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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

Cover Page Footnote

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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

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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

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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

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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

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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

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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

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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.

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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

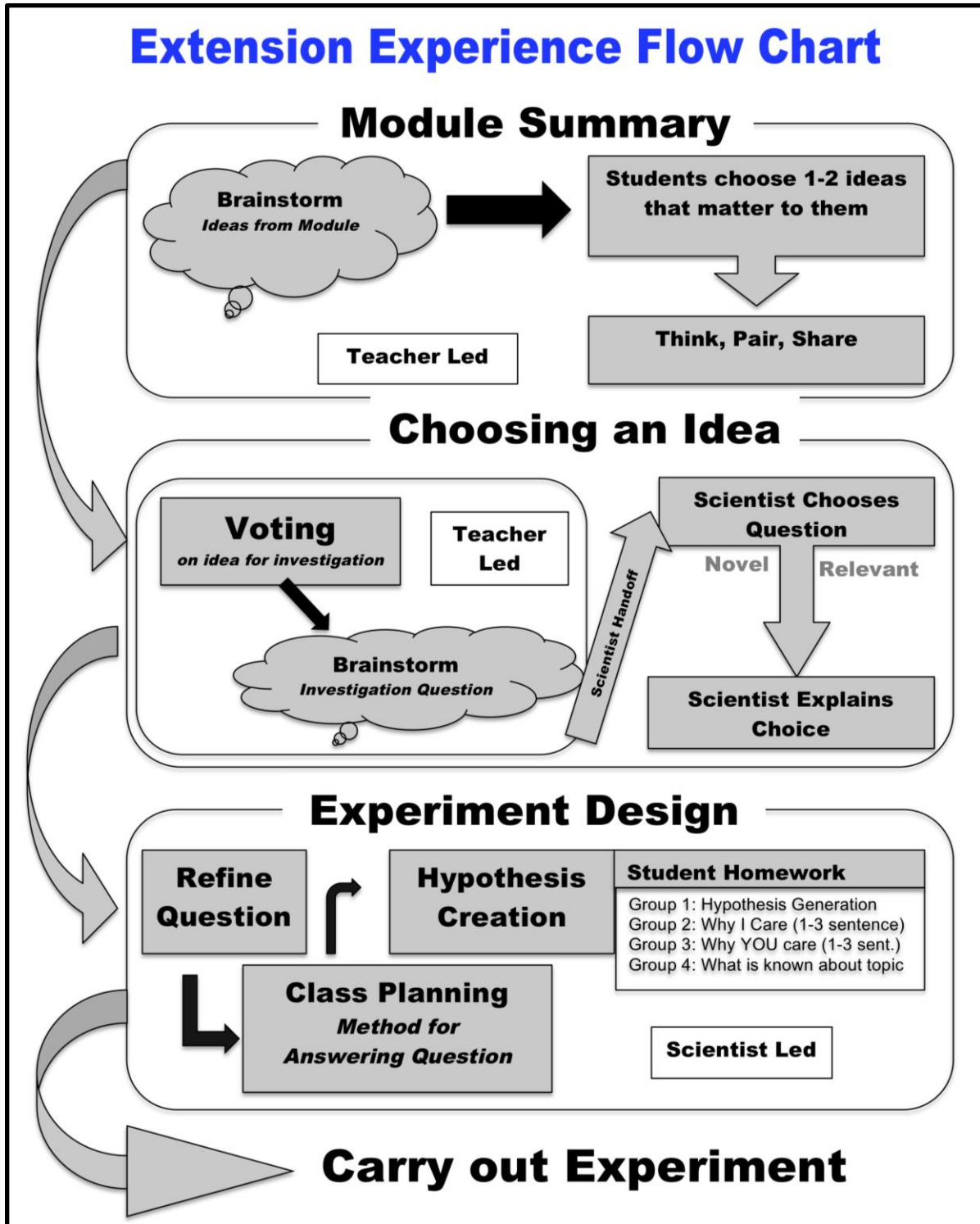



Figure 1. A flow chart of the extension experience.


