E's. Elaboration calls for students to deepen their understanding of a concept through additional activities. Extensions also aim for deeper student understanding, but go further by engaging students in novel authentic scientific research.

The extension process begins at the end of a curricular module and serves to extend student knowledge through scientific inquiry. A local scientist comes to the classroom and works with the classroom teacher to facilitate the extension experience. It begins with students brainstorming a list of ideas and concepts they learned throughout the previously mentioned curricular module. After completing the brainstorm, the scientist leads the students through a process to identify a scientific question to research. This process begins with an exploration of topics that are personally important to the students in the class that are based on the class brainstorm. After exploring these topics, the students vote to determine the topic the class will research. From here, the scientist draws on their scientific knowledge to create a research question that falls within the selected topic and to which the scientific community does not already have an answer. After this, students work in small groups to create a hypothesis and rationale for the investigation, and then design and run that investigation with the support of their scientist partner. See figure 1 for a visual representation of this process.

Novelty, a Capacity of Science

One of the main goals of the extension phase is to engage students in novel scientific inquiry. This means that students ask questions to which science has no current answers. This is authentic scientific inquiry, as it mirrors career scientists engaged in research, who first determine what is already known through literature review and seek to create lines of research based on questions without answers. Involving students in novel scientific inquiry has several benefits. When doing novel research, there is no doubt about the value of what they are doing, and the question of ‘when will we ever use this?’ is answered by the work itself. In addition, the students have the opportunity to contribute to scientific knowledge in a tangible way, including the potential for authorship on scientific publications.

Novelty is one specific value that partnerships with science experts bring to the extension process. Where students and teachers may not be familiar with cutting-edge research in the scientific field they are studying, the scientist they partner with has the tools available to them to become familiar, if they are not already. In addition, there is a reciprocal value to the scientist, as students engaging in novel science have a different perspective than scientists and that fresh perspective has value to scientific ideation.

Community Building Through Extension

Ideally, extensions are guided by a practicing scientist from the local community in partnership with the classroom teacher. Working with community scientists can also lead to the creation of authentic scientific products. Generally, these products fall into two categories: posters and papers. Since communicating the results of research is a vital step of authentic scientific research, it is also included in the extension process. In our experience, posters are an effective method for the students to communicate the results of their investigation, and they can occur at one of two levels. Students can create a poster describing their research and present it to others students and parents in a poster session at their school. Figures 2 and 3 are examples of student posters. It is also possible for students to partner further with the scientist and create a professional poster to be presented at a scientific meeting or conference. Figure 2 is a poster created by InSciEd Out students showcasing elements of various extension experiments done by students in partnership with scientists. Figure 3 is a poster created by an InSciEd Out student that presents his work to create a low cost, highly efficient thermocycler. While this poster is not from a specific extension, it highlights the scientific interest that can be generated and supported through extensions and scientific partnership.

In addition to posters, students can also partner with the scientist to write professional manuscripts for publication in scientific journals. Both of these communication tools situate students as producers of authentic science and help them to genuinely take on the identity of a scientist. As a part of the broader extension process, allowing students to 'try on' the identity of a scientist can effectively promote scientific career paths.

Connection to NGSS

The extension process described here has natural connections to several strands within the Next Generation Science Standards, or NGSS. In regard to 'Connections to the Nature of Science', there are two specific areas that are applied during an extension: 'scientific investigations use a variety of methods' and 'scientific knowledge is based on empirical evidence'. In an extension, students are guided through an entire scientific investigation and have the opportunity to apply a variety of methods in the process. Students also gather empirical evidence during the investigation, and so have another opportunity to experience an application of the nature of science.

Extensions also allow students to explore the cross cutting concepts of patterns and cause & effect. Recognizing patterns in experimental data can be very useful in analyzing data and looking for the impact of variables. The principle of cause and effect is readily evident in any investigation, as the purpose is generally to determine how one variable is impacted (effect) by changing another variable (cause). Overall, there can be significant benefits to giving students the opportunity to apply these concepts in a unique and authentic way.

Finally, many of the science and engineering practices identified in the Next

Generation Science Standards are naturally embedded in extension investigations. In any given extension experience, students are engaged in asking questions, planning and carrying out investigations, analyzing and interpreting data, and constructing explanations. Using models and engaging in arguments based on evidence are also common elements of extensions. These practices represent 75% of the science and engineering practices present in the Next Generation Science Standards (NGSS Lead States, 2013). There is significant value in applying these science practices in authentic investigations, and additional value because of the partnership with a practicing scientist. The presence of an expert in experimental design lends authenticity to the science practices the students engage in, and help students see how what they are learning in school applies to the real world.

