We present findings from the University of Colorado's Partnership for Informal Science Education in the Community (PISEC) [1,2, 3]. This model of university-community partnerships brings together elementary school students with university educators in Math, Engineering, and Science Achievement (MESA) sponsored after school programs. The elementary school students worked through flexible inquiry based circuit activities based on the Physics and Everyday Thinking (PET) curriculum [4] with physics graduate and undergraduate students learning about education in the community. We document the interactions that these informal science education (ISE) environments support and present findings on conceptual learning gain and attitude shifts of the children who participated.
Acknowledgements

I would like to thank Noah Finkelstein and Laurel Mayhew, both of whom I would not have been able to complete this work. I would additionally like to thank the Physics Department and the PER group at the University of Colorado for providing the opportunity for this research. Finally, thanks to Jeff for things uncountably infinite.
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1. Background

1.1 Introduction

Competition in the world market demands competence in technological and scientific fields. In 2007, Congress requested a study from the National Academies [5] identifying actions that must be taken in order to "compete, prosper, and be secure in the global community of the 21st century" [6, p.2]. This study recommended the dramatic improvement of K-12 mathematics and science education. In 1998, students in their final year of secondary school participated in a survey [7] that ranked the U.S. 18th out of 21 countries in mathematics and science literacy, and last out of 16 countries in physics achievement, as shown in Table 1.1.

While U.S. student science achievement is significantly less than in other countries, underrepresented U.S. student populations achieve considerably less in science literacy than non-minority U.S. students [8]. The U.S needs typically under represented populations to meet the demands of the technical world [5], but minority students are far less likely to register for physics courses in either high school or college [9]. In 2001, only 21% of Hispanic students were enrolled in high school physics, and in 2004, Hispanic Americans received only 5% of awarded physics bachelor’s degrees [9]. As a further result of the No Child Left Behind legislature, general science curriculum has been displaced in favor of additional focus on reading skills, especially for students in English as a second language (ESL) programs [10].

Causes for the science literacy gap include a severe need for qualified physics and math teachers [5, 11], insufficient learning materials such as text books or computers [11], low teacher self-efficacy in science instruction arising from incorrect or limited content knowledge [12], school sanctioned emphasis on standardized test achievement rather than critical thinking ability [10], and the displacement of science curriculum for other essential skill sets such as reading or
writing [10]. Science learning in formal environments is even further limited by unchangeable factors such as teacher to student ratios and time constraints via state dictated curriculum.

While increased effort has been devoted to better the quality of K-12 science, technology, engineering, and mathematics (STEM) formal education for minority students, little research exists, especially for under-represented populations, on student learning in after school informal science education (ISE) environments [13]. This thesis documents the types of interactions allowed by after-school ISE settings and presents findings on learning gains and attitude shifts resulting from an after-school ISE program.

<table>
<thead>
<tr>
<th>Country</th>
<th>Mean Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netherlands</td>
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<td>Sweden</td>
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<td>International Average</td>
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<tr>
<th>Country</th>
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<td>United States</td>
<td>423</td>
</tr>
<tr>
<td>International Average</td>
<td>501</td>
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</table>

Table 1.1 Findings from the IEA Third International Mathematics and Science Study (TIMSS), 1995-96 [7] on the math, science, and physics literacy of international students in their final year of secondary school.
1.2 Literature Review

The literature addresses theoretical aspects of K-12 science education in both formal and informal settings as well as experimental results from successful ISE programs. From the theoretical perspective, a 2007 National Research Council (NRC) report [14] gives a “Strands of Science Learning” framework that identifies six learning characteristics specific to informal science learning in grades K-8, as listed below.

- **Strand 1** -- Experience excitement, interest, remember, and use concepts, explanations, arguments, models, and facts related to science.
- **Strand 2** -- Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science.
- **Strand 3** -- Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world.
- **Strand 4** -- Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena.
- **Strand 5** -- Participate in scientific activities and learning practices with others, using scientific language and tools.
- **Strand 6** – Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science.

While these six strands are specific to informal science learning, the NRC report places additional emphasis on the value of learning strands 1 and 6 in ISE environments. The first strand generates excitement, interest, and motivation in science learning, thus providing a foundation on which other facets of science learning rely [14]. ISE settings commonly employ inquiry and play-based curriculum [15] that can develop student interest and satisfy aspects of science learning specific to strand 1. Though motivation and excitement can certainly be, and often are, cultivated in formal science settings, informal discovery-based science activities can
inspire student excitement in a way uniquely specific to ISE environments. Strand 6 addresses student’s personal identification with science and science activities. ISE programs often explore topics directly related to real-world phenomena, while students in formal classrooms traditionally perceive science lessons as abstracted and separated from their every-day lives [10]. According to one study [16], this perceived detachment between science learned in schools and every-day experiences can cause students to disengage completely from science learning in the formal setting. So, while formal settings may traditionally alienate students from personal identification with science, informal settings aim to engaging students in authentic activities that increase interest in science and support student identity as contributors to and participants in science.

Formal settings can benefit from the six strands framework by providing students with complementary learning goals, thus creating a more organized system of science learning shared between formal and informal science settings [14]. ISE environments can then provide students supplementary time to further learn science content, engage students in informal activities designed to increase interest and competence in the material, and offer mentoring opportunities with adults in scientific fields. Such opportunities are particularly valuable for under-represented populations who have difficulty perceiving themselves as capable of achieving in science [15]. Hispanic youth who participated in an ISE program through the New Mexico Math and Science Achievement Program (MESA) showed continual increase in positive attitudes, but still believed they were not smart enough to pursue science in college as a carrier, possibly due to a lack of exposure to role models in science [17]. But [15,18] show students of similar demographic who interact with university science mentors and who have positive attitudes towards science classes, science teachers, and carriers in science are significantly more likely to pursue science as a carrier.

ISE aims to confront these challenges, but there are different categories of ISE that can each support students in varying ways. It is important to address which ISE environments allow interactions that most support students and communities, especially for under-represented
populations. There are two main forms of ISE: museum science and reoccurring out of school science programs. Traditionally the research and practice of ISE has been limited to the Museum setting [10]. Museum ISE often involve field trips to science / natural history museums or other institutions in which authentic science activities are conducted. While this genre of ISE may generate student interest in science, the literature finds that museum field trips are often infrequent events while reoccurring ISE programs are more likely to teach a curriculum. Museum science thus cannot support student learning in the same ways reoccurring science programs do [10].

Reoccurring ISE provides regular times in which students may interact with science curriculum and adults in scientific fields. Support for student learning and development through consistent mentors positively effect student attitudes towards science, particularly for under-represented student populations [15]. Further, reoccurring ISE curriculum is not limited to the structure of formal settings. State required standardized tests set high stakes for school funding, which dictates topics covered in formal environments. Teachers must address various topics quickly, which results in the rushed presentation or eradication of science curriculum. Reoccurring ISE programs allow students time to develop critical thinking skills and work through science curriculum at a slower pace. The federal government has recognized the importance of reoccurring out of school programs, especially for low-income minority students, and currently provides over $1 billion in national funding for after school programs [19]. But these programs are primarily aimed at youth development. Though increased effort continues to address after school programs for K-12 students, little research exists describing the potential impacts of after school ISE programs [10].

Where after school youth development programs primarily focus on providing students with positive social attitudes about themselves, one of the goals of after school ISE programs is to provide students with positive attitudes about themselves towards science. After school ISE environments may be able to give students social support similar to that of youth development
programs while additionally increasing student self-confidence and self-efficacy in science. Often located within the formal environment, after school ISE programs can form an “intermediary space” [10] between formal classroom science, museum ISE, and youth development programs that has the potential to bring together school and community.

Not only does after school ISE have the potential to uniquely support student interactions with science, it also has the potential to uniquely support formal K-12, university, and community settings. One study [20] showed students, especially those from traditionally under-represented communities, became increasingly interested in science material when the curriculum was embedded within community issues. Thus, by connecting science learning with the community it is possible for after school ISE to further improve science learning and science literacy for disadvantaged student populations [21]. In addition to helping students, after school ISE has the potential to positively affect formal institutions and university volunteers. The University of Colorado’s Partnership in Informal Science Education in the Community (PISEC) [3] is currently studying the effects of after school ISE programs on participating children, volunteer university undergraduate and graduate students, and the impact on the K-12 and university institutions themselves. These after school ISE programs follow a university-community partnership model, shown in Figure 1.1 [1]. This model bridges university partners (faculty and volunteer undergraduate and graduate students interested in teaching) with community organizers (community centers and schools) in after school based ISE activities [1].
A recent survey [15] of the literature summarized effective aspects of existing ISE programs. According to this survey, successful ISE programs often (1) use an inquiry-based curriculum that actively integrates science standards, (2) have high quality teachers with positive attitudes towards and academic competency in science, (3) are co-sponsored with a professional organization such as a university, (4) provide student mentors in scientific fields, (5) inform students about and positively portray scientific careers, (6) create personal relevance for students with the curriculum, (7) encourage the support and involvement of student families with the program, and (8) cultivate student self-confidence in science. The survey also indicates many successful ISE programs had onsite outreach in K-12 classrooms by university science students and faculty while K-12 teachers were present, had a target population to which curriculum was directed, used technology and web-based resources, involved field trips with mentors to sponsoring universities, and allowed student to present a cumulating project to their family and peers. The program studied in this thesis (discussed in more detail in section 2) applies all of these above listed qualities.
2. Problem

2.1 Methods

We would like to show participating students had a positive science experience as indicated by favorable attitudes towards science and science learning and positive learning gains on conceptual surveys. We would also like to show the PISEC [3] after school ISE program successfully retained students over several weeks.

ISE environments can provide for students unique opportunities to learn science. In summary of the literature, traditional formal environments have one teacher who attempts to engage many students in what might be a rushed and even incorrect presentation of science material [12,10]. Studies have shown students, particularly from under represented populations, may view science in formal environments as alienating and abstract [10,16]. ISE seeks to directly address these problems by providing opportunities for students to engage in authentic science activities with multiple teachers at their own pace. Little research exists on the interactions after school ISE programs allow and how these interactions influence formal institutions [10]. This thesis attempts to further this research and provide direction for future studies.

In this work, several volunteer university educators (UEs) and one 5th grade teacher facilitated a seven-week long ISE program located in an elementary school classroom after school hours. The curriculum used non-traditional methods to teach basic circuits. The participating students and 5th grade teacher were given pre and post content and attitude surveys. We expect to see positive content knowledge gains, favorable shifts in attitudes, and an increase in teacher content knowledge after participation in the after school ISE program.
2.2 Context of Study

The community partnership model of Figure 1.1 aims to benefit all participants by bringing together UEs with community partners in the context of after school ISE programs located in the community [1]. Sponsored by JILA outreach [22] and the University of Colorado (CU) Physics Education Research Group, PISEC [3] operates several after school ISE partnerships in under-represented communities. Five programs in current operation are after school ISE programs at Longmont, CO community center Casa de la Esperanza (Casa), Spangler Elementary School in Longmont, CO (Spangler), Boulder Preparatory Charter School in Boulder, CO (Boulder Prep), and a remote e-learning program at an inner city housing project in San Diego, CA (San Diego Remote) [2]. University student volunteers (possibly recruited from the Learning Assistant or CU Teach programs [23]) complete curriculum training and facilitate the PISEC programs.

This study focuses on the Spangler Fall 2008 PISEC program, which took place after school hours in a Spangler Elementary classroom. The participating students were in 5th grade and of Hispanic ethnicity. The program was run in concert with St. Vrain MESA [24], whose mission is to "encourage, motivate, support and prepare" underrepresented students for "success in the pursuit of undergraduate degrees and careers" in STEM fields [25]. 46% of students participating in St. Vrain MESA programs identify as Hispanic while only 26% of area district students identify as Hispanic [26]. Though the program was primarily facilitated by volunteer UEs, a volunteer Spangler 5th grade teacher was present for each weekly meeting. This teacher sometimes worked with students and curriculum and sometimes the teacher did not interact with students or UEs. The Spangler program met one a week for seven weeks and had an average of 13 participating students at each session.