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Student Science Excellence Through InSciEd Out

1. [Redacted]¹, [Redacted]², and Team InSciEd Out³
USA: 2. [Redacted] USA; 3. Rochester, MN, USA

*These authors contributed equally



Abstract


Integrated Science Education Outreach (InSciEd Out) is a collaboration initially formed between Mayo Clinic, Winona State University, and Rochester Public Schools (MN). InSciEd Out's mission is to share the culture, language and practice of science excellence with all students in our local, national and global communities.

One of the biggest opportunities for improvement at [Redacted] was in the area of Nature of Science (how and by whom science is done). Analysis of Minnesota Comprehensive Assessment questions and scores by faculty and staff of [Redacted] showed little connectivity by students between the "facts" of science and the process and practice of science. The five-year focus of [Redacted]'s science program in partnership with InSciEd Out has been to build opportunities for students to find their own science. Student scientific research is not only intended to be new to the students, but also new to the world. The novel work of these student scientists has corresponded with significant growth of [Redacted] students in science proficiency. [Redacted]'s middle school students now lead the state of [Redacted] in science proficiency.


Here we share a collection of student scientific work done in partnership with InSciEd Out.

Data (Project 1)


The Setup:



Before 10 days




After 10 days



Data (Project 2)

Solutions	Average Rating
Canola Oil	2
Olive Oil	0
Vinegar	1
Tap Water	2
Boiling Water	3
Saline	2
100% Grain Alcohol	1
Isopropyl Alcohol	1

Rationale, Method, Results (Project 1)



Rationale:

- To find a more eco friendly way to grow crops to help the environment.
- To increase the net production of food to help the overall population of the world.
- To help people realize that we need to change the amount of deforestation to produce more agricultural land from a high rate to a lower one.

Method:

- The color, wavelength, of each light was measured.
- Then throughout the ten days each plant was measured to see if the wavelength affected the growth of each plant.

Result:

- The end result was that the blue wavelength made the plant grow the best and the red wavelength made the plant grow the worst.

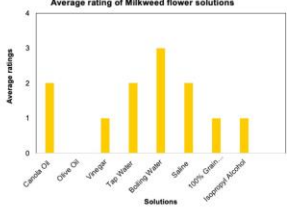
Question/Hypothesis (Project 2)

Question: Can we extract the scent from the milkweed flower?

Hypothesis: If olive oil is used, then the test subjects will identify it as the strongest milkweed scent.

Results/Conclusion (Project 2)

Average rating of Milkweed flower solutions



Conclusion: My Hypothesis was not supported. Boiling water generated the strongest scent.


Acknowledgements

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• Additional Funding from [Redacted]

• This presentation was made possible in part by CTSA Grant Number UL TR000135 from the National Center for Advancing Translational Sciences (NCATS), a component of the National Institutes of Health (NIH). Its contents are solely the responsibility of the authors and do not necessarily represent the official view of NIH.

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

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MAYO CLINIC

A Low Cost, Highly Efficient Thermocycler

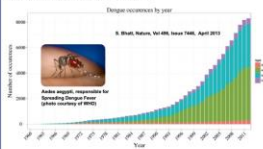
1. [Redacted], 2. [Redacted], 3. Chris Pierret^{2,4}

1. [Redacted], USA; 2. Biochemistry and Molecular Biology, Mayo Clinic, Rochester, MN, USA; 3. Special Purpose Processor Development Group, Mayo Clinic, Rochester, MN, USA; 4. Center for Clinical and Translational Science, Mayo Clinic, Rochester, MN, USA



Introduction


Dengue Fever is the most rapidly spreading mosquito-borne virus in the world. Each year, the virus causes over 50 million infections and 15,000 deaths in over 8000 locations worldwide.



Rapid detection and identification is a key part of preventing Dengue, Malaria, and other mosquito-borne diseases from spreading. Diagnostic tests based on Polymerase Chain Reaction (PCR) are both faster (few hours instead of days or weeks for cultures) and are more specific (can distinguish the four serotypes of Dengue), allowing for rapid response mosquito control in areas with confirmed cases.

