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Don’t forget to submit YOUR article for the next issue of The Science Teachers Bulletin!

Deadline for the fall issue is: January 15, 2012!
Building Leadership through Action Research

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Introduction
In a poem by the Nobel Prize winning Irish poet Seamus Heaney, the narrator remarks, "She taught me what her uncle once taught her: how easily the biggest coal block split if you got the grain and the hammer angled right." Getting the grain and the hammer angled right is never an easy task for leaders in any complex organization. However, if the coal block-size dilemmas of education are to be split into problems that are manageable, comprehensible, and mutable, then school leaders will have to work assiduously and persistently to accomplish just this.

The Teacher/Leader Quality Partnership Program
In an attempt to get the “grain and hammer angled right” in the domain of professional development, 40 math and science teachers from the Rochester City School District (Rochester, NY) and surrounding suburban school districts participated in an initiative entitled the Teacher/Leader Quality Partnership (TLQP) program. The program, through a Title III grant, created partnerships consisting of an institution of higher education and local K-12 schools, including at least one high-need school district. Drawing on their respective experiences, skills, and knowledge, the program directors and partners worked together to design and implement effective professional development programs that helped practicing teachers and teacher leaders meet the needs of their students.

The TLQP Mission
At the center of the TLQP mission was an ideal that envisioned a two-dimensional goal for all professional development that can be defined as “those processes and activities designed to enhance the professional knowledge, skills and attitudes of educators so that they might, in turn, improve the learning of students” (Guskey, 2000, p. 16).

The focus of the project’s efforts was centered not simply on developing knowledge and skills, but on building a professional learning community that better understands the nature of teaching and learning - particularly with an eye toward mitigating the achievement gap between affluent students and students of poverty. To accomplish the goals of the program, a wide variety of research-based strategies and skills were shared, modeled, and practiced.

In short, the design of the TLQP project attempted to construct a learning community that envisioned professional development not purely as a matter of increasing technical competence, but as one concerned with gen-
uine inquiry and thoughtfulness. Instrumental to this vision was a conception of teaching that challenged the dominant view of professional development - merely as the linear transmission of knowledge from presenter to participant. Rather, it envisioned professional development as a venue for meaningful learning and inquiry where teachers actively and purposively engaged in action research projects that were transformative, thereby enabling the participants to view themselves as both practitioners and researchers.

What is Action Research?
Action research is a systemic and often collaborative inquiry conducted by teachers and teacher leaders for the purpose of improving their practice and performance. By gathering information and evidence about effective instructional strategies, teacher-researchers explore their teaching methods for specific situations and how students learn best - ultimately leading to increasing student motivation and academic achievement.

As a spiral and reflective process, the inclination toward undertaking an action research project often commences with a single observation or phenomenon that arises from a classroom discussion or a student comment. For the TLQP program, the action research started with the formulation of a question, a problem, or an awareness of an achievement gap. Through coaching and informational sessions, participants planned (a) a means to investigate and to study the phenomenon; (b) collected and organized both quantitative and qualitative data related to their question; and (c) kept journal notes and anecdotal records. The teachers then analyzed evidence provided in the form of student work, portfolios, or standardized achievement tests and communicated their findings to other TLQP participants as well as colleagues at their individual schools.

Action Research into Secondary School Science Learners
During the TLQP program, one high-school science teacher, Kathy Hoppe, focused her multi-year action research on Problem-Based Learning (PBL) at an alternative education program for at-risk students. Here she monitored improvement in academic performance, attitude, and interest in science.

Her action research project, “The Effect of Problem-Based Learning (PBL) Curriculum on Academic Performance, Behavior, and Motivation in High School Biology Students,” connected real world biology situations to the students’ lives through integrated PBL labs. During the first year of this project, Kathy found that students expressed a greater interest in biology when participating in problem-based learning units versus traditional instruction. In addition, students’ results on the New York State Biology Regents final examination demonstrated an increase in academic achievement with PBL lessons. The first part of this action research project led seamlessly into the second part in which she analyzed a four-week PBL
curriculum implemented with a regional summer school program. During year two, student motivation, behavior, attendance, and academic achievement were measured. In all categories Kathy’s findings and supportive evidence strengthened the claim that students in PBL biology classes were more motivated, attended class more frequently, and achieved higher passing grades versus the traditional instruction at that same summer school program with a comparable group of students.

**What are the Benefits of Action Research?**

In spite of the day-to-day demands teachers have placed upon them, one might expect that adding another task, namely conducting classroom research, would seem like “the straw that broke the camel’s back.” TLQP participants, however, through on-going support, embraced the notion of their role of “teacher as a researcher” and used their classroom as a laboratory for investigating both their profession and their practice. The project directors and coordinating team members provided print resources including Hubbard and Power’s *The Art of Classroom Inquiry - A Handbook for Teacher-Researchers* and Mertler’s *Action Research - Teachers as Researchers in the Classroom, Second Edition* to assist participants in narrowing a question for their inquiry, designing a data collection system, and analyzing and interpreting the evidence from their explorations.

In addition, sets of theme issues from *Educational Leadership* were purchased for discussion via jigsaw strategies. Issues included “Science in the Spotlight” (December 2006-January 2007), “Teachers as Leaders” (September 2007), “Making Math Count” (November 2007), and “Data: What Now?” (December 2008-January 2009). In the end, TLQP participants expressed numerous positive declarations concerning their action research projects. Feedback from each of the monthly sessions and focus group discussions indicated that teachers felt the experience was a rewarding and fulfilling process - one that deepened their understanding of an aspect of their classroom practice not previously examined.

**Changing Attitudes through Action Research**

Normally, teachers conduct action research in the interest of enhancing student achievement. Although the primary goals of the TLQP program were to provide an opportunity for teachers to inquire into their own teaching practices as well as their students’ learning for the improvement academic performance, this article focuses on the effect action research had on changing the important intangibles: the attitudes, values, and beliefs participating teachers held about their own professionalism and practice. Figure 1 illustrates the feedback loop identifying the intangibles in transforming teachers’ attitudes and dispositions about their roles and practices.
The TLQP Evaluation Design

Following the framework of Loucks-Horsley, et al. (2010) for designing professional development and Guskey’s (2000) model of evaluating professional development, the TLQP goals were assessed in a systematic approach at five interlocking levels: (1) participants’ reactions, (2) participants’ learning, (3) organizational support and change, (4) participants’ use of new knowledge and skills, and (5) student learning outcomes. Of particular interest for this project was Level 4: participants’ use of new knowledge and skills. Qualitative data was collected from a focus group and analyzed as the primary assessment indicator.

Focus Group

A focus group session was conducted with seven participants of the TLQP program, as part of a summative evaluation. The focus group session was audio-taped, transcribed, and examined for key themes using content analysis. Six themes emerged, each denoting a change in participants’ attitudes or beliefs concerning: (a) effective professional development, (b) conducting action research, (c) the role of the teacher-researcher, (d) inquiry-based teaching, (e) listening to students, and (f) teacher leadership.