The curriculum used at Spangler, provided in Appendix A, was a modified form of the Physics and Everyday Thinking (PET) curriculum [4]. This modified PET curriculum provided
modular, inquiry-based activities through which students worked at their own pace building, testing, and learning about circuits. This PET curriculum aims to expand student understanding of physics ideas, provide for student practice with the scientific process, and encourage student awareness about how their physics ideas develop over time [4], thus it was ideal for use with the six strands ISE learning framework. In the modified PET curriculum, students were required to consult with an instructor before moving from one activity to another. This ensured each student completed each portion of the curriculum in full. In addition to the modified PET curriculum, students used JILA-provided computers, cameras, white boards, and markers to create stop action motion (SAM) [27] animations about basic circuits. By using built-in or USB cameras, students demonstrated content knowledge through sequential drawings that were then converted into a continuous movie. This nontraditional technology provided students with a nonverbal and playful medium through which to engage in science. These engagements are particularly useful for ESL students, or students who have difficulty with reading or writing [2].
3. Data

3.1 Analysis

In this section, we present and discuss data obtained from the Spangler PISEC after school. We describe the data sources, present results, then examine case studies.

The data sources include a conceptual survey of circuits (Appendix B), attitude and beliefs surveys (Appendix C), student-created Stop Action Motion (SAM) movies [27], and attendance. The conceptual survey was given as a pre and post test to determine initial content knowledge, measure learning gains, and assess student’s ability to apply learned content to never before seen questions.

3.1.1 Description

**Conceptual Survey of Circuits Description**

The conceptual survey of circuits, given in Appendix B, was offered as a pre and post test with two sections. The first section, S1, asked students to draw a working circuit using one battery, one light bulb, and one wire [28]. The second section, S2, asked students to predict whether or not four circuit drawings would illuminate. The pre test contained only section S1 while the post test contained sections S1 and S2. S2 questions tested material beyond what was covered in the PISEC program, thus it was meant to examine the robustness of final student content knowledge.

**SAM Movie Description**

The modified PET curriculum instructed students to create a SAM movie documenting whether or not two circuits, shown in Figure 3.1 below, worked and why or why not. The students, working in teams of two or three, were taught how to use the SAM software but were not instructed on content or style of presentations.
Attitude and Beliefs Survey Description

The attitudes and beliefs survey issued by PISEC is based on questions from the Colorado Learning Attitudes about Science Survey (CLASS) [29], used to measure college students' attitudes and beliefs about science, the nature of science, and the nature of learning science. Though the CLASS survey is intended for college students, the PISEC survey was worded with ELS elementary school populations in mind. The attitudes survey was administered at the beginning and end of the program. Students were presented with questions, followed by potential answers and were instructed to circle the answers they most agreed with. The full survey can be found in Appendix C and the questions are listed below.

1. How do I feel about doing science activities?
2. Do I think there is science in everyday life?
3. Would I like to do an experiment or be told about it?
4. How would I feel about doing science as my job?

3.1.2 Results

Content Survey of Circuits S1 Results

The conceptual survey S1 was scored by awarding one point for each of six correctly answered categories. These categories, as well as visual examples, are shown in Table 3.1. In

---

Figure 3.1 Two circuits from the modified PET curriculum about which students created their SAM movies. The students' movies discussed whether or not the pictured circuits successfully light the bulb, and why or why not.
category 1, if the student attempted to draw a schematic involving a battery, one or two wires, and a bulb then they received a point. In category 2, if the student drew two connections to the battery and bulb then they received a point. A student who did not demonstrate the idea of a circuit did not receive a point for this category. In category 3, if the student drew a circuit that involved both the side and the bottom terminal of the light bulb, they received a point. There were some students who indicated that they could attach the wire to both the bottom and the side of the bulb, but not necessarily to both at the same time. Thus, in category 4, the student received a point if they drew a circuit in which the bulb was attached at both the side and the bottom terminals. See example drawing for category 4 in the table. In category 5, if the student drew the circuit using only one wire they received a point. Finally, in category 6, if the student drew a circuit that would light, using either one or two wires, they received a point.

For S1, the total possible score was 6. We collected 12 matched S1 tests at the Spangler PISEC site. The average pre and post were 1.6 and 5.7 respectively, as shown in Figure 3.2a. Standard error on the mean (standard deviation over the square root of degrees of freedom) is shown in the figure. All students scored higher on the post test than they did on the pre test, and all but one student scored perfectly on the post test, as shown in the individual student results of Figure 3.2b. Two Spangler 4th and 5th grade teachers were also given the S1 pre test. Their scores, given in Figure 3.2a, were similar to average student S1 pre scores. Unfortunately, neither teacher took the S1 post test.

Aggregate data, not shown here, from the Casa Fall 2008 PISEC site (where students of similar demographics worked through identical curriculum and conceptual surveys) demonstrate similar learning gains. We conclude that the PISEC program successfully taught students about the material assessed by content survey S1.
<table>
<thead>
<tr>
<th>Categories:</th>
<th>Points: 0 or 1</th>
<th>Examples:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The student response had some content (they had some idea).</td>
<td><img src="image1" alt="Image" /> This student did not demonstrate content</td>
</tr>
<tr>
<td>2</td>
<td>The student demonstrated the notion of a circuit.</td>
<td><img src="image2" alt="Image" /> No circuit</td>
</tr>
<tr>
<td>3</td>
<td>Circuit drawing involves both the bottom and side of the bulb.</td>
<td><img src="image3" alt="Image" /> This student did not use both the side and bottom of the bulb.</td>
</tr>
<tr>
<td>4</td>
<td>Did the student know they could attach wires at the side or bottom of the bulb?</td>
<td><img src="image4" alt="Image" /> This student drew two pictures demonstrating they knew they could connect wires to both the side and the bottom of the bulb. Student examples pictured in rubrics 2 and 3 did not demonstrate this.</td>
</tr>
<tr>
<td>5</td>
<td>The bulb will light and the student used only one wire.</td>
<td><img src="image5" alt="Image" /> The student used one wire and drew a correct circuit.</td>
</tr>
<tr>
<td>6</td>
<td>The circuit is correct.</td>
<td><img src="image6" alt="Image" /> This student drew a correct circuit but used two wires.</td>
</tr>
</tbody>
</table>

Table 3.1 The Conceptual survey of circuits S1 grading rubric. Examples from student tests are shown for clarity. We note a subtly regarding rubric 4: this category assesses whether or not students knew wires could connect to both side and base bulb terminals. Rubric 4 does not require students know that they can connect to both base and side terminals at the same time.
Figure 3.2 Plot (a) contains pre / post test scores averaged for n=12 Spangler Fall 2008 students, shown with standard error. The S1 pre test scores for two Spangler 4th and 5th grade teachers, T1 and T2, are also shown. The average student learning gain (post – pre) is 4.1 points. Plot (b) contains individual pre / post S1 scores. All students had a positive learning gain.

**Content Survey of Circuits S2 Results**

The content survey S2, provided in Appendix B, was only given at the end of the program. S2 asked students to predict whether or not four circuit drawings worked. Students received 0 or 1 point for each part (a through d), depending on the correctness of their answer. Student had never before seen S2 circuit drawings, but they had used similar circuits during program curriculum. The literature finds [30] students tend to have difficulty taking content they have learned and applying it to new problems. Students tend to focus on surface features of the problem instead of underlying concepts. For this reason, we were not expecting positive results.
Figure 3.3 The concept survey S2 scores are averaged for n=13 Spangler Fall 2008 students, shown with standard error. On average, students answered questions a through d with respective 92%, 69%, 62%, and 46% accuracy. Images of each question are also pictured.

When creating the S2 test, three of the four circuits (a, b, and c) were directly drawn from summary PET curriculum questions. The last circuit (d) was copied from the modified PET activity 1.1 (through which students worked) and rotated 90 degrees counter clock-wise. Because the students had seen a rotated version of circuit d in their previous activities, we believed they would do well on part d, but not on parts a, b, and c. The results for the Spangler PISEC site are shown in Figure 3.3, including pictures of the circuits for each part.

We collected 13 S2 conceptual surveys at the Spangler PISEC site. Students scored an average of 0.92, 0.69, 0.62, and 0.46 respectively. All but one of the 13 students answered part a correctly, 9 answered part b correctly, 8 answered part c correctly, and only 6 answered part d correctly. Thus, the average scores shown in Figure 3.3 above represent the percentage (in decimal) of students who correctly answered questions. We find that students were more able to answer the questions for part a through c but had difficulty with part d, counter to our expectations.
Table 3.2 shows some similarities between S2 circuits and circuits used during the program activities. There are three differences between circuit S2a and a circuit students used during the program, as pictured in the upper left quadrant of Table 3.2. These differences are: (1) S2a has an additional wire connecting the tip of the bulb to the battery’s positive terminal, (2) the wire connecting positive and negative battery terminals is flipped from right to left, and (3) the battery terminals are switched. Circuit S2a was meant to test the student’s ability to understand wires as connectors, a topic that was not explicitly discussed during the PISEC program. The circuits in the upper right quadrant of Table 3.2 (S2b and curriculum circuit) have wires connected to either the bottom or the side of the bulb. Circuit S2c in Table 3.2, bottom left quadrant, does not have an obvious analog circuit in the curriculum. Circuit S2c is meant to test student understanding of how the battery provides electricity through the light bulb. S2d and curriculum circuits, lower right quadrant of Table 3.2, are rotated 90 degrees from each other.

<table>
<thead>
<tr>
<th>Circuit from Curriculum</th>
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<th>Circuit from Curriculum</th>
<th>Circuit from S2</th>
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</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td>a</td>
<td><img src="image2.png" alt="Image" /></td>
<td>b</td>
</tr>
<tr>
<td><strong>No direct analog</strong></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
<td>d</td>
</tr>
</tbody>
</table>

Table 3.2 Similarities between curriculum through which the students worked and circuits from the S2 conceptual survey. Seminaries are described more thoroughly in the text.
**SAM Movie Results**

Student SAM movies are student-created animations that allow students to demonstrate their knowledge through "show and tell" [2]. Figure 3.4 shows some snap shots of a student SAM movie from the Spangler site. The students were instructed to indicate whether or not two different circuits (see Figure 3.1) worked and to describe why. Due to the unformatted and unscripted nature of SAM movies, many grading rubrics are possible. We created the rubric with separate characteristics of content and style. Notably these are not exhaustive categorizations, however they capture significant qualities in student projects. For the content rubric, the three categories included correct circuit drawings, correct indication of whether the circuit worked, and explanation quality. For the style rubric the two main categories were sense of student identity and assessing the process of creating a SAM movie. These three rubrics are given in Table 3.3.

![Figure 3.4 Images from Spangler Fall 2008 student SAM movies. The students used provided computers, cameras, white boards, and markers to creatively present what they had learned about PET circuits #1 and #2.](image-url)
<table>
<thead>
<tr>
<th><strong>Content Rubrics</strong></th>
<th><strong>Description (see text)</strong></th>
<th><strong>Score</strong></th>
</tr>
</thead>
</table>
| C1                  | Circuits are drawn correctly. | Both correct = 2  
|                     |                             | One correct = 1  
|                     |                             | None correct = 0 |
| C2                  | Correct answer to whether or not the circuit worked. | Both correct = 2  
|                     |                             | One correct = 1  
|                     |                             | None correct = 0 |
| C3                  | Explanation for each circuit. | For each circuit:  
|                     |                             | Good explanation = 2  
|                     |                             | Adequate explanation = 1  
|                     |                             | Limited / no content in explanation = 0  
|                     |                             | Total possible score for C3 is 4 (for good explanations for each of the two circuits). |

<table>
<thead>
<tr>
<th><strong>Style Rubrics</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
</table>
| E1                | Personalized    | Very personalized = 2  
|                     |                 | Some personalization = 1  
|                     |                 | No personalization = 0 |
| E2                | Use of color    | More than one color used to represent meaning = 2  
|                     |                 | More than one color used, not used to represent meaning = 1  
|                     |                 | Only one color used = 0 |

Table 3.3 Grading rubrics on which Spangler Fall 2008 student SAM movies were scored. These categories are not exhaustive but address important aspects observed in student movies. Unspecific wording (such as “adequate” or “good”) is further clarified in the text and through visual examples in Figure 3.5.