PCR requires expensive thermocyclers (>\$10K) which limits both clinical and educational use in resource-constrained regions that need them most. Lack of equipment in universities means fewer people will have the expertise to use it. For routine disease diagnosis, sophisticated thermocyclers may not be necessary. We have designed a portable, low-cost thermocycler with laboratory-grade accuracy to improve the availability of equipment for both clinical and educational use. This could expand diagnostic capability and training and potentially save thousands of lives.

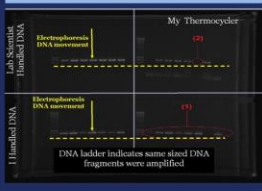
My Thermocycler



Descriptions

- Portable
- Low-cost
- Laboratory-grade accuracy
- Simple to use
- Rugged
- Easy to repair
- No international shipping for repair
- Easy to program temperatures and dwell times for annealing, extension, and denaturing stages
- Accurate temperatures and transition times to meet strict PCR protocols
- Menu and manual in the local language
- Must operate without interruption during frequent power glitches or long periods without AC power
- Battery operation requires high efficiency (uses tens of watts, not 400-600W that lab models require)

PCR Lab Validation



Lab Scientist: Handled DNA

My Thermocycler

Electrophoresis DNA Assessment

Handled DNA

DNA ladder indicates same sized DNA fragments were amplified

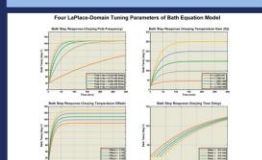
Travelled to India

Presented Thermocycler to Scientists at Amity University in New Delhi:

- Discussed advantages of low-cost thermocyclers for better access in education and disease detection.
- Exchanged ideas and received valuable feedback
- Demonstrated thermocycler to scientists at the Institute of Genomics and Integrative Biology
- Met with Dr. W. Selvamurthy, the president of Amity Science, Technology and Innovation Foundation
- Several copies of thermocycler requested

Used thermocycler in a training program for New Delhi teachers to emphasize hands-on science curriculum

Tuning Laplace Domain



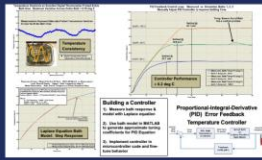
Four Laplace-Domain Tuning Parameters of Both Equation Model

Single-Pole Laplace Equation with Four Fitting Parameters

When: $\omega = 1 \text{ rad/sec}$ and $\omega = 2\pi \text{ Frequency}$

$\omega_{max} = 2\pi \text{ (Unit Frequency)}$

Temperature Control



Building a Controller

Proposed Integral-Feedback (PI) Error Feedback Temperature Controller

Key Findings

Inexpensive

- Can be built for \$150 or less, after designing a printed circuit board
- Replacing expensive buttons, dials, displays and expensive packaging with simpler, low-cost circuit board. Laptop or smartphone software will provide interface, control and thermocycle profile control
- Extensive research and testing can reduce unit cost

High Precision

- Passed lab thermistor validations with estimated precision of 1°C across any given bath
- Passive convection keeps oil temperature mixed
- Inexpensive aluminum heat spreader design improved temperature uniformity across test tubes

Power Flexibility

- Design focus on efficiency allows it to run on batteries or AC
- Withstands power outages and rapid power dropouts
- Portable for operation in remote areas
- Solar recharging circuits to be added for remote operation

Conclusions

- PCR can be performed without sophisticated and costly equipment
- Scientists and teachers in New Delhi, India expressed interest in thermocycler and confirmed it would be beneficial in educational settings.
- Excited about the potential for this machine and hope to implement it in a clinical setting in Ghana within the next year. I truly believe that it has the potential to save many lives.

Acknowledgements

This poster was made possible by CTSA Grant Number UL TR000113 from the National Center for Advancing Translational Sciences (NCATS), a component of the National Institutes of Health (NIH). Its contents are solely the responsibility of the authors and do not necessarily represent the official view of NIH.

A special thanks to Mayo Clinic, Institute of Genomics and Integrative Biology in New Delhi India, and Amity University.

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