Connection to Inquiry

As scientific inquiry is such an integral goal for both NGSS and the 5E instructional model, it is important to mention our use of The Essential Features of Inquiry, which were described in *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning* (National Research Council, 2000). In order to more effectively understand the nature and level of inquiry utilized in extension lessons we apply the five features of inquiry described in those standards. Specifically, we use "Table 2-6. Essential Features of Classroom Inquiry and Their Variations " (National Research Council, 2000, p. 29) to ensure that students are engaging in all areas of inquiry, and to evaluate the teacher or student-driven nature of that inquiry. Overall, it has proven to be a valuable complement to the 5E's in driving student inquiry.

Conclusion

The extension experience is a transformation of the elaboration phase of the 5E’s in which students engage in novel scientific inquiry and create authentic scientific products, while potentially contributing to scientific knowledge. These extension experiences allow students to extend their recent classroom learning while applying authentic scientific skills and practices. In addition, students are able to interact with a practicing scientist, who provides experimental support and role modeling. This experience allows students benefit from the modeling of the scientific process while also making them legitimate participants in that process, exposing them to the scientific career pathway by letting them try it out for themselves. Overall, extensions can provide a valuable scientific learning experience for students, and are a positive addition to the 5E instructional model, or any model of inquiry-based science instruction.