Pictorial examples of scored student movies are given in Figure 3.5 so as to clarify vague wordings in rubrics C3, E1, and E2. Rubrics C1 and C2 are unambiguous and will not have additional clarification. Rubric C3 addresses student explanations of why circuits #1 and #2 (Figure 3.1) worked or did not work. An explanation was considered good if it contain sufficient and clear reasons for why the bulb did or did not light. An explanation was considered adequate if the student group demonstrated correct content knowledge but only provided a partial explanation for why the circuit did or did not work (for example, if the student did not discuss the meaning of a “full circuit”). An explanation with limited or no content might contain correct phrases but the student was not able to show why the bulb was able or not able to light. Three examples of good, adequate, and limited content explanations are given in Figure 3.5a.

Style rubrics E1 addresses the level of personalization of student SAM movies. We considered movies to be very personalized if the students included their names or photos of
themselves in the movie. Screen shots illustrating examples of very personalized movies cannot
be shown here due to identifiers. It is impossible to quantify all forms of personal identification,
thus the description of movies with some personalization is left intentionally vague. Examples of
student movies with some personalization are provided in Figure 3.5b. Student groups who
included idiomatic phrases such as “D end” or extraneous decorations such as stars, hearts, or
smiley faces fell in this category. Style rubric E2 assessed the use of color as a device to
communicate meaning. Student groups who alternated colors between letters, words, or screens
did not use color to communicate meaning. Student groups who used color to emphasize answers
or differentiate meaningful objects were considered to communicate meaning through color.
Screen shots exemplifying scoring for rubrics E1 and E2 are shown in Figure 3.5b.

![Screen shots](image)

<table>
<thead>
<tr>
<th>Good Explanation</th>
<th>Adequate Explanation</th>
<th>Limited/No Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some personalization</td>
<td>Some personalization &amp; Color used without meaning</td>
<td>Color used to represent meaning</td>
</tr>
</tbody>
</table>

Figure 3.5 Screen shots from Spangler Fall 2008 student SAM movies. Example scorings for content rubric C3 are given in (a) while example scorings for style rubric E1 and E2 are given in (b). Each pictured example is further explained in the text.
Students worked in groups of two or three to create SAM movies. The results for each rubric category, scored by group, are pictured in Figure 3.6. We find that for the content and the style rubrics, each group scored within one point of each other. All groups scored perfect on rubrics C1 and C2, suggesting students learned content about PET circuits #1 and #2 (Figure 3.1). All but one group scored perfect on E1, suggesting the students created movies with a high degree of personalization. Groups received lower scores on rubrics C3 and E2, perhaps indicating difficulties communicating through words or color. The link between content and style scores is indeterminate.
**Attitude Survey Results**

The attitude survey is a modified form of the CLASS [29] administered to physics students at the University of Colorado. Some of the questions for the attitudes survey were reworded so as to cater to the 5th grade ESL population at Spangler Elementary. Attitude surveys were graded on a -2 to 2 scale, negative values corresponding to unfavorable or novice attitudes towards science, and positive values corresponding to favorable or expert-like attitudes towards science. Neutral attitudes received a score of 0. Matched pre / post scores for Spangler are given in Figure 3.7. For questions 1, 2, 3, and 4 there were 11, 11, 8, and 10 matched pre / post attitude surveys respectively, which is reflected in the standard error. Once more, the questions asked were:

1. How do I feel about doing science activities?  
   “Really like them” to “Really don’t like them”
2. Do I think there is science in everyday life?  
   “There definitely is” to “There isn’t any”
3. Would I like to do an experiment or be told about it?  
   “Definitely do the experiment” to “Definitely be told about it”
4. How would I feel about doing science as my job?  
   “Really like it” to “Really not like it”

![Matched Pre / Post Attitude Survey, Spangler Fall 2008](image)

Figure 3.7 Average attitudes and beliefs survey results for Spangler Fall 2008 students. For questions 1 through 4, there were a respective n=11, 11, 8, and 10 matched pre / post surveys. Standard error reflects variances in n. The attitude shifts (post – pre) are -0.1, 0.4, -0.6, and -0.9 for questions 1 through 4 respectively.
Students averaged with favorable scores in each question for both pre and post surveys. Attitude shifts were -0.1, 0.4, -0.6, and -0.9 for questions 1 through 4 respectively, but t-tests indicate the following shifts are not significant: questions 1, 2, and 3 at the level p<0.01 (with t-values of -1.0, 1.0, and -1.5).

It is unclear why students experienced negative attitude shifts towards science carriers, though similar results have been observed in other studies [17]. For questions 1 through 3, the PISEC program successfully retained favorable student attitudes towards doing science, viewing science in every day life, and doing experiments. In CLASS studies, no shifts are considered desirable results [29]. Further, aggregate data (not shown here) from three consecutive PISEC Casa programs show average zero shifts over each program, but significant positive shifts over larger time scales [31]. The curriculum in these three Casa programs was not the same but the participating students were. These current longitudinal studies demonstrate stepwise improvement overall and suggest positive attitude shifts occur over longer periods of time.

**Attendance Results**

Participation alone does not ensure the success of an ISE program, but the ability to retain participants over reoccurring sessions is a valuable and important quality for voluntary after school ISE programs. Time spent actively engaged with inquiry instruction or the creation of SAM movies might indicate the amount of student and community commitment to the program. Attendance data is given in Figure 3.8. Here, intermittent students were considered to have attended less than four days of the PISEC program. Over this seven-week program, attendance averaged at about 13 total students, where 12 of those students were returning participants. From this we can conclude that the Spangler PISEC after school ISE program successfully retained student participants.
3.2 Discussion

3.2.1 Case Studies

Before discussing average data, we consider two case studies to understand particular interactions the Spangler PISEC program allowed. We first look at the performance of student I, whose learning gains and attitude shifts were similar to averages. We then look at the performance of student H, whose learning gains and attitude shifts were not similar to averages. Both students participated in the program for all seven weeks. Through their individual experiences, as documented by lab book drawings, writings, and survey performances, we hope to better understand effects from participation in the after school ISE in detail.
Student I

A summary of student I’s performance on the conceptual survey S1 and S2 and on the attitudes and beliefs survey is given in Figure 3.9. Student I had a learning gain of 4.0 on S1, answered S2 questions a, b, and c correctly, and indicated favorable attitudes towards science but experienced no shifts over the course of the program. On average (as shown in Figures Figure 3.2a, Figure 3.3, and Figure 3.7), participating Spangler PISEC students experienced an S1 learning gain of 4.1, answered S2 questions a through d with 92%, 69%, 61%, and 46% accuracy, and experienced no significant shifts for attitude survey questions 1 through 3 and a small negative shift for question 4. Student I scored similar to averages, indicating their experience might be representative of typical student experiences.

Figure 3.9 The top two plots show student I’s performance on the S1 and S2 sections of the conceptual survey of circuits. Results from student I’s attitudes and beliefs survey (given pre and post) are shown in the bottom plot. The student’s remarks for pre and post attitude survey questions are provided in Table 3.4. Student I performed similar to average student scores during the Spangler PISEC program.
Figure 3.10 Pre and post S1 drawings for student I are given in (a). The student’s lab book responses to modified PET curriculum are shown in (b), (c), and (d). We see this student’s circuit drawings increase in sophistication over time.

Student I’s S1 pre test drawing, pictured in Figure 3.10a, indicates the student entered the PISEC program with some knowledge of a complete circuit. The student’s lab book shows four out of six correct predictions for circuits in modified PET activity 1.1. In response to what was most likely an instructor’s question, the student wrote “full curcit, bulb not broken, batterie [sic] has to have power” in their lab book. This statement seems to give qualifications the student believed necessary to light a bulb. The student’s lab book response to modified PET activity 1.2, in which the student was asked what criteria they used to make their predictions, is given in Figure 3.10b. The student’s drawing for this activity, similar to their S1 pre drawing, indicates the student believed the wire must only touch the bottom of the bulb. Their written response to activity 1.2 implies the wire should touch “each end of the baterie [sic] and bulb”. At this point in the program student I appears to have believed a working circuit requires wires touching both
positive and negative battery terminals (the student called this a “full circuit”), and wires touching only the base of the bulb.

In modified PET activity 1.4 student I correctly observed each circuit. The student then drew two additional arrangements in activity 1.6, shown in Figure 3.10c, only one of which was correct. Unlike student I’s previous drawings, both images show the bulb and battery in direct contact and a wire connected to the side of the bulb. Next to these images the student wrote, “the bulb touches the knob in the middle of the positive side. The wire touches the negative end of the batterie [sic] and the metal part of the bulb.” Student I appears to have altered their idea of where a wire can connect to a bulb (at the side or the base), and how a bulb can connect to a battery.

In modified PET activity 1.7, shown in Figure 3.10d, the student drew a correct circuit with two wires connecting to both battery terminals to the side and base of the bulb. At this point in the program, student I appears to understand that a working circuit must involve connections to both the side and the base bulb terminals. This is further evidenced in the student’s circuit drawing for the S1 post test, shown in Figure 3.10a. The student’s progress over the course of the program shows that they addressed and corrected initial misunderstandings about basic circuits.

Student I articulated very favorable pre and post attitudes, given in Table 3.4. The student expressed confidence and enthusiasm towards doing science and had sophisticated views about science found in every day life. In question 4 the student believed a carrier in science would be fun but perhaps too difficult.

This case study indicates that, after attending all seven weeks of the after school ISE program, student I successfully learned content knowledge about basic circuits and retained very favorable views towards the process of learning and doing science. Student I scored close to the average of all students on the conceptual survey S1 and S2 and the attitudes and beliefs survey, perhaps indicating theirs was representative of typical experiences in the after school ISE program.
1. How do I feel about doing science activities?

- **Pre:** “I really like science because I learn and do new stuff.”
- **Post:** “I like how it is a [sic] adventure to me. Also I like how I get to do it myself.”

2. Do I think there is science in everyday life?

- **Pre:** “You use light and TV and more electricity from the day that is electricity.”
- **Post:** “I think there is because cooking is a use of science. And you can’t live a day without eating.”

3. Would I like to do an experiment or be told about it?

- **Pre:** “To see amazing new stuff and try them is defently [sic] more exited [sic].”
- **Post:** “I would like to do an experiment instead of being told about it because doing it is more exiting [sic] and I learn about it more.”

4. How would I feel about doing science as my job?

- **Pre:** “It would be fun to use science and do science every day but it would be hard to keep up.”
- **Post:** “It would be hard doing math and science it is fun and I’m good at math but everyday science as a job is fun [sic].”

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>How do I feel about doing science activities?</td>
<td>“I really like science because I learn and do new stuff.”</td>
</tr>
<tr>
<td>2.</td>
<td>Do I think there is science in everyday life?</td>
<td>“You use light and TV and more electricity from the day that is electricity.”</td>
</tr>
<tr>
<td>3.</td>
<td>Would I like to do an experiment or be told about it?</td>
<td>“To see amazing new stuff and try them is defently [sic] more exited [sic].”</td>
</tr>
<tr>
<td>4.</td>
<td>How would I feel about doing science as my job?</td>
<td>“It would be hard doing math and science it is fun and I’m good at math but everyday science as a job is fun [sic].”</td>
</tr>
</tbody>
</table>

Table 3.4 Student I’s written responses for the pre / post attitude and beliefs survey. The student shows very favorable views towards doing science activities and learning new material.