Based on the respondents’ perspectives, the TLQP model appears to have raised the teachers’ expectations for what effective professional development should embody; namely, it should be research-based, collegial, centered on genuine inquiry, and data-driven using multiple measures for assessment. Focus group members also perceived constructive professional development as a vehicle for bridging theory and practice.

Several focus group participants mentioned the restructuring process for effective professional development and how well action research modeled it, helping them guide the efforts of the professional learning communities and collegial circles that were emerging in their respective schools. A train-the-trainer dynamic seemed to emerge where the participants brought mean-
ingful models and messages back to their students and colleagues.

Numerous focus group participants described the action research project as a worthy form of professional development that can replace supervisory observations as a method of evaluating the growth of tenured faculty in some schools. They talked about how analyzing student work and collecting alternative and authentic forms of data at school was becoming more commonplace in their practice. They described these practices as a part of their own continuous development as teachers, but also connected the activities to improvement efforts in their buildings or districts. “Action research, for me,” said one participant, “really validates everything that I do. I know how to collect the data, I know how to analyze the data, and I know how to assess the data. It’s no longer just using my intuition.”

When asked about the role of the teacher-researcher in schools, one participant commented, “It is not an assigned role,” which received consensus from the other participants. “Being a teacher-researcher is not in the job description.” The teacher continued, “I don’t have an assigned role as that of teacher-researcher and I am not a Teacher on Special Assignment in the building. I am a 4th grade teacher. But with my combined knowledge of action research and the leadership development I’ve learned here (and with my Master’s degree in literacy), I have a lot of people wandering into my classroom. I don’t get additional pay for anyone asking for advice, but I do feel good when people come to me and request help.”

Intellectual engagement and stimulation was another attribute that permeated much of the talk of the teacher-researcher identity in the focus group discussions. Participants talked about using inquiry-based methods learned through the action research process and how meaningful that learning had been to their own scholarly growth. To that notion a high school teacher affirmed, “For me, I think being a teacher is the most important profession. Then I think about doctors. And I think, gosh, I really wouldn’t want to go to a doctor who has not kept abreast with all of the medical changes when taking care of me. I really can’t honestly look at a kid (pause) and I can’t look at myself in the mirror (pause) if I don’t keep on top of my craft. And yes, it’s exhausting, but I think we owe it to our kids. And these are kind of the things that - I mean - I drive all the way from Penn Yan to come to this. But this is what I was looking for. This is really meaningful.”

Listening to students was another theme that emerged from the focus group comments. Teachers suggested that their action research experience helped them to be better observers and listeners of students. In spite of the pressure of accountability in their schools, these teachers wanted to look beyond standardized test scores to see if they were being successful with children. “I’m seeing the grades of the kids as not being the ultimate judge of what
they are getting out of the class,” explained one teacher. “This was what I was looking for - Do they understand it better? Maybe they’re still having difficulty with algebra. Are they having trouble figuring out how to use the keys on their calculator? I think teacher-researchers see their students as active learners and not as acquisitionists of content. I no longer view students’ minds as containers with me pouring information into them.”

Several participants believed that action research helped them become a better resource for administrators and other teachers, and with that added responsibility comes a certain level of respect and trust. One participant commented, “Administrators who encourage and support teachers to be teacher-researchers demonstrate respect and trust for the person in a profession that cultivates personal and professional growth. I feel bad for teachers in other places that don’t have that.”

Closing
The coal block is the symbol of the problems and the promising possibilities embedded in many of social and organizational systems that we inhabit. The problems are large, bulky, and ever-present - just like our physical resources of coal. The possibilities are waiting to be created.

If we are to turn that coal potential into power, into something usable, we will need to break it into manageable pieces just like the enormous challenges educators face. To do that we will need teacher-researchers with both problem knowledge (the grain) and the right tools (the hammer). Action research and teacher leadership is an untapped resource for many schools. Changing the attitudes and beliefs of teachers and their profession can start with a single swing of the hammer.

References

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Abstract

Inquiry Centers are science-focused stations consisting of everyday materials, along with open-ended questions or open-ended tasks. Using an Inquiry Center Approach, upper elementary and middle school students can construct their own Inquiry Centers and interact with their classmates’ centers, while teachers support and assess the development of their basic process skills. Deliberate instruction and encouragement of the development of these skills is essential in preparing students for successful problem-solving experiences.

Purpose

The vast majority of inquiry-based science curricula used in Elementary and Middle Schools are referred to as “skills-based” curricula. Science process skills or abilities reflective of the behavior of scientists (e.g. observing, inferring, predicting, measuring, etc.) are used while students are engaged in the active exploration of science concepts. The use of science process skills and the learning of science concepts become inseparable when a skills-based curriculum is implemented. Colvill & Pattie (2002) state that a “skills-based” science program is necessary if teachers base their lessons on problem-solving or inquiry-based learning experiences; “nothing can be more frustrating in a problem-solving program if the work is held up by a lack of skill in the basic processes” (pp. 20-21). Problem-solving activities require scientific reasoning and critical thinking abilities which, in-turn, require proper use of the basic science process skills. Therefore, teachers must not take for granted that students have adequately developed these skills; rather, “we must be deliberate in how we instruct students and encourage their development of these skills” (Froschauer, 2010, p. 6).
Providing upper elementary and middle school students with a wide range of meaningful, hands-on science experiences to assess their developing process skills should be a primary objective for all science teachers. One way to achieve this goal is through the use of Inquiry Centers. Inquiry Centers are science-focused stations consisting of everyday materials, along with open-ended questions or open-ended tasks. Using an Inquiry Center approach, students can construct their own Inquiry Centers and interact with their classmates’ centers. In doing so, teachers can actively support and assess students’ understanding and use of science process skills. This, in-turn, will help to inform teachers about students’ readiness to participate in problem-solving activities which require the use of “integrated process skills” or “experimenting abilities” (i.e. skills which require the use of basic process skills).

**Background**

In the field of education, there is no standard definition of “scientific inquiry.” Rather, educators find it more effective to describe key characteristics of inquiry or inquiry behaviors. In the vision presented by the National Science Education Standards, scientific inquiry is described as a “hands-on” and “minds-on” approach to learning science in which students learn skills, such as observation, inference, and experimentation. The vision of the Standards is a holistic one which requires that students combine process skills and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science. It is important to note that the use of Inquiry Centers as described in this article is consistent with the vision of the Standards and is not a return to a piecemeal, process skills curricular approach popular in the 1960s through the late 1980s where process skills were separated from content knowledge (Padilla, 2010, p. 8). Rather, Inquiry Centers are presented as a type of performance task that teachers can use to assess students’ competence and understanding of the basic process skills before transitioning to learning experiences characterized by critical thinking, scientific reasoning, and problem-solving. At the same time, Inquiry Centers provide an authentic learning experience which allows students to continue to develop and practice their skills. According to Beeth, Cross, Pearl, Pirro, Yagnesak, and Kennedy (2001), “In combination with district and state level evaluation of specific science content and themes, information obtained from assessing students’ science process knowledge can provide a more complete picture of the process knowledge a student needs to master in order to learn science well” (p 16).