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Figures

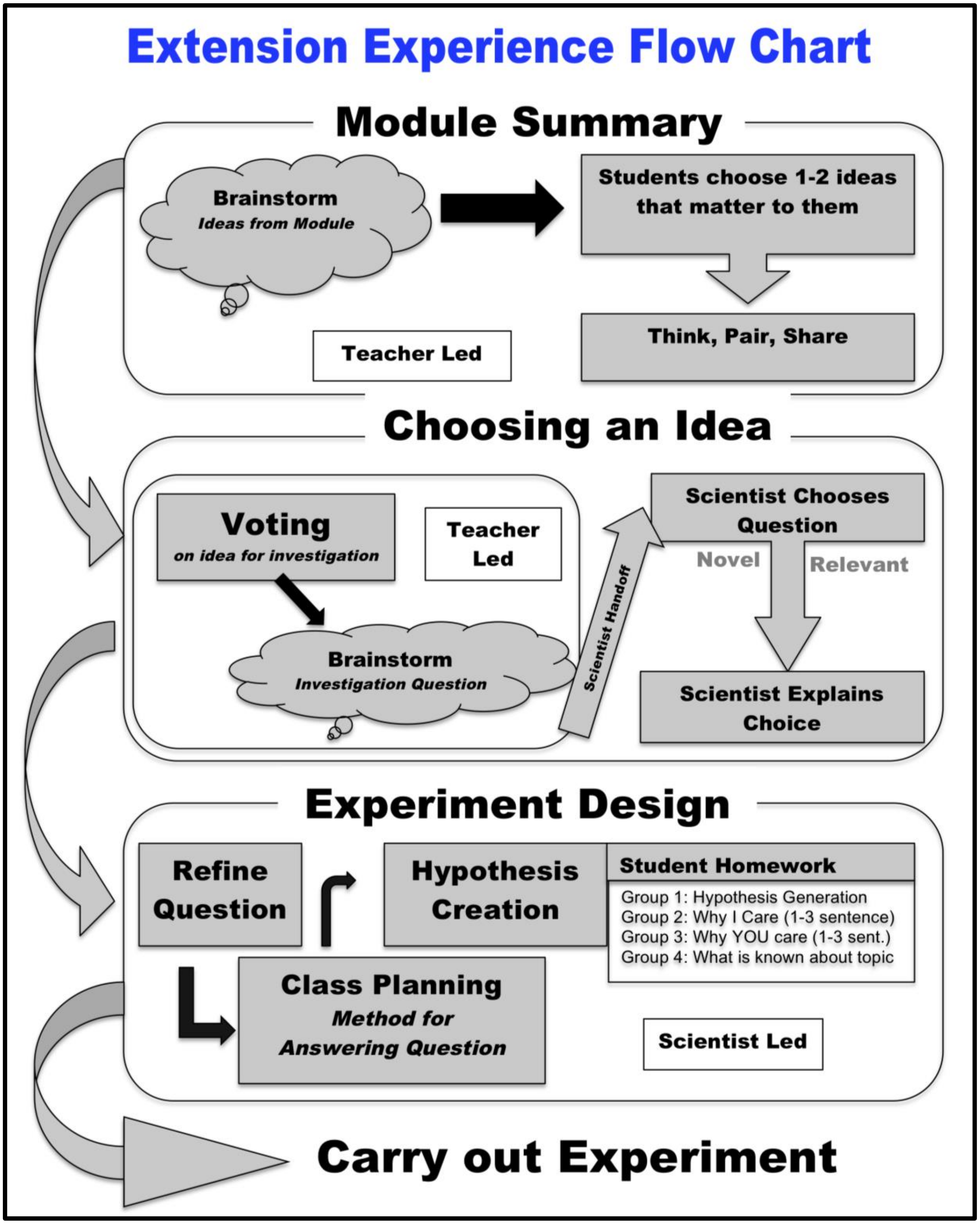

Figure 1. A flow chart of the extension experience.

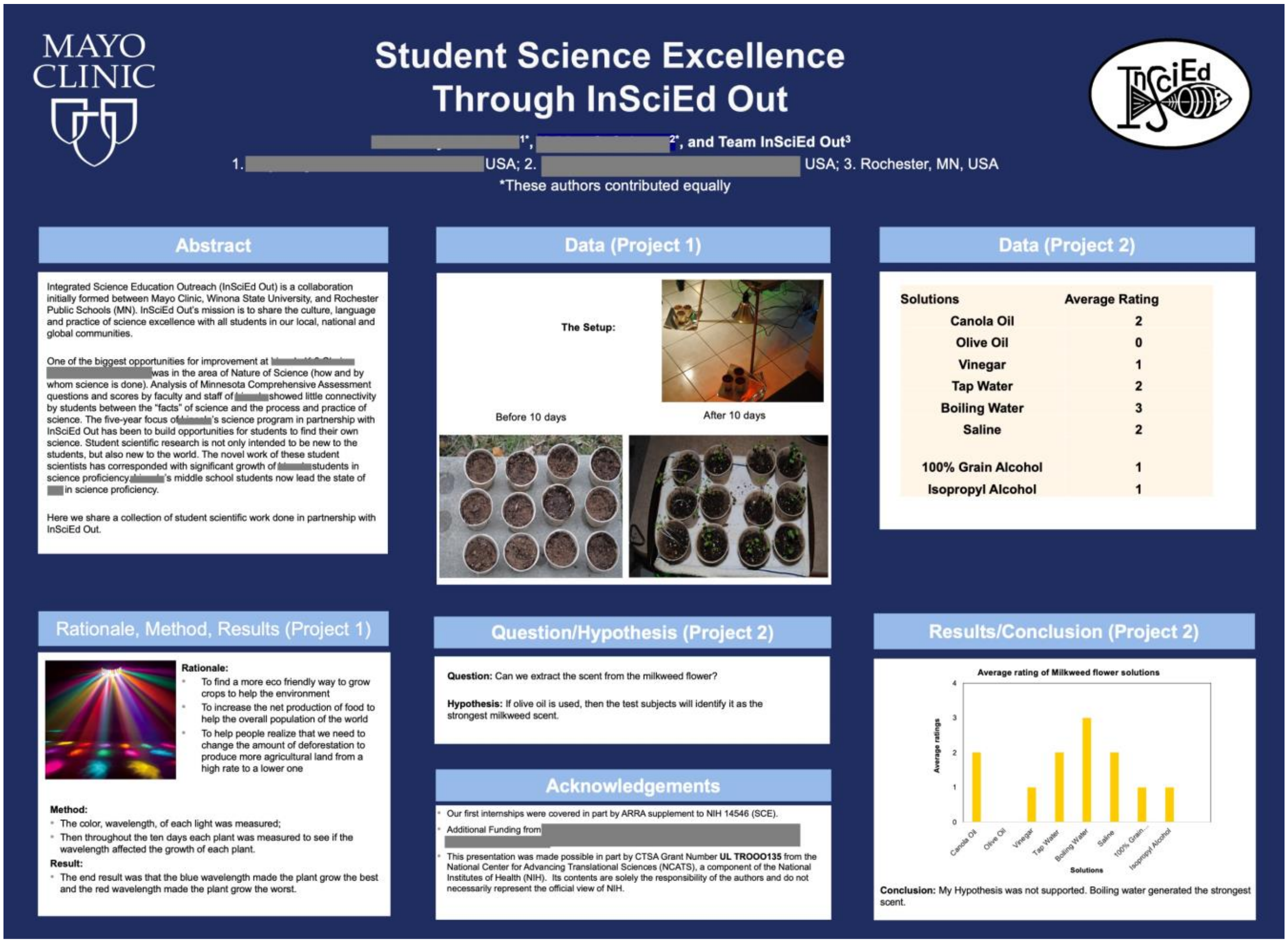

Figure 2. A poster of extensions by InSciEd Out students [student names redacted] (Bartlett, Schears, & InScied Out, 2014).