**Student H**

A summary of student H’s performance on conceptual surveys S1, S2, and the attitude and beliefs survey is given in Figure 3.11. Student H had an S1 learning gain of 6.0 points, answered S2 questions c and d correctly, and retained mostly favorable attitudes towards science and science learning throughout the program. The student’s attitude shifts for survey questions 1 through 4 were 0.0, 3.0, 0.0, and -2.0 points respectively. As before stated, students showed an average S1 learning gain of 4.1, answerd S2 quesusitons a through d with 92%, 69%, 61%, and 46% accuracy, and shifted -0.1, 0.4, -0.6, and -0.9 points in attitude survey questions 1 through 4. Student H’s S1 learning gains were significantly higher than the average, their S2 and attitude shifts for questions 1 and 3 were close to the average, and their attitude survey shifts for questions 2 and 4 were respectively above and below the average. This cases study attempts to understand this student’s nonrepresentative experience in the after school ISE environment.
Figure 3.11 The top two plots show student H’s performance on the S1 and S2 sections of the conceptual survey of circuits. Performance on the attitudes and beliefs survey for student H is given in the bottom plot. Student remarks for pre and post attitude survey questions are recorded in Table 3.5.

Though the S1 pre test was administered, student H did not provide an answer. This indicates the student did not have a coherent initial mental model about basic circuits upon entering the ISE environment. At the beginning of the PISEC program, student H correctly predicted the results of three out of six total circuits in modified PET activity 1.1. The student explained their predictions in their lab book as, “Because the battery makes the bulb light one so they need to be together [sic],” perhaps indicating the student believed the battery must be in direct contact with the bulb. The student also wrote, “The battery needs power. The wire needs to touch the battery and bulb.” Coincidentally, student H’s responses to activity 1.6 are identical to those of student I (see Figures 3.10c and 3.12a), indicating students I and H worked in the
same group for this activity. The response to this activity imply the student believed the bulb must directly touch the battery, but wires can touch the bulb at either side or the bottom. Student H appears to have believed a working circuit must contain (1) a bulb and battery in direct contact, (2) a wire touching the side or base of the bulb, and (3) a wire touching both the battery and the bulb.

Student H’s activity 1.7, completed individually, is provided in Figure 3.12c. In this activity the student drew but crossed out two incorrect circuits, one in which wires touched just the side of the bulb and the other in which wires touched just the base of the bulb. The student then drew a correct circuit in which battery terminals were connected by wires to the side and base of the bulb. These drawings indicate student H no longer believed the bulb must directly touch the battery. Presumably, the student completed the program believing that an illuminated bulb must be connected to a battery (via wires or directly) at both the base and the side. Thus, by the end of the program, the student created a correct theory about basic circuits. Though, it is unclear whether or not this student was able to articulate these ideas.

Student H entered the program with very favorable attitudes on survey questions 1, 3, and 4, but unfavorable attitudes on 2. The student left the program with very favorable attitude on survey questions 1, 2, and 3, and neutral attitudes on 4. Their comments, provided in Table 3.5, contain little content but indicate the student believed science is fun because it involves doing activities. Over the course of the PISEC program, this student shifted from an unfavorable to a very favorable view about science in every day life. The student’s comments are unclear, so we cannot determine why this shift occurred. Whatever the cause, the shift indicates the curriculum successfully connected science with the student’s life.
Figure 3.12 Student H’s lab book responses to selected modified PET activities are given in (a) and (c). Their post response to concept survey S1 is given in (b). The student did not provide a pre S1 drawing.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How do I feel about doing science activities?</td>
<td>“I like science because we do experiments.”</td>
<td>“Because we do a lot of things.”</td>
</tr>
<tr>
<td>2. Do I think there is science in everyday life?</td>
<td>“I think because.”</td>
<td>“I think there is science everyday life.”</td>
</tr>
<tr>
<td>3. Would I like to do an experiment or be told about it?</td>
<td>“Because you touch the tinks [sic] when you doing experiments.”</td>
<td>“Because there are fun things and because we do a lot of things.”</td>
</tr>
<tr>
<td>4. How would I feel about doing science as my job?</td>
<td>“Because.”</td>
<td>“Because I feel doing science.”</td>
</tr>
</tbody>
</table>

Table 3.5 Student H’s written responses for the pre / post attitude and beliefs survey. There is little content in the student’s remarks, making it difficult to understand why the student answered as they did.

Potential Effects of after school ISE on Students

These case studies give a detailed documentation of student interactions with the curriculum and in the after school ISE environment. The student in the first study entered the
program with a well established theory about circuits, namely that a working circuit required wires connecting both battery terminals to the base of the bulb. By the end of the program this student successfully confronted and replaced this incorrect model with a correct one. The student’s average performance on the S1 and S2 suggests their experience might be representative of typical experiences in the ISE environment. In contrast, the second student did not appear to have any initial theory about basic circuits. By the end of the ISE program, this student created, tested, and verified a correct theory about circuits, thus demonstrating a large learning gain.

Additionally, both students were able to successfully complete S2 survey questions extending the material past what the program addressed. This suggests both student’s ideas about circuits were robust enough to apply to never before seen situations. As a result of the after school ISE program, both students were able to use deep-structure knowledge instead of surface features to correctly solve problems. Findings from these case studies are consistent with average results. The large learning gain from content survey S1 indicates students were successfully able to learn content in the PISEC after school ISE environment.

In both case studies, students expressed positive attitudes about the nature of science and the process of doing science. While student I experienced zero shifts over the course of the program, their remarks were very favorable towards science. This student, possibly representative of characteristic Spangler participants, expressed excitement about doing science activities and interest towards sense making. Student H experienced a large negative attitude shift towards science careers and a large positive attitude shift about science in everyday life. This student showed very favorable attitudes towards science activities and doing experiments. The student was not able to verbalize why they held these opinions, thus it is difficult to further understand the effects of after school ISE on this student’s attitudes.

On average, Spangler data indicates attitudes towards science careers decreased while other attitudes shifts were fixed. However we find students hold favorable views and might
exhibit stepwise increase over longer time scales. The case study for student I seems to indicate students were interested in science but believed going into a science carrier would be too challenging. Similar results have been observed in a different MESA study [17]. Perhaps, if the students are allowed to further increase confidence in their scientific abilities, either in formal or informal settings, their attitudes towards science carriers will become more favorable over time.

Our content and attitude findings are consistent with the six strands framework for learning in ISE environments, particularly for strands 1 and 6. Conceptual surveys indicate students developed and used correct models about basic circuits, while attitude survey remarks expressed excitement and interest towards science activities. These survey comments also indicated the after school ISE environment allowed students to think about themselves as science learners. Further, the high degree of personalization with which students created SAM movies suggests students may have developed a sense of science identity over the course of the program.
4. Conclusions and Recommendations

Data form the Spangler after school ISE program suggests student develop content knowledge in these environments. Attitudes towards science carriers decreased while other attitudes shifts were fixed. However we find students hold favorable views and might exhibit stepwise increase over longer time scales. Students choose to continually participate in the after school ISE program, which suggests they had a positive experience. Further, all students successfully created highly personalized movies about accurate content knowledge.

The data also shows that participating Spangler teachers could not correctly draw a basic circuit at the beginning of the program. In future studies, volunteer K-12 teachers will be asked to complete both pre and post content surveys. We suspect results will indicate significant learning gain in teacher content knowledge after involvement with the program. Future PISEC programs might be able to prevent teacher conceptual misunderstandings sooner by providing volunteer K-12 teachers the opportunity to participate in UE training sessions. Additionally, future studies should investigate the effects of after school ISE programs on formal institutions by interviewing participating K-12 teachers or other MESA coordinators. If granted more time for this study, this topic would have been discussed in more detail.

Spangler students were often ESL students and sometimes had difficulty reading and interpreting the PET curriculum or survey questions. In future PISEC programs, existing directions might be reworded so as to better accommodate ESL populations. In reviewing student lab book, content, or attitude survey responses, students often had difficulty expressing themselves in English. Sometimes students provided written responses entirely in Spanish. PISEC Researchers could not interpret these responses because, sadly, we cannot speak Spanish.
In future work, it would benefit students and PISEC research if at least one of the volunteer UEs at each site spoke Spanish.

Future studies should address how after school ISE programs can affect formal institutions, university participants, and communities. Future longitudinal studies (perhaps involving new or continuing participants over many sequential programs) might indicate student attitudes towards science increase significantly over time.
5. Appendix A: Modified PET Curriculum

**Activity 1: Light the Bulb**

**Instructor Instructions:**

1. Each student should have a lab book with a sticker on the front with their name, date, and location. Students should already have seen the Electric Circuit Demos and learned how to make a documentary.

2. These are the **materials** you will need for this activity:

   - 2 Loose batteries
   - 2 batteries in holder
   - Camera
   - Camera holder
   - 2 Loose bulb
   - Bulb in holder
   - White board
   - Scissors
   - 3 alligator leads
   - 2 bare copper wires
   - Switch
   - Markers
   - Tape
   - Computer
   - Eraser

3. Cut out each sub activity and put into a folder. Give out one sub activity at a time. Do not give out the review sub activities on the same day that they do other parts of the activity; wait until the next day. Cut out extra documentary pages and cut outs below.

4. Make sure the student has completed the whole activity before initialing it. This is to make sure they do all of it. For predictions, the answers do not have to be correct, whereas for measurements or questions they may need to be. Use your judgment.
Activity 1.1  Do this activity individually, not with your group.  Instr. Init.______
Imagine that you had a battery, a small bulb and some wires.  You were curious about what arrangements would cause the bulb to light.  Next are pictures of six possible arrangements, with brief descriptions of how the wires are connected in each case.  Look at each arrangement carefully and predict whether that particular arrangement would cause the bulb to light.

Write “YES” next to Prediction: for each arrangement that you think would light the bulb.  Write “NO” next to Prediction: for each arrangement that you think would not light the bulb.

#1
The tip of the bulb touches the negative end of the battery.  A wire touches the negative end of the battery and the positive end of the battery.
Prediction:__________

#2
The tip of the bulb touches the negative end of the battery.  A wire touches the positive end of the battery and the metal side of the bulb.
Prediction:__________

#3
One wire touches the positive end of the battery and the tip of the bulb.  A second wire touches the negative end of the battery and the tip of the bulb.
Prediction:__________

#4
The tip of the bulb touches the positive end of the battery (but not the knob in the middle).  A wire touches the metal side of the bulb and the negative end of the battery.
Prediction:__________

#5
A single wire touches the positive end of the battery and the negative end of the battery.  The tip of the bulb touches the middle of this wire.
Prediction:__________

#6
The metal side of the bulb touches the positive end of the battery.  A wire touches the tip of the bulb and the negative end of the battery.
Prediction:__________
Activity 1.2  Do this activity individually, not with your group. Instr. Init.______

What criteria were you using in making your decisions? That is, what did you think was necessary for the bulb to light?

Activity 1.3  Do this activity with your group Instr. Init.______

Group members:______________________________________________________________

Discuss your answers and reasons with your group members. If you change your mind, do not erase your original answer, but instead just add the opposite answer alongside your original answer.

Activity 1.4  Do this activity individually, not with your group. Instr. Init.______

Collecting and Interpreting Evidence

Experiment #1.4: What conditions are necessary to light the bulb?

Each student will need:

- One loose battery, one loose bulb, two bare copper wires

Try each of the six arrangements pictured on the previous pages. In some cases you will need another group member to assist you to hold all the pieces together.

Write “YES” next to “Observation:” for each arrangement that actually lights the bulb, and write “NO” next to “Observation:” for each arrangement that does not light the bulb.
<table>
<thead>
<tr>
<th>#1</th>
<th>#2</th>
<th>#3</th>
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<tbody>
<tr>
<td>The tip of the bulb touches the negative end of the battery. A wire touches the negative end of the battery and the positive end of the battery. Observation:__________</td>
<td></td>
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</tr>
<tr>
<td>The tip of the bulb touches the negative end of the battery. A wire touches the positive end of the battery and the metal side of the bulb. Observation:__________</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One wire touches the positive end of the battery and the tip of the bulb. A second wire touches the negative end of the battery and the tip of the bulb. Observation:__________</td>
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</table>

<table>
<thead>
<tr>
<th>#4</th>
<th>#5</th>
<th>#6</th>
</tr>
</thead>
<tbody>
<tr>
<td>The tip of the bulb touches the positive end of the battery (but not the knob in the middle). A wire touches the metal side of the bulb and the negative end of the battery. Observation:__________</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A single wire touches the positive end of the battery and the negative end of the battery. The tip of the bulb touches the middle of this wire. Observation:__________</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The metal side of the bulb touches the positive end of the battery. A wire touches the tip of the bulb and the negative end of the battery. Observation:__________</td>
<td></td>
<td></td>
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</tbody>
</table>

**Activity 1.5** Do this activity individually, not with your group. Instr. Init._______

🔍 Which of the setups use a battery, bulb and a single wire and the bulb lights?
**Activity 1.6** Do this activity individually, not with your group. Instr. Init.____

Figure out one more different arrangement of battery, bulb and a single wire that lights the bulb.