According to the Standards, “Engaging students in inquiry helps students develop 1) understanding of scientific concepts; 2) skills necessary to become independent inquirers about the natural world; and 3) the dispositions to use the skills, abilities, and attitudes associated with science” (National Research
Council, 1996, p. 105). Accordingly, if students are going to be engaged in inquiry in the classroom, they should be provided with a framework to help them think about and organize their science learning experiences. Teachers can help students understand that scientific inquiry can be thought of as set of interrelated elements by which scientists pose questions about the natural world, investigate phenomena, and cultivate deeper understanding. Science content, process skills, and dispositions/attitudes associated with science (e.g. wonder, curiosity, respect for evidence, openness to new ideas) are key elements that characterize scientific inquiry as a way of knowing and finding out new things about the world (See “The Inquiry Triad” in figure 1).

This description or framework for scientific inquiry focuses on the active learning of science in which the use of basic science process skills play a major role. In my experience, introducing students to this framework can better help students comprehend what it means to think and act scientifically rather than simply offering the scientific method as an explanation of what scientists do. Using the Inquiry Triad, teachers can help students realize that scientific inquiry entails scientists asking questions about objects and events because they are curious (dispositions/attitudes); scientists use their science process skills to construct explanations and test those explanations (skills); when evidence confirms their explanations, scientists develop and further their understanding of science (content knowledge).

Introducing Science Process Skills
After students are presented with the “Inquiry Triad” as a framework to understand the core elements of what it means to think and act as a scientist does, students can then be introduced to the basic science process skills: observing, inferring, predicting, measuring, classifying, communicating

![Figure 1. The Inquiry Triad](image-url)
recoding data, comparing and contrasting, and planning an investigation (Adapted from Koch, 2005). (See Appendix A for a working definition of the basic science process skills.) When introducing the basic science process skills, I have found that it is important to emphasize that “observation” is the launching pad for all other process skills and, therefore, is an incredibly important skill to develop. Also, the process skills are not just confined to the field of science, but are used in many subject areas, as well as our everyday lives. To make the initial learning of these skills meaningful, it is important to make reference to a variety of everyday situations in which we use these skills. For example, we use clocks as a tool for “measuring” time; we use the skill of “comparing and contrasting” when we decide upon an item to purchase; and the skill of “classifying” is used in the organization of grocery stores to help partition the store into appropriate sections and aisles depending upon food type. The introduction of science process skills using a discussion format will be quite helpful in setting the context for the use of Inquiry Centers. In addition, depending upon the grade level, as well as students’ readiness, teachers may also want to begin to introduce their students to the “integrated process skills” also referred to as “experimenting abilities” (See Appendix B for a working definition of the integrated process skills).

**Constructing Inquiry Centers**

When introducing Inquiry Centers, students should know that they will be participating in a variety of activities in which they will have a chance to further develop their science process skills. The use of Inquiry Centers has been adapted from Koch’s “science circus” (2005) in which she describes a teacher in a fourth grade classroom who made use of simple, everyday materials that were familiar to the children. The teacher used several different stations for the purpose of developing science process skills. As the children visited each station, they performed various activities and recorded their ideas (pp. 87-96). Using an Inquiry Center approach, students work together in small, cooperative groups to construct their own Inquiry Centers rather than having the centers pre-made by the teacher. This strategy will not only allow students to have a sense of ownership over the activity, but also it will immediately provide students with the opportunity to think about the basic science process skills in ways that are meaningful to them. I have found it helpful to offer a few examples of Inquiry Centers to give students a concrete idea of what an Inquiry Center looks like. As previously stated, there are good examples provided in Koch’s book, however, I have also provided a sample listing of Inquiry Centers (See Appendix C for a sample listing of Inquiry Centers).

A key component of the Inquiry Center strategy is the use of an open-ended question or open-ended task to invite exploration of the materials at the center. For example, you might ask
your students to compare the two sample tasks: a) “Sort the objects into three groups.” versus b) “Sort the objects into as many groups as you can.” The students should recognize that the second task would allow students to classify the objects in different ways and come up with as many groups as possible. On the other hand, the first task is much more directive (or convergent) in nature because students can only sort the objects into three groups. Therefore, the second task is more “open-ended” because students have choices and are able to explore different classification possibilities.

Give the students about five minutes to brainstorm what types of materials they think would be fun to work with and what the question or task will be. Then have each group explore various everyday materials placed in boxes or tubs at the front of the classroom. Some ideas for materials to include are: dish soap, magnets, pipe cleaners, sponges, blocks, clay, string, plastic cups, craft sticks, water, paper clips, rubber bands, leaves, etc. – the possibilities are endless! Also, certain tools such as a ruler, graduated cylinder, pan balance, stopwatch, and a magnifying glass should be available for the students. Be prepared for a high level of motivation among the students; they will be talking with each other, moving about the room, and excitedly searching for items necessary to construct their centers. (Note: It is also important to briefly discuss safety considerations and the importance of using the materials in the proper way.) As students bring the materials back to their tables, it will be essential for the teacher to guide the construction of the centers by asking probing questions such as: What will your classmates be doing with these materials? What science process skill(s) will be used? Can your center easily be

Directions for Constructing an Inquiry Center

Work with your cooperative group to construct your own Science Inquiry Center. Make sure your centers are easy to reset because each group will have the chance to explore your center:

a) Use simple, everyday materials found either in the classroom or natural materials from outside to develop your Inquiry Center.

b) Develop an open-ended question or open-ended task which will invite participation and interaction with your Inquiry Center. Write your question on the index card provided for you.

c) Think about and write down which Science Process Skills will be practiced at your Inquiry Center.

d) Develop a title for your Inquiry Center. Write the title on the opposite side of your index card.

The students should then be instructed to work with a cooperative group (3 – 4 students) to create their own Inquiry Centers (See Appendix D for the Inquiry Center Task Sheet). The following instructions are given:

Directions for Constructing an Inquiry Center

Work with your cooperative group to construct your own Science Inquiry Center. Make sure your centers are easy to reset because each group will have the chance to explore your center:

a) Use simple, everyday materials found either in the classroom or natural materials from outside to develop your Inquiry Center.

b) Develop an open-ended question or open-ended task which will invite participation and interaction with your Inquiry Center. Write your question on the index card provided for you.

c) Think about and write down which Science Process Skills will be practiced at your Inquiry Center.

d) Develop a title for your Inquiry Center. Write the title on the opposite side of your index card.