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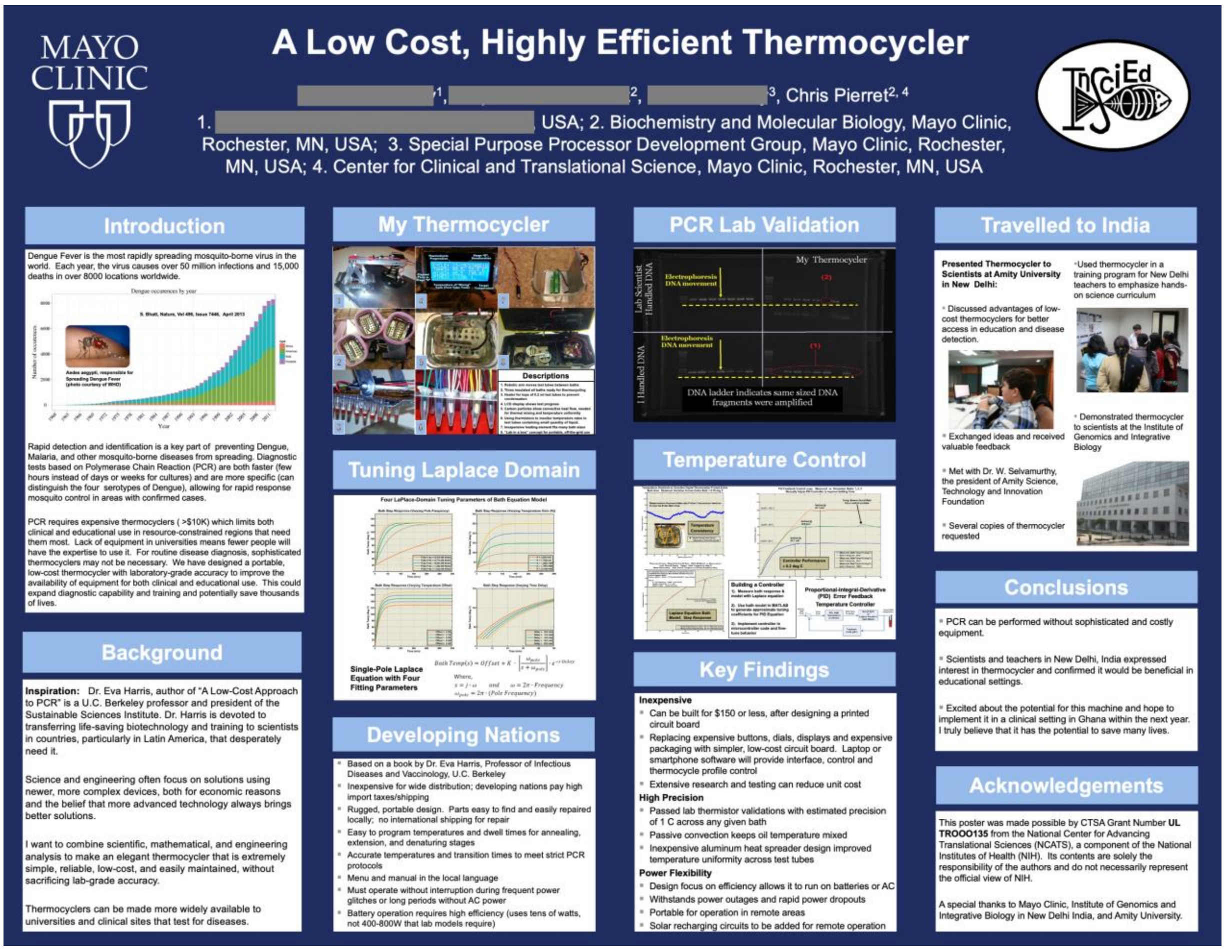

Figure 3. A poster of extensions by InSciEd Out student (McCoy, Westcot, McCoy, & Pierret, 2014)