- Draw a sketch of your new successful arrangement.

**Activity 1.7** Do this activity individually, not with your group. Instr. Init.____

Figure out an arrangement using the battery, bulb and two wires that light the bulb.

- Draw the circuit below.

**Activity 1.S1** Do this activity individually, not with your group. Instr. Init.____

- You are going to make a documentary movie about what you have learned.
  - On the story board, enter your name and the title.
  - Enter the general idea of your movie.
  - In the first part of your movie, *explain why* circuit #1 worked or did not work.
  - Next, *explain why* circuit #2 worked or did not work.
  - At the end of your movie, write “The End”.

**Activity 1.M1** Do this activity with your group. Instr. Init.____

- Group members:_____________________________________________________

- [SAM] Make a stop action motion (SAM) movie Documentary using your storyboard ideas. Remember that we will be showing this movie to everyone, so make sure it is complete.
6. Appendix B: Conceptual Survey of Circuits

6.1 S1: Offered as a pre and post test

Name________________________________    Date________________________

1: On paper, can you draw one wire, one light bulb, and one battery that will light the bulb?
6.2 S2: Offered only as a post test

Name ___________________________ Date ________________

**Review Question for Activity 1**

The pictures below represent three different ways of putting together a battery bulb and one or more wires. In each case:

1) Indicate whether the bulb will light or not light.
2) Justify your choice in terms of the ideas developed in this activity (i.e. the conditions necessary to light a bulb).

<table>
<thead>
<tr>
<th>Image</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td>(a) One wire touches the positive end of the battery and the tip of the bulb. A second wire touches the positive end of the battery (not the knob in the middle) and the negative end of the battery.</td>
</tr>
<tr>
<td><img src="image2.png" alt="Image" /></td>
<td>(b) One wire touches the negative end of the battery and the metal side of the bulb. A second wire touches the positive end of the battery and the tip of the bulb.</td>
</tr>
<tr>
<td><img src="image3.png" alt="Image" /></td>
<td>(c) One wire touches the positive end of the battery and the metal side of the bulb. The other wire touches the negative end of the battery and the metal side of the bulb.</td>
</tr>
<tr>
<td><img src="image4.png" alt="Image" /></td>
<td>(d) One wire touches the negative end of the battery and the tip of the bulb. The metal side of the bulb touches the positive end of the battery.</td>
</tr>
</tbody>
</table>
7. Appendix C: Attitudes and Beliefs Survey

Name__________________________________________Date____________________

Male If under 18: Age _____
Female If over 18: Occupation____________________________________________

1. How do I feel about doing science activities? I …. (circle one)

Really like them Kind of like them Feel in between Kind of don’t like them Really don’t like them

Why? What do you like or dislike about them?

2. Do I think there is science in everyday life? I think…. (circle one)

There definitely is There is some I feel in between There isn't much There isn't any

Why do you feel this way? Give one example.

3. Would I like to do an experiment or be told about it? I would like to…. (circle one)

Do the experiment: Be told about it:
Definitely Maybe In between Maybe Definitely

Why?

4. How would I feel about doing science as my job? I would…. (circle one)

Really like it Kind of like it Feel in between Kind of not like it Really not like it

Why? What do you like or dislike about it?
8. Appendix D: Formal and Informal Environment Observations

8.1 Spangler 4th Grade Class Observation:

Field Notes
Name: Jessica Bartley
Date: Tue 2/25/09, 12:50-2:30pm
Site: Spangler Elementary
Topics Covered: Observation of T.’s 4th grade class completing “Predictions #2 (Embedded Assessment)” from Learning Experience 7
Instructors Present: T. and myself (as observer)
Number of Students present: 24

I arrived early to ensure that I was present for the start of the lesson. On the drive the Spangler I practiced what I was going to say to the kids. My practice speech consisted of how I was there to observe and how they should pretend that I wasn’t even there. It was a very nice day outside and I was happy to be driving out there, but my mind was also elsewhere. My mother had been having health problems for the past week and she called me that morning very ill. We haven’t yet been able to find out what is wrong with her, and I have had to be ready to take her to the hospital when and if she needed me too. I thought perhaps this morning I would have to cancel my appointment with T. to do this. As it turned out I did not have to, but I was still worried about my mother, and still expecting a call at any moment asking me to take her in to the ER. I tried to put this out of my mind for the time being so that I could focus on what I needed to do for observing T.’s class. Before I drove out to Longmont I printed off an excel sheet so that I could document the time of instruction and what types of instruction the students were receiving. The options I chose to look for were “direct instruction”, “individual activity”, “group work”, “prescriptive”, “generative”, and “other”. Noah suggested I look for these things. I also printed off multiple sheets to document the types of questions asked by both the teacher and the student. I left a space so that I could tally the number of questions asked by students or teachers in the lesson.

When I arrived at the site I signed in as a visitor at the main office and walked over to T.’s classroom, which was located in a separate temporary building just outside of the school. I knocked on the door and I could hear a few kids yell out “It’s Jessica!” A few students came to the door and let me in. I apologized to T. for being a few minutes early and she said it was completely all right. She got the classes’ attention, introduced me by name, and said that some of them might already know me from MESA. I then introduced myself, saying, “Hi everybody. Like T. just said some of you might already know me, but for those of you who don’t my name is Jessica. I’m here today to visit your class and observe how you guys learn science.” There were some cheers after I said this. “So you might see me sitting here in the back, walking around, and maybe taking some notes.” I continued, “What I need you guys to do for me is pretend like I’m not even here. Can you guys do that for me?” The students responded with a dutiful “yes”. T. then took over again as I found a seat in the back of the room.

At the front of the room was a projector that T. was standing next to. The students were sitting in desks arranged in groups all facing each other. There were four groups of desks with 5 or 7 students sitting together. Affixed to each of their desks was a large nametag with the student’s full name, a cursive alphabet and a times table. At the front of the room, next to the projector stand, was a rocking chair (presumably T.’s) and a stand holding a large (about two by three feet) white pad of paper. On the side of the room was one computer and a chair, next to that was T.’s desk. At the back of the room was a large semi-circular table at which I was sitting. There were posters around the room illustrating phonics and other 4th grade curriculum items. While I was sitting at the back table I noticed some of the students kept
looking back at me to see what I was doing, but for the most part, the students were paying attention to T. who was at the projector talking about multiplication tables. There was a teacher to student ratio of 1/24.

II

Before T. started the science lesson, I observed the student’s classroom behavior during T.’s lesson on times tables. I noticed that there were students who were sitting up in their desks and paying attention to what T. was writing, but there were also students who were lying their heads down on their desks or were otherwise passively engaged as well as students who were carrying out conversations with each other at their desks quietly in Spanish. T. was asking students to call out numbers all together as she wrote them down on the projector, filling in blank spaces on her multiplication tables. This method of having student call out numbers served as means to engage them, but it was evident (by the number of students whose heads were resting on their desks) that only a portion of the students were actively interested in the material. The students with their heads down were calling out numbers quietly. During this lesson some of the students lost focus and started to talk to each other in louder voices. The sound level of the room rose. When the students started to talk to each other too much T. would simply stop talking and wait. Students would then get quiet and watch her. This seemed to be an effective method at gaining their attention again.

After T. finished the lesson on multiplication tables she called out to everyone saying, “I need everyone up at the meeting area”. The students got up from their desks and moved towards the front of the room. The students then gathered around at the front of the room near the large white pad of paper, sitting cross-legged on the floor. There was not enough room for every student to sit on the floor, so some of the student sat at desks near to the white paper pad. T. made an point to ask if students could see. She asked individual students, especially students sitting towards the back of the group, whether or not they could see the paper. These students responded yes, and T. started the lesson. This occurred at 1:07.

T. drew the outline of a large light bulb on the white paper pad. She started asking the students questions. I tried to tally how many times T. asked questions to her students and how many times her students asked her questions, but it was difficult to keep track. T. asked many, many questions. I did not hear any of the students once ask T. a question. While she drew the outline of the light bulb she asked “do you remember that drawing we did with the bulb from last time?” Some students nodded their heads and said yes. She drew a dark strip of color at the bottom of the bulb and asked, “What am I going to call this right here?” pointing to the colored in region at the bottom of the bulb. The students shouted out many answers all at once. Some of the things the students shouted out included “metal”, “terminal”, “ice terminal”, “plus terminal”, and “insulator”. When T. heard the student who said “insulator” she congratulated the students for coming up with the correct word and wrote it on the picture with an arrow pointing to the bottom of the bulb. While T. was writing “insulator” on the picture, one student had her hand raised. T. did not see her and the student eventually put her hand down. “What material is it made out of?” she asked, still referring to the bottom of the bulb. One student called out “metal”. T. did not directly address this student suggestion but rather asked something different. She called out to all the students, saying, “everyone show me a light bulb,” as she held her hands up as if she was holding a very large light bulb. The students did the same, holding their hands up as if there were holding large light bulbs over their heads. “Now everyone she me where the base is,” T. said. The students pointed to the bottom of their imaginary light bulbs. She then asked, “What is that part called?” Students called out “base terminal”. T. said, “Yes! It is called the base terminal”. She then wrote this on the picture and drew an arrow to the bottom of the bulb. She then asked, “What else do we need to add to the picture?” The students said they needed to add wires. T. said, “The wire touches the base terminal,” as she drew a wire going up from the base terminal. The students directed her, telling her where to draw the rest of the wire. She drew it going all the way up to where the filament would soon go.

At this point the students were much louder than they were at the beginning of the activity. T. stopped talking and waited quietly, looking at the loud students. They soon grew quiet again. She then continued to draw her picture. She put a large emphasis on colors while creating this picture. She drew the next wire inside the bulb starting from the side of the bulb. She reminded the students of what the
bulb looked like when they broke it open in a previous class, and asked, “What did we notice about the wires?” The students answered that they crossed. She said yes, and then drew the rest of the wire into the picture. She drew this wire overlapping the first wire. She emphasized that the two wires inside the battery crossed one more time. While she was drawing students were talking quietly in small groups on the floor for about three minutes.

She then asked, “Where does the filament go?” The students told her to draw the filament in between the two tops of the drawn wires. She drew this in. “What else am I missing?” she asked. The students said that she needed the ball around the two wires holding the filament. T. drew in the glass bead, emphasizing that it was glass and labeling it as “glass bead” on the picture. “Anything else we need to draw in?” she asked. One student (E., a MESA student) commented, “The filament needs to be curly”. T. was confused by this comment, asking, “The filament should be curly?” E. insisted, saying that she saw the filament was curly in the movie they had watched (presumably in an earlier class). T. then said, “oh yes, in the movie you saw the filament under a microscope so it was really big. Right?” E. nodded. “It was curly under that microscope,” T. said, “but those are really small curls. So we can pretend that the filament is curly in the picture.” E. was insistent and wanted T. to draw the curls in. Student sitting at the far end of the group sitting on the floor were beginning to loose focus and talk about other things. T. said, “OK.” and drew in very small curls in the center of the filament. T. drew these small curls only in the center of the filament wire, about two inches in from both ends of the filament. Students at the far end were still talking amongst each other and had lost focus. “What do you think the little curly part does?” she asked all the students. Everyone answered, “It makes the light!”