Give the students about five minutes to brainstorm what types of materials they think would be fun to work with and what the question or task will be. Then have each group explore various everyday materials placed in boxes or tubs at the front of the classroom. Some ideas for materials to include are: dish soap, magnets, pipe cleaners, sponges, blocks, clay, string, plastic cups, craft sticks, water, paper clips, rubber bands, leaves, etc. – the possibilities are endless! Also, certain tools such as a ruler, graduated cylinder, pan balance, stopwatch, and a magnifying glass should be available for the students. Be prepared for a high level of motivation among the students; they will be talking with each other, moving about the room, and excitedly searching for items necessary to construct their centers. (Note: It is also important to briefly discuss safety considerations and the importance of using the materials in the proper way.) As students bring the materials back to their tables, it will be essential for the teacher to guide the construction of the centers by asking probing questions such as: What will your classmates be doing with these materials? What science process skill(s) will be used? Can your center easily be
re-set? Is your open-ended question/task truly open-ended? Do you think your classmates will know what to do when they read the question/task on your index card? Asking these types of questions during the construction period will help to insure the success of the exploration of the centers by the various groups. Also, collecting each group’s Inquiry Center Task Sheet at the end of class will allow the teacher to give additional feedback to help insure that the centers meet all of the assigned criteria and are clearly focused on one or more science process skills.

**Exploring Inquiry Centers**
Before beginning the exploration, I give each group a large piece of chart paper to place on their table. The chart paper will not only aid in the clean-up process after the exploration of the centers, but also it will serve as a focal point; all materials should be placed on top of the chart paper, along with the index card. I have also found it helpful if the students write the title of their center in large letters at the top of the chart paper for each group to clearly see. Each student should be given an “Inquiry Center Log” which is essentially a T-chart for the students to record what they did at each center and which science process skills they used (See Appendix E). The students should be given approximately 7 – 8 minutes to explore each center and should be given a two-minute warning before the time expires. Before the groups rotate to a different center, it is important to give each group approximately two minutes to complete their Inquiry Center Logs by writing a brief summary of what they did at each center and what science process skill(s) they practiced. This should be done independently to assess individual students’ competence levels. The Inquiry Center exploration period ends when each group has visited all of the centers.

It is critical to debrief the students’ experiences with the centers by creating an inventory of all of the science process skills used while allowing the students to share specific experiences. To extend the learning experience, you may consider taking pictures of your students in action at the centers. Posting the pictures on a class bulletin board and using the science process skills as captions for each picture may assist students in further developing their process skills by referring back to the display. Lastly, the Inquiry Center Logs should be collected since they will provide the teacher with formative assessment data regarding the students’ level of understanding of the basic process skills.

**Conclusion**
Although I have used this approach with upper elementary and middle school students, Inquiry Centers have become an integral part of my undergraduate methods course in science teaching. At the very beginning of my course, after I introduce my students to the Inquiry Triad and the basic science process skills, pre-service teachers work in small, cooperative groups to create their own Inquiry Centers following the procedure outlined in this
article. Since my science methods course is focused on inquiry teaching strategies, I emphasize the importance of students’ understanding of the basic science process skills for effectively creating an inquiry learning environment. As Colvill & Pattie (2001) state, “A science program that ignores process skills development is like a reading program that ignores the basics of reading and writing” (p. 20). Padilla (1990) explains, “The research literature indicates that when science process skills are a specific planned outcome of a science program, those skills can be learned by students” (Summary and Conclusions section, para. 2). Pre-service and in-service teachers alike need to realize the importance of the science process skills as an integral part of the science curriculum and be deliberate in how they instruct students in the development of these skills. As Froschauer (2001) states, “Don’t assume that students develop these skills without your careful guidance; students must be prompted to investigate in such a way that they can develop increasingly more sophisticated skills and attitudes” (p. 6). The Inquiry Center strategy is one way in which teachers can guide students in the development of their process skills and, at the same time, provide a formative, authentic tool for assessing their skills. I find this strategy to be particularly effective because it connects assessment with instruction. I invite you to try Inquiry Centers in your own classroom.

**References**


Appendix A. Basic Science Process Skills

1. **Observing**: using all of your senses (see, hear, taste, touch, and smell) to gather information about an object or event. This is the most basic and most important out of all of the science process skills. We are always observing, always taking in stimuli from our environment.

2. **Inferring**: interpreting or explaining an observation. An inference is an explanation of an observation based upon previously gathered information; that is, we infer about something that happened in the past (i.e. why something happened or how something happened).

3. **Predicting**: forming an idea of what will occur (a future event) based upon present knowledge and understandings (not a guess). (e.g. “Predict” what will happen.)

4. **Classifying**: sorting objects or ideas into groups based on similar or different properties/attributes.

5. **Measuring**: comparing unknown quantities (attributes such as length, width, height, mass, and time) with known quantities such as standard units in the metric or English system (e.g., inches, yards, centimeters, or meters) or nonstandard units such as student-generated frames of reference (e.g., using paperclips to measure the length of an object).

6. **Communicating Ideas & Recording Data**: gathering and conveying information and ideas to others using the written and spoken word, graphs, demonstrations, drawings, diagrams, or tables. Communication is another very important process skill that permeates all areas of science. To share ideas in a collaborative setting or to convey information in an organized nonverbal way (charts, graphs, etc.) is extremely powerful. The sharing of information and knowledge consistently occurs in scientific communities and helps to sustain and maintain scientific communities.

7. **Comparing and Contrasting**: discovering similarities and differences between objects or events. Comparing and contrasting is a process often used while observing and/or classifying.

8. **Planning an Investigation**: determining a reasonable procedure that could be followed to test an idea including listing the materials needed, basic procedures to be followed, and identifying which variables to keep constant (extraneous variables), to change (independent variable), or that respond to change (dependent variables). Usually, in planning an investigation, a thought experiment is the best way to proceed. Once an investigation has been mentally planned with only one independent variable identified, one can then conduct the investigation.
Appendix B. Integrated Process Skills
(…require the use of the basic process skills)

1. **Interpreting Data**: analyzing and synthesizing data using tables, graphs, and diagrams to locate patterns that lead to the construction of inferences, predictions, or hypotheses.

2. **Formulating a Hypothesis or Hypothesizing**: making an educated guess based on evidence that can be tested through experimentation. A hypothesis should be in the form of a causal statement, along with a reasonable explanation of what is going on (e.g. *If* I do this… *then* this should happen… *because* this is what I think is going on.)

3. **Making Models**: constructing mental, verbal, or physical representations of ideas, objects, or events to clarify explanations or demonstrate relationships. Scale models have a lot of explanatory power (e.g. a scale model of the solar system). Making models can also help to make complicated objects and events more approachable and understandable.

4. **Defining Operationally**: explaining a variable in working terms or based upon observable characteristics. When you define a variable operationally, you explain exactly how you will measure a variable in an experiment so that others can replicate your experiment. For example, if you want to measure bean growth, you can define that variable operationally by stating that the change in height will be measured from the top of the soil to the top of the highest shoot. This variable can be measured in millimeters per day or centimeters per week.