T. then told her students that they were going to do something different. They were going to go back to their desks and predict whether or not they thought some circuits would make a light bulb light. She tore off the picture of the light bulb they had just drew and set it on a group of desks, saying that she would hang it up on the wall where the rest of their science drawings were hanging. T. then shifted the focus to defining what a prediction was. She asked the students (who were at this point still sitting on the floor), “When you make a prediction, what do you do?” There were a lot of responses to this question. They all shouted out answers at once and it was difficult to catch any particular quotes. “What could I write for a definition of prediction?” T. asked. The students suggested many things that T. commented verbally on, but she did not write any of them down on the white pad of paper. She asked the class whether or not a prediction could be wrong. She read off the definition of “prediction” from a piece of paper she was holding. This paper was supposedly from the activity that the students were going to start working through. This definition was very long and complicated. It used large words that confused the fourth graders. T. read through the definition somewhat quickly and the sound level in the room decreased as the students tried to listen to what T. was reading. After she finished, while kids were worriedly looking at her, she said, “Now that’s a mouthful! Let’s try and come up with a simpler definition that we can understand.” The students liked this. They didn’t look as worried as they had a few moments before. She started calling out for ideas from students about what she should write on the pad. One student suggested she write down something about “what we know will happen”. She said, “Ok, but what if you don’t know but you still have to make a guess?” The students were quite, trying to think of a response to her question. T. responded to this silence by saying, “You guys do it!” asking them to create a definition. The students were more responsive to this. Someone shouted out a definition that was “explaining what will happen next.” T. liked this and wrote it on the paper pad. She asked the class, “Does it have to be right?” The class answered that it didn’t have to be. “If it isn’t right,” she continued, “what should we do? Should we laugh at you?” She moock laughed at some students saying, “oh you had the wrong guess.” Students sitting on the floor, especially students towards the back, responded to this by also fake laughing with abnormal sounding laughs. “No,” she said, “We don’t laugh at them. We help our friend who didn’t have the right guess, or we try to guess again.” T. emphasized that predictions can be wrong but that even if the predictions are wrong we don’t erase it. She said this many times over, saying that if the prediction is wrong then we can make a different prediction. This activity ended at 1:20.

T. told the class they would be doing something different now, saying, “We’ve been talking for much, much too long.” At 1:27 students went back to their seats and T. gave them directions about what
they would be doing next. She said that they would be predicting whether or not circuits would light a bulb. She said that they were to do this activity by themselves. She handed out the activity “Science Notebook Page Predictions #1” to the students. As she did this she said, “Everyone put your pencils away!” The students were shocked at this statement and called out, “What!” T. walked over to her desk and got a cup full of pens. She said, “Put your pencils away so that you cannot change your predictions. You need to use pen.” She said once more, “These are predictions you make by yourself.” T. then said, “You may start.” The students started at 1:30.

While the students were starting, T. called out, “Some of you will be done pretty fast. If you have already seen this stuff at MESA then when you are done draw a picture, maybe a circuit, on the back of your paper.” The classroom was still pretty loud at this point, even though students were supposed working by themselves. I looked around from table to table and saw that there were many students who were working on the work sheet, but others were talking to each other or walking around the room.

After a few minutes of walking around the room talking to individual students, T. called out “I’m going to give you three more minutes to make your predictions.” There was still talking at tables and between tables when she said this. T. continued to walk from table to table, asking students if she could see their predictions. I also walked around the room to see what students were doing. Some of the activities I saw students doing were working on the worksheet, doodling on themselves with the provided pens, talking to other students, reading, drawing on the backs of their papers, playing with their papers, and playing with their desks. These were only a few of the activities students were doing. Much of the conversation I heard was in Spanish and I could not tell what was being said. My walking around distracted a few students, making them look up from what they were doing. A few girls seemed very interested in me and kept smiling in my direction. When the students were finished with their predictions they were supposed to turn their papers over. At 1:33 T. called out “Everyone turn their papers back over now.” The classroom was getting very loud at this point. All students were talking together or looking at other students talking together. This was the loudest the classroom had been since I had arrived. T. got their attention by turning the lights off and on again. She said once more “flip your papers over so you can see your predictions.” She also asked them to put their name at the top of their papers.

T. then explained to her students that they were going to be discussing what they had predicted in their science groups. “You all in your groups have to come to the same conclusion,” she said. “You have to come to a conscious – when everyone agrees.” She then handed out papers (“Group Recording Sheet Predictions #1”) for the groups to work on. She explained one more time what they were to be doing as she handed out papers. “This again,” she said, “is really similar to what you did in MESA.” The students got up and sat in their “science groups” and the room became very loud. While the students were moving around S. came up to me and asked me to give him the answers. I told then that I couldn’t and he should talk to his group like T. had just explained. It was 1:37 when the students started working in groups.

T. walked around from table to table checking in on students. I observed her while she talked to one table. She explained once more what the students should do. After she left the table one of the students said, “Because it works” to another student, pointing at a prediction the other student had written down. A conversation in Spanish then ensued. At this moment half of the students in this group were working alone on their work sheets while the other half conversed in Spanish. A few minutes later all students in the group were discussing in Spanish, pointing to their papers and writing things down.

T. had moved on to talk to another group and had, presumably, had to explain, once more, the directions for this groups as well. I do not know if this is true because I could not hear her, but after a brief interaction with the table she called out to the entire class and instructed them on what they were doing for a third time. This occurred at 1:42. She explained how the students were to talk about what they predicted individually, compare what people in their group had predicted, and discuss why they had written down their predictions. After discussion, T. told them they should all make new group predictions that were all the same. Two minutes later she sent them back to work in their groups.

I walked around to other groups and noticed that many of them were off task. One group was looking at and playing with a photo they had found lying on a table at the side of the room. There were
three or four groups who had members with their hands raised. T. could not get to all of them at once. The room was very loud at this point. T. turned the lights off. Once all the students had lowered their voices she turned the light back on. I looked around the room and there were students with their heads down on their desks. I began to walk around once more and noticed that many students were bouncing their pens up and down off of their desks, some female students were playing with their jewelry, and the MESA students were telling answers to other non-MESA students in their group. As I was walking around one student noticed me and asked what the date was. This student asked me for my name, I told her, she then asked if I could help her and her group. Her group had their hand raised and T. was talking to another group at that moment. I told them I didn’t know the worksheet they were working on (which was not entirely true), but I pointed out that T. was on her way over to their table. I told the group they should ask T. their question after she was done talking with the group next to them. I hoped that this was a polite way to not interfere with this group’s learning process. The student who asked me my name looked disappointed, but she did not ask me to help her group again. This was at 1:45.

T. then started to hand out boxes within which were batteries, bulbs, wires, motors, and battery holders. The students immediately started playing with the materials. Students started making the motors run and the room became even louder with the buzzing of tiny motors. She called out to the class to not play with the motors or the battery holders, but only with the materials that were drawn on the worksheet, saying “I see a lot of battery holders out, do you need those to be out?” The class responded with a mixed “no”. “No” T. called out, “You only have out the objects that you need to test your circuits.” After a few minutes of group work the room became very loud once more. T. responded to this increase in room noise by turning off the lights. She told the students that she wanted them to work in groups of twos for the next part of the worksheet. She asked her students, “What are you going to write when you write stuff for analysis?” T. and her students had a brief discussion about what analysis meant. She attempted to define analysis verbally for the students. After this, T. turned the lights back on once more and the students went back to work. This was at 1:52.

The students, now in groups of twos, started playing with the wires and batteries again. Many more groups were on task at this point. I was observing one group of two who was playing with their materials and testing their predictions. One student said, “That one doesn’t work. So we were wrong!” These students wrote down something (presumably “yes” or “no”) on their papers and moved on to test a different circuit. When they got the bulb to light one of the students excitedly shouted out, “It works the... oh!... yes, yes!” While I was watching this group S., a MESA student, came up to me holding a light bulb so that I could see. He said, “See! Look! Out light bulbs are different.” He was referring to how the light bulbs they were using were slightly more tinted and had a more square like shape than the light bulbs we use the outreach program. I told him that yes our light bulbs did look different. I wanted to deflect his attention without ignoring him. I do not recall exactly what I said, but I probably said, “there are many different kinds of light bulbs, but the important thing is that they all can give off light”. I then told him to get back to his group and keep working on his worksheet. He then said OK and walked back over to his group.

I looked once more around the room to see how many tables were on task. After walking around a bit, I noticed that almost every group was writing something on their worksheets. Some groups were working on the second worksheet (“Group Recording Sheet Predictions #1”) at this point. T. continued to walk around the room talking to groups. I heard her ask one group, “Did you guys start to test your predictions? OK, what happened?” I tried to hear what students at other tables were saying to each other but most of their conversations were in Spanish. Many of these students were writing on their worksheets and constructing the pictures circuits. It seemed as if their conversations were about the circuits they were building, but I cannot be sure.

T. called out to the entire class once again, asking the students to write about “why did it work, why didn’t it work? What was it touching?” She pointed up to the picture of the light bulb they had drawn at the beginning of the lesson, saying “…Base terminal, side terminal, was it touching those?” The students continued to fill out their work sheets. When I walked from table to table I heard students
talking about the MSEA program. They might have started talking about the MESA program because I was walking past their tables.

I passed one group who excitedly exclaimed, “Jessica! Look… we try with the earring!” They held the battery, the wire, and the bulb up a student’s earring. The bulb light up when they did this. They were excited. I told them that that I thought that was really cool, as I moved on to the next table. This happened at 1:55.

The room was becoming very loud once more. I noticed many more students filling out the analysis portions of the “Group Recording Predictions #1” worksheet. Students were writing on the analysis portion of this work sheet alone, or they were looking at group member’s pages. There were also students still playing with bulbs. Students were still playing with motors and battery holders as well. It was very loud in the room. T. got the student’s attention by turning off the lights. She said “What I’m seeing is some people doing what I’m asking and some people doing what I’m not.” She stressed that she needed students to be on task. “If it doesn’t work,” she said, “then I’ll have to ask individual students to sit outside.” She then took away the motors from students who had been playing with them. This occurred at 1:59. The disciplined students who had had their motors taken away started to work in the groups and fill out their worksheets.

I began to walk around the room once more. I walked past G., a MESA student, and heard him say “…because I tried that in MESA with Steve.” The student that G. was talking to asked who Steve was, and G. pointed at me, saying “He is a friend of Hers.” T. called out to the whole class once more, “Some people are asking me questions about how to spell wire so I’m going to write it down here on this picture.” She walked over the drawing of the bulb hanging on the wall, stepped up onto a chair, and drew a red wire on the picture. She labeled it “wire”. While T. was drawing and labeling this, many students lost attention and started being loud.

At 2:00 T. called out to everyone, and asked E. to come up to the front of the room and give the other students an example of what sorts of things they should be writing for analysis. E. came up to the front and started reading her explanation. “The base terminal is touching the end of the battery and the wire touches the side terminal,” she said. T. emphasized what E. had just said, saying “the base terminal touches the end of the battery and the wire touches the side terminal.” She thanked E. and then said “OK, you guys can get to work.”

At 2:11 students began to get loud once more. Some students began to play with a roll of white out tape between two adjacent tables. The students were off task at this point. T. began to collect materials from groups. She asked the students “What did you think about making predictions?” She talked about what the students would do next time, she assigned them homework (mostly about times tables), and she asked them to bring a form back the next day with parent signatures and $5. She said to me, in front of the class, that the $5 was so that after CSAP they could build clocks out of recycled materials. She described it as “something fun” during CSAP. The science lesson ended at 2:19.

After the class, once the students had left and all the materials had been put away, I thanked T. for letting me observe her class. She said that it was her pleasure and that I should come in again if I needed to. We talked a bit about how difficult it is to manage a classroom of this many 4th graders. T. said that they send her emails sometimes about facilitating tips. She said that these help. She also told me that she “has learned a lot from the MESA program.” She said that she gets a lot of ideas from the things that we do during the outreach program. She said, for example, “using the pens for their predictions was an idea I got from you guys.” She said that she would have never thought of that without our program. I asked her if she would be open some time for me to interview her about her opinions on how MESA effects her teaching. She said that she could do this. I also asked her about the possibility of giving all of her students the same pre surveys that we give the MESA students, in order to test how MESA and non-MESA students compare. She was very open to this idea. I told her I would bring extra surveys to next week’s MESA program.

III
It was impossible for T. to get all students engaged.

Upon walking in to the classroom, I was reminded of working at CASA with Heather. I thought “I wouldn’t be able to handle this many students alone.”

Cross legged at front is not typically formal

At the end of the lesson, I had tallied that T. had asked 23 questions, while the students had asked none. This number is probably inaccurate.

Why did T. draw and emphasize the wires overlapping? She didn’t clarify that the wires have a coating and that the crossing of the wires was not metal touching metal. I saw students drawing this in activity 1.5 A and 1.6 A in the PISEC program too. They emphasized to me that the bulbs internal wires cross.

There were plenty of student discipline issues

E. really wanted to see curls in the filament wire. Is this evidence of resistive nature of filament?

Emphasis on definition of “prediction” and whether or not a prediction could be wrong – nature of science?

T. told me after the class that the pen idea was from us. She didn’t want them to use pencils because she didn’t want them to erase their predictions. She said that she has learned “so much from what we have done with the kids.”

T.’s “you may start” comment reminded me of a teacher telling their students they may start a test. This was very formal.

The only questions I heard from the students were questions directed towards me about whether I could help them in some way. I did not hear any questions directed towards T. or about science.

T. walking to tables, interacting with students, was very instructive and prescriptive.

Earring thing – is this generative? – was T. referring to this group (among others) when she said “what I’m seeing is… what I’m asking.” Does formal discourage try and discourage generative activity?

It was very difficult for T. o manage the entire classroom. She placed an emphasis on prescriptive but also maintained a friendly atmosphere.

The question “what did you think about making predictions” – is that nature of science?

How does MESA effect T.’s teaching?

Why did T. draw and emphasize the wires overlapping? She didn’t clarify that the wires have a coating and that the crossing of the wires was not metal touching metal. I saw students drawing this in activity 1.5 A and 1.6 A in the PISEC program too. They emphasized to me that the bulbs internal wires cross.

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Emphasis on definition of “prediction” and whether or not a prediction could be wrong – nature of science?

T. told me after the class that the pen idea was from us. She didn’t want them to use pencils because she didn’t want them to erase their predictions. She said that she has learned “so much from what we have done with the kids.”

T.’s “you may start” reminded me of a teacher telling their students they may start a test. This was very formal.

The only questions I heard from the students were questions directed towards me about whether I could help them in some way. I did not hear any questions directed towards T. or about science.

When T. handed out the boxes with electronic instruments in it, I thought that it was a very generative activity. I marked an x on the generative category on my printed out sheet. But As I observed the kids I added a questions mark next to the generative x I had drawn. The students were playing with the materials, but many of them were not using them to understand what a circuit needed. Some of them were using the circuits to test their predictions, but others were merely playing with the motors, popping the batteries in and out of the battery holders, or just making the light bulbs like without any focus on building a mental model around why the bulb light. I am no longer sure that the activity was generative. I need to address a more rigorous definition of “generative” learning before I am able to answer this.

T. should have known that the students would immediately play with the motors and other unnecessary equipment in the boxes. A good teaching tactic would have been to remove the unnecessary equipment before handing out the boxes. I do not know if she didn’t do this because she didn’t think to, or because she didn’t have time to, or because of some other reason.

Really good facilitation technique to separate large groups into groups of two when they were talking about and testing their predictions. T. is very good at facilitating.

Should talk about what effect my present might have had in the class

Discuss the two (maybe three) girls who were interested in me, discuss how students started talking about MESA when I was near (G. saying something about Mike and Steve and how they were “friends of mine”), how the girls said I was “very nice” and wanted to start talking about the stuffed animals on the bookshelf, also talk about how I deflected their questions. T. talked to me sometimes too, but it was very brief and only in passing. Her comments to me during the class were mostly about the room temperature (an explicative about how she couldn’t handle it).

Kids were constantly walking around while T. was doing something with the large group. I also see this at the PISEC program – saw this last week. Look for things next week when I observe the PISEC program with the same metrics.

On my notes when I found that every group was working on task (and it was not immediately after T. had called out to everyone) I wrote down “lost of students testing the circuits. → every group!!” I was very excited that every group was working on task. I was surprised that this level of work was being accomplished. I thought T. (or any teacher in her position) would not have been able to accomplish that sort of facilitation. But I later noticed that this productivity was not long lived.

T. often had to interrupt group work to make sure they understood what they were supposed to be doing, make sure they were not doing things that were off task, get the noise level in the room down…
8.2  Spangler Spring 2008 PISEC after school ISE Observation:

Field Notes
Name: Jessica Bartley
Date: Tue 3/3/09, 2:00-4:30pm
Site: Spangler Elementary
Topics Covered: Observation of PISEC/MESA program, topics covered: 1.7 through 1.8 (for most students)
Instructors Present: Mike, Steve, Laurel, T. (volunteer Spangler teacher), and myself (as observer)
Number of Students present: 9

Laurel and I had talked about her coming today to fill my role in the PISEC program so that I could observe the day’s events using the same rubrics I had used when I observed T.’s class. I met Laurel down in the JILA lobby at 1:55. I ate my lunch while we waited for Mike and Steve to show up. They came down at 2:00. Steve asked Laurel if she had brought the computers with her (the students were going to work on their SAM movies for the first time today). She had not. This was my fault as I had completely forgot to tell her that we needed them today. We decided that Mike, Steve, and I would meet Laurel at Spangler while she ran back to her office and gathered the computers. Laurel usually drives in her car to Spangler so that she can drive to her nearby home afterward. This worked out.

Mike drove again today. I explained to them while we were walking to the car what was happening. I explained that I had observed T.’s class this past week and was going to do the same thing for the PISEC program. Laurel was coming to play my role. We got out to the car a bit late but ended up making it on time to Spangler. Laurel was only five minutes behind us.

Mike, Steve, and I arrived at the classroom on time and I started facilitating the usual drill. The desks were set up, as they usually are, in a front row and a back row. The students were sitting in these desks when we arrived, eating a snack. The students saw us through the window and called out “their here!” We greeted them when we walked in, asked how there were doing and if there were ready to do some science. I then called out for four new volunteers to pass out lab books. While I did this Mike and Steve left the room to let Laurel in at the back entrance. I had other students pass out nametags and pens. The students asked me if they were going to make movies today, and I told them they were but we were waiting for Laurel to come in with the computers. Shortly after Mike, Steve, and Laurel all came into the room with the box full of computers. Apparently in the mess of trying to get the computers into the car on the way to Spangler, one of the computers fell on the asphalt. Laurel said to me that she hoped it would still work. I got everyone’s attention by asking if they remembered Laurel. Most people said yes. I then asked them “Who here was in T.’s class when I came in to observe a science lesson?” Most students raised their hands, bouncing on their chairs. “Well,” I said, “So most of you. But some of you weren’t, so I can get someone who was there to say what they saw me doing in T.’s class?” I had a few volunteers. I called on G., who responded, “You, um, you were walking around and writing, um, writing things down.” “Yeah,” I said, “I was walking around, maybe listening in to your conversations, and making some notes. I’m going to be doing that same thing here today, so I won’t be able to help you with your activities. But that’s why we have Laurel – Laurel is going to be me for the day.” Laurel make a joking comment about how she should have written ‘Jessica’ on her name tag. “So, just for today, I need you guys to pretend that I’m not even here, OK? Can you do that for me?” They nodded and said yes. “OK great,” I said, “Let’s get started.”
We started the day at 2:45. I realized that I had left my cell phone in the car and would have to go off times from the wall clock. These times that I recorded are therefore not exact by the minute. The teacher-to-student ratio was 4 teachers to 9 students. Some students were absent today (about three, I can get the actual numbers from the attendance that was taken). The teachers were Steve, Mike, Laurel, and T. In programs from previous weeks, T. usually helps a small bit with facilitation. She does not usually engage with the students as often as the three of us do, but moves between sitting and working on paper work and walking around the room talking to students about their answers. This day was no different, but I still count her as one of the teachers present.

The room was still a bit quiet from when I had been talking to everyone. Some of the students asked Laurel, who was standing up at the front of the room, whether or not they were going to make movies right now. Laurel described, in front of the whole group, what they needed before they could make movies. She talked about how they had to have storyboard, and asked the students to find their partners from last time. Some of the student’s partners were not here. The students then started working on their storyboards. I noticed that, for most of the students, this was an individual activity. The instructors started to disperse around the room, talking to individual students. At this point I heard a lot of instructor voices explaining to the students once what they must do for their storyboard. I counted this as individual activity mixed with prescriptive activity.

There was a new student sitting in the back next to T. Laurel walked past this new student and T. asked, “She hasn’t been here before. Is it still ok for her to do this?” Laurel responded with, “Yes! Of course!” She said something about how new students are always welcome, whenever. Laurel then rushed back to the boxes we had brought and gave the new girl (named L.) pre-test materials.

S. was trying to get my attention by playing with his nametag, trying to rename himself as ‘Jessica’. I gave him a smile and said jokingly, “That isn’t you name.” I then moved on as not to interact with him further. I tried to focus on what activities all the students were doing, similar to how I had observed the students in T.’s class. I noticed that the instructors were working one on one with various students while other student either worked on drawings for their storyboard or sat at desks waiting to be helped. The instructors were helping individual students by rewording the directions printed on the activities or using direct instruction to make sure students understood the concepts. Steve handed out new activities to students, telling them to “tape this into your books”. Students nearby were calling out “Stevie! Stevie!” Laurel was working with individual students in the back row. One student in particular, N., needed an instructor to sign off on activity 1.6A (the activity where they were asked to draw the wires inside of the bulb for all the circuits in activity 1.1). Laurel was working with him and asked him to explain his drawings to her. I did not see what he had drawn, but I observed from the conversation that ensued that N. did not have the correct drawings. Laurel told him that it was not correct, saying, “if the wire went here,” pointing to his paper, “how could it also go here?” She then told him where the wires had to go, telling him that a wire had to got “from here to here,” pointing at the paper, “and another one from here to here.” N. watched as she pointed to his paper, he did not say anything audible. “So you should cross that out.” She paused, looking at his next drawing, “This one doesn’t make any sense either,” she said, “so cross that one out too.” N. crossed out the indicated drawings. “Would this one work?” Laurel asked. N. responded “No.” “Good,” Laurel said, “I’ll let you try and draw the rest of these and I’ll be back to check on what you did.” She then moved on to work individually with the next student. I marked this interaction on my observations as an instance of direct instruction. N.’s and Laurel’s interaction occurred at 3:00.

I looked around the room again to see what had happened while I observing Laurel and N.’s conversation. I noticed that one computer had already been handed out. I also noticed Laurel handing out activities and bustling with papers while students talked in groups, walked around the room, or continued to draw pictures on their storyboards. Students were working if instructors were talking to them, but were often not working unless an instructor was talking with them. There were students waiting for instructor attention. Group work started to immerge at this point. I saw some students talking to nearby students asking what activity they were working on. B., one student, talked to showed his story board to nearby students, talked with them about it, then went back to drawing. He added in more images after discussion.
with his peers. Shortly thereafter some students asked for Laurel’s help, but Laurel was busy handing out activities. T. was helping L., the new student, with the pretest materials. I heard her explaining what each question was asking. “It says ‘would I like do to an experiment or be told about it… I would like to do an experiment at lot, I would like to do an experiment a little…” She was talking one on one with this student, who seemed shy to interact with the other students. T. was asking L. what she thought about doing experiments. She was not telling L. how to answer the questions.