5. **Experimenting**: performing an experiment to test a hypothesis. This is a complex skill which begins when the scientist observes some event or object in the universe that interests her. She then makes an inference or hunch as to what might be going on. The inference can be tested by formulating a hypothesis. If the result of the experiment matches what was stated in the hypothesis, then the hypothesis is verified. If this does not happen, further testing and modification of the hypothesis is required until the result matches the stated hypothesis. When this process of experimental verification occurs a large number of times, the hypothesis may become a “theory.” However, it is important to note that a hypothesis or a theory is never “proven”; rather it can only be verified or unverified/disproven.

Appendix C. Sample Inquiry Centers
*(see following page)*
<table>
<thead>
<tr>
<th>Inquiry Center Title</th>
<th>Question/Task</th>
<th>Materials Used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mystery Bags</strong></td>
<td>After feeling the object in each bag (without looking), describe and record (using pictures and words) each object’s texture, size, shape, and other characteristics. What do you think each object is?</td>
<td>Tree branch, pine cone, weathered rock, tree bark, dice, packing peanuts, sponge, bolt</td>
</tr>
<tr>
<td><strong>Process skills:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Observing</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Communicating Ideas &amp; Recording Data</em>, <em>Predicting</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sound Discovery</strong></td>
<td>How many different sounds can you make using the materials? Can you explain how the different sounds are being made?</td>
<td>Foil, sandpaper, straw, rubber bands, tuning fork, cup, rock, craft stick</td>
</tr>
<tr>
<td><strong>Process skills:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Observing, Inferring</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Eyeing the Line</strong></td>
<td>Predict how many paperclips it will take to measure each line. How do your predictions compare with the actual results? How long is each line in centimeters?</td>
<td>Chart paper, marker, paperclips, string, scissors, ruler</td>
</tr>
<tr>
<td><strong>Process skills:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Observing, Predicting</em>, <em>Comparing &amp; Contrasting, Measuring</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Soaking Up the Water</strong></td>
<td>These two items have the same mass: a piece of sponge and cotton ball. Which material becomes heavier when the same amount of water is added to each? Explain your procedure and your findings.</td>
<td>Small pieces of sponge and cotton balls (with the same mass), pan balance, gram masses, water, eyedroppers, measuring cup, graduated cylinder</td>
</tr>
<tr>
<td><strong>Process skills:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Observing, Measuring</em>, <em>Planning an Investigation</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Magnetic or Not?</strong></td>
<td>Are all metal objects magnetic? Predict which objects are magnetic. Can you sort the objects into groups according to their magnetic properties?</td>
<td>Magnets, D-size battery, paperclip, tuning fork, staples, metal washers, penny, dime, nickel, quarter, aluminum foil, nail, key</td>
</tr>
<tr>
<td><strong>Process skills:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Observing, Predicting</em>, <em>Classifying</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sink or Float?</strong></td>
<td>Predict which objects will sink and which will float and then test your predictions. Can you make an object that floats, sink? Explain your procedure.</td>
<td>Plastic disc, cork, wax candle, golf ball, Styrofoam ball, clothespin, cotton ball, rubber band, water, bowl, tape</td>
</tr>
<tr>
<td><strong>Process skills:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Observing, Predicting</em>, <em>Planning an Investigation</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mixing Fun</strong></td>
<td>What happens when a small amount of each substance is mixed with water? What results appear to be the same and which results are different? Can you explain what is going on?</td>
<td>Clear plastic cups, water, spoons, dish soap, flour, vegetable oil, food coloring, sugar, salt, sand</td>
</tr>
<tr>
<td><strong>Process skills:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Observing, Comparing &amp; Contrasting</em>, <em>Classifying, Inferring</em></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix D. Inquiry Center Task Sheet

Constructing & Exploring Science Inquiry Centers

Directions: Work with your cooperative group to construct your own Science Inquiry Center. Make sure your center is easy to reset because each group will have the chance to explore your center.

Group Members: ___________________________________________________________

a) Use simple, everyday materials found either in the classroom or natural materials from outside to develop your Inquiry Center. List the materials in the space below:

b) Develop an open-ended question or open-ended task which will invite participation and interaction with your Inquiry Center. Write your question or task in the space below and on one side of your index card:

c) Think about which Science Process Skills will be practiced at your Inquiry Center. Write the science process skills in the space below and briefly explain how they will be used by your classmates

d) Develop a title for your Inquiry Center. Write the title in the space below and on the other side of your index card.
Appendix E. Inquiry Center Log

Inquiry Center Log

Summarize what you did at each Inquiry Center in each space below:

Center title: ____________________

Identify the science process skill(s) you used at each Inquiry Center.

Center title: ____________________

Center title: ____________________

Center title: ____________________

Center title: ____________________
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Constellations Are Out of This World
A Historical and Present Day look at Constellations and the Stories Behind Them

Joan Gillman
The Calhoun School
New York City, New York

What child does not gaze at the night sky and is held spellbound by the awesome sights above! Their feelings of awe are not unlike those of the ancient civilizations. Ancient observers from around the world would look at the night sky and imagine that the groups of stars formed pictures of animals, people, and other objects. Those patterns are what we call constellations.

If you look at different cultures, you will be able to see that the various civilizations had their own names and stories for the patterns they viewed in the sky. For example, Ursa Major—The Big Bear becomes “The Never-Ending Bear Hunt” for the Micmac people of Nova Scotia, Prince Edward Island, eastern New Brunswick, and the Gaspe Peninsula of Quebec. The bowl of the Big Dipper is the bear, the handle and stars in the Herdsman are the hunters, and the Northern Crown is the bear’s den.

Since Astronomy is a major topic in the 5th grade science curriculum, I decided to use the study of constellations as the back drop for my Action Research project. As in most schools, my classes include students with varying degrees of knowledge and skills. With this in mind, I decided to look at ways to address all learning styles in the classroom so that the constellation unit would be comprehensible to all my students. I also wanted to use cooperative learning to create a more student-centered environment.
This year, I began with a constellation pre-assessment to identify what knowledge my students already had. For this activity, the 5th graders were shown a sheet with a variety of constellation pictures. Students were asked to identify what was on the sheet. The majority of my 5th graders were able to articulate that the pictures showed different constellations. Once this fact was established, the students were asked to come up with their own definition of a constellation. Sample responses included, “They are group of stars that form a pattern in the sky.” Another comment was, “Stars that look like a picture when grouped together.”

The next step involved much more of a challenge. The 5th graders were given three sheets of paper containing various constellations. An additional two sheets recorded the names of the constellations found in the original three sheets. Working in groups, the students were asked to match the names of the constellations to their actual picture. The 5th graders had a few successes matching the constellation to its title. Gemini-The Twins was easily found as well as the three stars forming Orion’s Belt. Most of the other constellations were very challenging to identify. As a result, the students came to the conclusion that ancient astronomers must have had a “vivid imagination” when it came to grouping stars and naming constellations.

The next activity used a Constellation Globe with a darkened classroom to get a better picture as to what the constellations really looked like in the evening sky. With the first activity already behind them, the students were beginning to develop more facility with constellation identification. It was quite exciting to hear the students’ enthusiasm mount as they found the various constellations.

Activity three used both Northern and Southern sky maps. The maps I have in my classroom are quite large in size. The advantage of the large size is that the students can all gather around the map as we use a ruler, chalk, and string to sketch out what constellation would be present in the sky on a certain date. As in the past, the 5th graders all wanted to see what constellations would be
present on their birthday. To make this activity more valuable, we used January, April, July, and October-months in the four seasons to see how the Northern sky changed throughout the year. Since I was fortunate to also have a Southern sky map, the pupils were able to compare and contrast the two maps. Of course, the students were amazed when they saw the plethora of stars in the Southern sky.

The next activity looked at some of the more famous constellations and the stories behind them. Since the children were learning about ancient Greek gods and goddesses in their Humanities ancient civilization classes, this really made for a terrific interdisciplinary connection. Leo the Lion, Orion the Hunter, Cygnus the Swan, The Big Bear, The Little Bear, and Cassiopeia, the Queen were the six stories we examined. Children took turns reading the passages and discussing the context. In addition, we also examined the Native American constellation myths so that we could compare and contrast their stories with those of the ancient Greeks.
One of the major difficulties in using the star charts is that they are large and bulky to use when outside during the evening hours. As a result, the 5th graders were given an opportunity to make their own portable star wheels. We were able to obtain the necessary materials from the LHS Hands-On Universe Project. Their website contained a variety of materials that would be suitable for classroom use.

To begin this project, the students glued the two sheets onto a manila file folder. The file folders give the wheels more support, and this prevents them from getting easily torn or damaged. From there, the students followed the directions on the sheets and cut out the necessary parts. For some of the students, this can be a challenge. Usually in my classroom, I will assist those that need help with the cutting. Since I stress that we are a community of learners, it is also not unusual to see the other students helping their peers. Once “Uncle Al’s Star Wheels” are constructed, the 5th graders now have their own personal star guide to use when viewing the night sky. The wonderful part of this wheel is that they can be used year round. You can also choose a particular hour in the night for more specific viewing.

For a few of the 5th graders, use of the star wheels can create another challenge. Sometimes the pupils will have difficulty lining up the date and time on the wheel. Others may find it hard to read the small print. Nevertheless, a recommendation would be to pair up the students so that a stronger pupil can help guide their partner. For the majority of the class, the students enjoy identifying the constellation present on their birthday or during other special dates and holidays.
This takes us to our next activity. After constructing the Star Wheels, we begin a discussion of circumpolar stars. These are the stars that circle around the pole. Polaris will always be at the same spot, but the other stars will circle around it. An example of circumpolar constellations includes *The Little Dipper, Draco, the Big Dipper, Cassiopeia, Cepheus,* and *Perseus.* A good exercise for the students would be to pick one circumpolar constellation. Have them select a date and then draw the constellation at different times of the evening. They could begin with 8 PM and then go to 10:00 PM, 12 AM, and end with 4 AM. This will give them an excellent opportunity to see how the position of the constellation changes as the night continues. The students could also do this to see how the constellation changes throughout the year.

Here is another fun activity to do with the students so that they can begin to master the shapes and names of the constellations. This next activity works especially well with students who need more of a visual and tactile approach for learning.

Divide the class into groups of five or more. Have each group select a different constellation. Use the Star Finder to see the date and time when their constellation could be found in the sky. Have each group form the constellation they have selected. Each person in the group could be a different star in the constellation. They could use string or cord to connect the stars in the patterns.

Once the students have practiced making their constellations, have the groups come up to the front of the class and form their specific constellation. Provide the audience with a clue to help them decipher which constellation is being presented. Clues would include a date and time when their constellation would be present in the night sky. The audience would use their Star Finders and clues to identify the star groups.

At the end of this constellation unit, we decided to have a star gazing and constellation identification night at my school. Since the Calhoun School has a “Green Roof” we thought that this would be the perfect place to hold our constellation night. This year, the students in the Calhoun High School were constructing their own telescopes, so we decided to make this more of an all school event. The High School students would lead the activity and share their equipment with the students. The 5th graders would show the other classes how to use the Star Wheels to identify what was in the sky.

For the constellation post assessment, the 5th graders were given an assignment to design a new constellation and write a myth describing its origins. In the past, all of the students were given the identical assignment. This year, I decided to have a basic assignment and then a second one that would stretch the students’ learning.
Basic Assignment: Using black construction paper and stick on stars, design your own constellation. Use white pencil to name the new constellation. Connect the stars using while pencil and add any necessary details to make the picture of the constellation stand out more clearly. Finally, write your own constellation myth. This can be done in the style of a Greek or Native American myth.

More Advanced Assignment: Examine the star charts. See if you can connect the stars in a new way to form your own special constellation. Using black construction paper and stick on stars, design your own constellation. Use white pencil to name the new constellation. Connect the stars using white pencil and add any necessary details to make the picture of the constellation stand out more clearly. Keep a record of the actual stars you chose to use in your new constellation. On another piece of paper, identify the names of the stars and add any information you can find out about the star’s status. Possible information could include the size, temperature, color, mass, and luminosity. Finally, write your own constellation myth. This can be done in the style of a Greek or Native American myth.

Examples of the new constellations and myths:

Sayason the Clever

Once there was a shark named Sayason who traveled the ocean in search of Poseidon, the God of the Sea. Sayason did this because he wanted wealth and power, but he could never find him. He grew old and wise so he decided on a plan. The plan was that he would go around eating all the fish so the other sharks would starve. He thought this clever idea would impress Poseidon, so that he would take him in and make him his guard shark. Instead of that happening Poseidon threw him in jail. In jail he would always brag about how clever he was. Poseidon grew tired of this and put him in the sky and because he used to brag about his cleverness, Poseidon put him so that you don’t know which way he is facing. In that way he looks confused, not clever.
My school is very fortunate to be within walking distance of the American Museum of Natural History. As the constellation unit came to a close, we took a field trip to the planetarium to see the IMAX show- “Journey to the Stars.” We were also given a tour of the planetarium hall and exhibits. This really crowned a wonderful science unit for the students.

All in all, this unit has been a very positive one. The students have developed an appreciation of constellations and they have been actively engaged in all of the lessons. Students were able to correctly use their Star Wheels to identify the various constellations in the sky. The course also enabled me to reach all levels of learners. The more advanced students were able to extend their comprehension by choosing to do the more advanced assignment. The other 5th graders were able to find success in their work while at the same time demonstrate pride in a job well done.