At 3:04 Laurel was working with a group of three students. The individual activity had now, almost completely, turned into group activity. One student working on activity 1.7B starting watching what the students working on their SAM movie were doing. Laurel walked by and started talking with him. “How can you use a wire to connect this to this?” she said. The student then was back on task. Shortly thereafter, after Laurel had left to talk to other students, she came back and commented “Oh! Awesome! Yes! Yay!” The student had apparently drawn a correct circuit. Once Laurel left again, he started looking once more over at the student using the computer working on their SAM movie. It was 3:06.

A few minutes later I noticed that ever student was engaged actively. I listened in on the group of two students who was making their movie. I will call this SAM group #1. Mike was instructing them on how to work with the SAM software. He had said things such as “Say I want to draw a smiley face…” as he drew a smiley face on the white board. He then told them how to take a picture of the image they had drawn. “Awesome,” C. (one of the group members) said. The two group members then started pointing and laughing at the computer screen. G. walked over to their group and was interested in what they were doing. The two students drew a face on the white board and took a picture of it. They laughed at their picture on the computer screen. Once Mike had finished instructing them on how to work with the SAM software the students started making their movie. Mike left their group and I stayed behind to observe what they were doing. The two students drew a face on the white board and took a picture of it. They laughed at their picture on the computer screen. Once Mike had finished instructing them on how to work with the SAM software the students started making their movie. Mike left their group and I stayed behind to observe what they were doing. One student started drawing while the other watched the movie screen. The first student drew something that, to me, resembled a pumpkin. They started conversing in Spanish. Then the first student erased what he had drawn and redrew what looked more like a battery. “Yeah! Si!” the second student called out. The first student drew a wire connected to the battery, but was unsatisfied with the way it fit on the computer screen image. He erased it again. He drew it one more time, smaller this time. The second student said, “put the lightning” and the first student said, “yeah!” and made a excited hand gesture. He draw in the lightning symbol on the face of the battery.

At this point there was another group of two students who had started working on their SAM movie. I will call this SAM group #2. G. was still walking around, watching the movie making processes of these two groups. He joined SAM group #2. The student who was working on activity 1.7B earlier was not walking around, watching SAM group #1 work on their movie. The two members of SAM group #1 asked this student if he wanted to join their group, but the student declined to go finish working on his materials. He walked off to his table once again. This was at 3:12.

SAM group #2 was playing with images on their computer. Steve was instructing them how to work with the SAM software. The camera on the SAM program was still set to the internal laptop camera and while Steve was trying to remember how to change the setting, a group of students were gathered behind the computer making motions and faces at the camera. They were making noises; some of them were singling like they were on TV. They saw their images in real time displayed on the computer screen. Steve asked me which tab the camera control was under and I showed him. He then got the camera to switch to the external camera that was pointed down towards the white board. The students in back of the computer stopped playing as if they were on TV. B., one student who was working with SAM group #2, stuck his face underneath the camera and continued to play with his image displayed on the screen. I counted this as generative instruction on my notes.

Members of SAM group #2 then started playing ticktacktoe on the white board. They were looking at the image on the computer screen. B. was still playing with the camera. He then started focusing the camera so that it the image it captured would be completely on the white board. I counted this as generative. Steve was still trying to instruct them on how to use the SAM software. He was mostly talking to G. at this point. The group members then noticed that the images they had drawn then
erased were still stored on the SAM screen. The commented “it’s a ghost!” T. was watching their interacting with SAM now. She was also paying attention to what Steve was saying to G. B., who was now paying attention to what Steve was saying, asked, “What if we want to cut some out?” This question was in reference to deleting captured images. Steve showed him how to delete images that they had captured. B. then drew a smiley face on the board and look at picture of it. He then added more to the picture he had drawn, coloring in teeth, clown eyes, and a nose. G. took another picture. Steve said, “OK B., I think you got the idea.” B. was drawing more to his smiley face, adding a body and hair. G. took another picture of this smiley face. “I like that one better,” B. said, pointing to the black haired smiley face on the computer screen. B. continued to add more detail to his image while Steve continued to teach G. about how to use the SAM software. B. had drawn in a voice bubble, in which he wrote ‘doughnut’. “Take a picture of the doughnut now!” he said. B. tired to get my attention. He was very excited about his picture. Steve was still trying to teach G. at 3:20. “See, now that gets rid of the ghost,” Steve said. Steve was still trying to teach G. at 3:20. “See, now that gets rid of the ghost,” Steve said. B. was drawing more to his smiley face, adding a body and hair. G. took another picture. Steve said, “OK B., I think you got the idea.” B. was drawing more to his smiley face, adding a body and hair. G. took another picture of this smiley face. “I like that one better,” B. said, pointing to the black haired smiley face on the computer screen. B. continued to add more detail to his image while Steve continued to teach G. about how to use the SAM software. B. had drawn in a voice bubble, in which he wrote ‘doughnut’. “Take a picture of the doughnut now!” he said. B. tired to get my attention. He was very excited about his picture. Steve was still trying to teach G. at 3:20. “See, now that gets rid of the ghost,” Steve said. B. was drawing more to his smiley face, adding a body and hair. G. took another picture. Steve said, “OK B., I think you got the idea.” B. was drawing more to his smiley face, adding a body and hair. G. took another picture of this smiley face. “I like that one better,” B. said, pointing to the black haired smiley face on the computer screen. B. continued to add more detail to his image while Steve continued to teach G. about how to use the SAM software. B. had drawn in a voice bubble, in which he wrote ‘doughnut’. “Take a picture of the doughnut now!” he said. B. tired to get my attention. He was very excited about his picture. Steve was still trying to teach G. at 3:20. “See, now that gets rid of the ghost,” Steve said.
out to him. “Do you need checking off?” S. answered yes and they walked together over to S.’s lab book. Laurel check off S.’s activity and S. started working on his storyboard. Laurel told him to write out his title. She told him how to spell ‘light’. I counted this as prescriptive. She then left S. to continue setting up groups of two who were done working on their storyboards and were ready for a computer.

I noticed SAM group #2 had changed their title from “How to light a bulb” to “To light or not to light”. B., who was writing the title down on the white board now, asked whether or not he should capitalize ‘to’. Steve said “no”. Laurel, who was walking by, said to B., “You know, were not too concerned with that. What we want to know,” she continued, “is whether or not you get this circuit stuff.” B. then moved on to continue drawing pictures for his movie.

I then noticed that N. had his hand raised. But none of the instructors saw him. He eventually put his hand down and continued drawing on his storyboard. This was at 3:34.

Laurel walked up to a group of two students who were finding themselves distracted by nearby groups working on their SAM movies. Laurel said to them “you’ve got to finish your stuff first – don’t let yourself get distracted.” The students then continued working on task as Laurel walked away towards SAM group #2. G. got Laurel’s attention as she walked past his group, saying “My brother has computers in his school but the key board is like this,” as he made a hand gesture. “Oh yeah?” Laurel said. “Yeah, and the screens are really big,” G. said. “Yeah, oh cool,” Laurel said. “Yeah we have to take these computers with us to they are small.”

T. then walked over to SAM group #2 and Laurel and her had a conversation about the curriculum we use at these outreach programs. Laurel said “That’s what’s so great about using modular curriculum – everyone can move at their own pace.” “Yeah!” T. said. “I think it is great.” Laurel turned to the SAM group #2 and said “Cool! You guys are great at this!” B. asked “Can I put it in this way?” moving the white board so that it was lengthwise. “Yeah,” Laurel responded, “as long as you can still see the image on the computer screen.” B. began to draw again. He drew a hand an a battery with both positive and negative terminals. G. took a picture of it and B. started erasing it. B. called out, “Yeah! The hand, it died! Oh wait, I shouldn’t have erased that... Oh I really don’t want to leave it like that, his hand will be cut off.” G. said, “No I mean the battery.” B. then drew in the rest of the battery and said “No we have to write it down!” They were referring to the fact that on both of their storyboards they had writing, but they had neglected to include it on their SAM drawings. They wanted to include it now. They asked Steve how they could add in writing to their images and Steve told them how they could take new pictures with writing and intermix them with the pictures they had already drawn. T., who was still standing there, said “Ahh... neat” at this aspect of the SAM process.

All but three students were working on computers at this point. S. was working alone, drawing faces on his white board. At 3:40 Laurel called out to all the students “OK gang! We need to start wrapping up now. You all need to save and export your movies.”

While students were cleaning up and saving their files Laurel checked in on the new student who had been working mostly with T. on pretest materials and early activities. Laurel picked up her papers, looking at them, and said to her “Your name is L.? My name is Laurel! Isn’t that interesting?” She smiled at the student, who had been very shy all day, smiled back at her. She looked over L.’s activity 1.1B and asked “What is your first one?” I tried to hear L.’s response but the room was too loud and L. was speaking very softly. I heard Laurel’s response as “OK, that’s one of your ideas – it has to be touching at the side.” The student then said something more to Laurel, also in a very soft voice, and Laurel responded “Oh OK... So what you telling me is it has to be touching both things. So this doesn’t work because it isn’t touching...” She trailed off as the room grew louder. I caught Laurel last words to this student “I think that is very good!” as she collected L.’s materials and brought them up to the front of the room. The session ended at 3:43 with students loudly talking with each other, putting on jackets and back packs, and rushing out of the door.
Most students did not notice my presence. This was surprising as they my presence distracted them during T.’s class. Perhaps it was because they were more actively engaged in the PISEC activities. They did not seem to notice me walking around making notes.

T. as one of the four teachers present – she does talk to students. And today she did work a lot with one student in particular (the new girl, L.). I thus counted her as one of the present instructors. She is also, in general, an authority figure. Merely sitting in the background filling out paperwork probably has an effect on the behavior of these kids.

Laurel’s comment to B. about we care about whether you get the circuit material – what did that communicate to him?

Laurel’s comment of new students always welcome encourages participation in science activities

B. talking with students about his storyboard – discussing – then adding in more images into his storyboard. Collaborative creation?

Student distracted by SAM movie – what does that say? The student wanted to work with the computer. He was interested by it. He wanted to make a movie too. He wanted to make a movie about science.

Many students interested in SAM group #1. They kept looking over to them or walking around to see what they were doing. They were interested by the technology and wanted to play with them.

It was difficult to score how much of the time was generative, group work, individual, direct, or prescriptive because the curriculum was so modular that no one group was receiving that same instruction at once. In general I noticed that there was primarily group work, but instructors were continually asked to explain in words what the students were supposed to do in any given activity. There was thus prescriptive instruction intermixed with group work continually. There were a few instances of direct instruction along with prescriptive instruction. When the students started working on their SAM movies I noticed a marked increase in generative instruction. But there was no way to catalogue the types of instruction from minute to minute. Each student was having a unique experience.

The student who was drawing in SAM group #1 kept erasing his drawing because he did not like the way it looked. Is this a signifier of ownership of drawing/knowledge?

SAM group #2 was played a lot! Steve tried to discourage it half heartedly, trying to get them to focus more on the material. But the students continued to play. They eventually did get content down. I believed they were learning how to use the program through play. This I counted as generative.

B.’s sequential pictures with his smiley face man could be considered animation.

I heard much more student questions on both content and procedure in the PISEC program than I did in T.’s class.

N. often had his hand raised and he was addressed all but one time an instructor. The time that his question wasn’t addressed, N. just continued to draw pictures on his storyboard.

Jeorge’s comments on computers illustrated personal attention, and relating what he was doing in this program to other areas of his life. This is a personalization of the material.
T. impressed with the SAM program. Will she use this in her class? Does she have the materials to use this in her class?

Hand raised student would not have been called on in the formal setting – especially moments after his hand was raised. We provide support for students that formal does not.

What were the differences between Mike, Steve, and Laurel’s methods for teaching students how to use SAM software?
9. References

(IEEE Format)


[22] http://jila-amo.colorado.edu/education.html

[23] The CU Teach Program is sponsored by a large grant from the National Math and Science Initiative and funded by Exxon Corporation, (http://stem.colorado.edu/cu-teach); The Learning Assistant Program at the University of Colorado is sponsored by NSF grant award #0833258, (http://stem.colorado.edu/la-program/la-program).


[27] http://www.samanimation.com


Personal communication with PISEC director Dr. Laurel Mayhew