Unit Timeline

References


STANYS The Science Teachers Bulletin Fall 2011


Internet Resource
Uncle Al’s Star wheels for the Northern Hemisphere. LHS hands-On Universe Project. May 2009
www.handsonuniverse.org/activities/uncleal/NorthStarwheel.pdf

Connecting to the Standards
This article relates to the following National Science Education Standards (NRC 1996)

Content Standards

Grades k-4 and 5-8
Standard A: Science as Inquiry
*Abilities necessary to do science inquiry
*Understanding about science inquiry

Standard D: Earth and Space Science
Grade K-4
*Objects in the Sky
*Changes in Earth and Sky

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Left: Reading from one of the constellation stories
The Full Moon Does Not Have A Significant Effect On The Number Of Discipline Referrals Among High School Students

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Groton High School  
Groton, NY

Abstract
There has long been the belief that the phase of the moon, particularly the full moon, can have an effect on human behaviors. From werewolves to an increased number of childbirths, there are numerous examples throughout history of the belief in lunar effects. Discipline referrals were selected as a proxy of behavior among high school students. Six years of discipline referral records were obtained and analyzed to determine the average number of discipline referrals on the full moon +/- three (FM) days, and the average number of discipline referrals on all other (AO) days. While two of the years in study did show an increased number of referrals on FM days, only the data for one of those years was significant. Further, when the data for all six years under study was analyzed together, no significant difference was found between FM days and AO days. A review of the literature concludes that the most probable reason for any change in human behavior during FM days is purely psychosomatic.

Introduction
It has been observed that there is a connection between human behavior and the phase of the moon (Snelson 2004). The literature is, however, ambivalent on the topic (Russell and de Graaf 1985). Many papers suggest that there is a strong correlation (Thakur and Sharma 1984), while others, even those with sample sizes in the thousands, find no significant correlation (Bickis, Kelly and Byrnes 1995). The only phenomenon, social, geophysical or otherwise to which the phase of the moon has been strongly and consistently related is the tides. The phase of the moon causes tides not because of the degree of lunar illumination, but rather because of the location of the moon relative to the earth. The position of the moon relative to that of the sun contributes to the tidal phenomenon as well. At times, the gravitational force of the sun and moon are pulling on the water on the earth in line with each other causing high tides, while sometimes the moon and sun pull at right angles, causing low tides.

The belief that human behavior can be influenced by the phase of the moon does not, however, have any significant scientific evidence to support it (Snelson 2004). While several studies have shown that a relationship can be demonstrated to exist, there is nothing in the literature to suggest a mechanism for the relationship. As an example, Liu and Tseng (2009) studied the
behavior of financial markets in relation to the phase of the moon. Their statistical analysis determined that for the stock markets of G7 countries, the average return per investor is higher during the new moon than during the full moon. Interestingly, they found that in many Asian markets, the average return is higher during the full moon. They also discovered that there were more variations in average return per investor during the full moon in G7 nations. The authors conclude that this data is easily explained by behavior being altered by the phase of the moon, but again fail to suggest a mechanism by which the moon influences human behavior.

An interesting instrument known as the BILE survey (Belief In Lunar Effects) was developed and has been given numerous times to many thousands of individuals. In one study of 325 individuals (Vance 2005), the author found that 43% of those surveyed thought that the phase of the moon had an effect on human behavior. Snelson (2004) goes on to confirm that nurses working in different wards had different scores on the BILE survey. As an example, those working in mental health wards had a higher BILE score than those working in an emergency room setting. Data from this survey shows that the work or living environment is strongly correlated to a belief in lunar effects, and, as such, the authors conclude that the mechanism for the upswing in emergency room visits or mental health ward problems is psychosomatic. That is, because many workers believe that more problems are likely on full moon days, they are more willing to perceive a situation as problematic or more likely to be on the “look-out” for evidence to support their theory.

Removing the human factor from an experiment (and thus, it seems, removing our penchant for unconscious analysis and psychosomatic factors), would seem to be an interesting way to see if an organism can be affected by the phase of the moon. Bhattacharjee et. Al (2000) discovered that the number of humans bitten by dogs is significantly higher on the full moon than on any other day of the month. Further, Raegan et. al. (2007) describe a study in which more visits to a veterinary clinic were noted on “fuller moon” days (days with a large percentage of the moon illuminated, not necessarily just a full moon) than on other days. The authors go on to posit that the increase may be caused by increased nocturnal activity due to the added light from a fuller moon, but, they admit that their clinic is in an urban setting with copious artificial light. This makes the theory seem less plausible. They do not describe any other potential mechanisms. Even so, it must be noted that it is still humans who are bringing animals to the clinic, or humans who are being bitten by dogs, so we cannot completely exclude the behavior of humans even from these animal trials. The humans involved may be behaving in a way that induces injury or bites.
SKIP PAGE!
While the literature is ambivalent on the subject, further study is certainly justified. The aim of this study is to determine if the behavior of high school students is influenced by the phase of the moon using the number of discipline referrals filed each day as a proxy of behavior.

Methods
Data was collected from Tomkins-Seneca-Tioga BOCES in the form of several Microsoft Excel spreadsheets. The data ranged from the 2005-2006 school year to the 2010-2011 school year. The data for the 2010-2011 school year is incomplete and extends only to February, as the school year had not yet finished at the time of analysis. The average number of referrals on the full moon +/- three days was calculated for each year. The average number of referrals on all other days was also calculated. A Student’s t-test was used to evaluate the significance of the findings. In addition to the yearly calculations, all data for all school years was collected into one table for evaluation.

Results
The school years 2005-2006, 2006-2007 and 2008-2009 were the only years that showed a greater average number of referrals on the full moon +/- three days (FM) than on all other days (AO). Of those three school years, only the 2005-2006 school year had a significant difference (see figure 1, page 30). The 2006-2007 and 2008-2009 school years had a greater number of referrals on FM days, but the difference in the data was not significant. All other years showed more referrals on AO days, but only the 2007-2008 school year showed a significant difference.

When all the data for all years (a total of 1,572 days of data) was collected and analyzed, the data showed that there were a greater number of referrals on AO days, though the results were not significant and the difference was slight (about 0.15 referrals per day).

Discussion
This study, though not equal in scope to many others, is not unusual in that the data were, on the whole, somewhat ambivalent. Within the data set, there were three years during which there were more referrals on FM days than on AO days. However, the difference was significant in only one of these years. Overall, though, the data points to the fact that there is no significant difference between the number of referrals on FM days vs. AO days.

The study has several limitations. The data has not been corrected for changes in administrators or teachers. The data also only encompasses six school years. This may not be enough time to see patterns that may emerge over a longer period of time. Further study is also needed to correct for the number of students enrolled (which changed each year) and for full moons that coincide with holidays, weekends, etc.

All sources of error aside, the more salient discussion surrounds why the
phase of the moon might have any effect on the behavior of students in the first place. Several studies and metasta-
tudies have shown that in a large num-
ber of situations ranging from ma-
ternity wards (Kuss and Kuehn 2008) and
emergency rooms in India (Zargar et. al. 2004) and hockey fights
in Canada (Russl and deGraaf 1985),
there is no correlation between the
phase of the moon and human behav-
ior. So why does this belief persist in
the population?

Rotton and Kelly (1985) devised a sur-
vey called the Belief In Lunar Effect
(BILE) test. It has been administered
widely and often, and in one case, 46%
of undergraduate students surveyed
indicated that they believed that
humans behaved strangely during the
full moon. Possible reasons for the per-
sistence of this belief in the power of
the moon can be attributed to folklore,
stories or other societal reasons. The
fact remains, however, that there is pre-
cious little science to back up these
claims. Careful consideration will lead
the reader to understand that the only
two things that might have a reasonable
chance of affecting behavior are the
gravitational force exerted by the moon
or the amount of light that it reflects
toward the earth.

The moon is in an eccentric orbit, and
as such is at some points closer or far-

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**Figure 1.** The average number of referrals on FM and AO days. T-test
results with an asterisk are significant (p-value < 0.05).

<table>
<thead>
<tr>
<th>School Year</th>
<th>Average Number of Referrals on FM days</th>
<th>Average Number of Referrals on AO days</th>
<th>T-test</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005-2006</td>
<td>3.728571429</td>
<td>2.307064746</td>
<td>0.003266439*</td>
<td>More referrals on FM days</td>
</tr>
<tr>
<td>2006-2007</td>
<td>1.523809524</td>
<td>1.298578199</td>
<td>0.209050622</td>
<td>More referrals on FM days, but data not significant</td>
</tr>
<tr>
<td>2007-2008</td>
<td>1.507936508</td>
<td>3</td>
<td>0.00154989*</td>
<td>More referrals on AO days</td>
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<tr>
<td>2008-2009</td>
<td>3.385714286</td>
<td>2.819047619</td>
<td>0.162821896</td>
<td>More referrals on FM days, but data not significant</td>
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<td>2009-2010</td>
<td>5.419354839</td>
<td>6.645454545</td>
<td>0.104687509</td>
<td>More referrals on AO days</td>
</tr>
<tr>
<td>2010-2011</td>
<td>6.285714286</td>
<td>7.213114754</td>
<td>0.227024133</td>
<td>More referrals on AO days</td>
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<tr>
<td>All Years</td>
<td>3.483783784</td>
<td>3.635078969</td>
<td>0.305482202</td>
<td>More referrals on AO days</td>
</tr>
</tbody>
</table>
ther away from the earth (by about 50,000 km). These changes, though, do not always line up with the phase of the moon. On average, the perigee (the closest point of the moon to the earth) only lines up with a full moon once about every 1.2 years. Even so, the force of gravity exerted by the moon is not much different during perigee and apogee.

At the closest recorded perigee in recent history, the force of gravity between the earth and moon was about $2.31 \times 10^{20}$ N. At the farthest calculated apogee, the force will be about $1.77 \times 10^{20}$ N. While we are contending with very large numbers (on the order of 17,000 to 23,000 exanewtons), the difference between these values is insignificant. It is also misleading, because we are concerned with the effect of gravity on humans, not the earth. Running those numbers, we find that at perigee, a 70 kg human would experience a force of 0.2179 N from the moon, while at apogee, the human would experience a force of 0.1687 N. Keeping in mind that a newton is very small amount of force, it is hard to imagine that this small change would have an effect on behavior, and even more difficult to find support for the idea in the literature.

There is, however, some evidence that supports the idea that gravity (or the lack thereof) can affect humans physiologically, if not, behaviorally. Koga (2004) describes a study in which EMG readings were taken of neck muscles of an astronaut on earth and in space. The readings were different when the astronaut was performing the same task in the two environments. The author attributes this difference to the lack of a gravity cue to orient the subject. Further, Grabherr and Mast (2010) conducted a review of several other low-gravity studies, and found that certain aspects of cognition (such as estimated body tilt or writing with closed eyes) were affected by a lack of gravity. It would be a very large logical leap to suggest that simply because body movements or writing were different in altered gravity environments, that behavior would be altered as well.

Going deeper, several studies presented by Sajdel-Sulkowska (2008) suggest that increased or decreased gravity can affect the development of the central nervous system in laboratory animals. Further, gene expression in the nervous system of mature laboratory animals can be altered with increased or decreased gravity. While both of these factors may logically lead to a change in behavior, the gravity changes described in the study were many times greater, more rapid and repeated than those experienced by humans from the moon.

The one idea that has been put forth involving gravity is that of “human tidal waves.” The logic, however fuzzy, for this argument is that being made mostly of water, humans are affected in much the same way as large bodies of water, e.g., they experience tides. This logic is faulted to the point
of absurdity; the only reasons that large bodies of water are affected are that they are (a) deformable, and (b) large. Their mass allows them to experience a greater force than a 70 kg human. In addition, humans are not always pointed toward the moon, and so the water, even if it was being tugged upon by the moon, would be moving in different directions in each person.

The other factor that might be different between FM days and AO days is the amount of light reflected from the sun. It is highly unlikely that the amount of light reflected is a cause of behavioral changes in human. Full moon nights are not always clear, and, while there is evidence to suggest that length of day can affect human mood, hormone levels and gene expression, there is no evidence that suggests that the amount of moonlight can affect mood.

Absent any factor that could logically affect the behavior of humans, we are left to conclude that the root cause of any possible changes in behavior is purely psychosomatic. That is, the persistence of the belief in lunar effects (as demonstrated by instruments such as the BILE survey) has caused humans to alter their behavior themselves without any gravity or light induced physiological changes.

*The author is deeply indebted to Dr. Julie Carmalt of Cornell University, whose statistical prowess proved invaluable in analyzing the data for this project. A great deal of gratitude is also owed to Betty Cosentino of the Central New York Regional Information Center for expertly providing the raw data. Mrs. Debbie VanZandt of Groton High School also deserves thanks for her knowledge of pretty much everything.

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The Geology of Howe Caverns

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Right here in New York State, in the hills and valleys formed by Ice Age glacial runoff, is a superb example of limestone dissolution and deposit. You and your students can experience it firsthand! Imagine stepping into an elevator that takes you 156 feet below the Earth's surface. You don't have to be a serious caver or speleolunker to appreciate the geology of Howe Caverns. Touch the stalagmites and stalactites. Hear the dripping of water as these processes continue on. See nothing as you experience absolute darkness on the underground boat ride. And remember, this cave was here long before even the ancient, extinct animal known as the woolly mammoth appeared on Earth! Students can also pan for gemstones. They will discover garnets, rose quartz, fool's gold, emeralds, aquamarines and many other beautiful stones and use the identification charts to accurately identify exactly what they have found. While here, your group can also challenge themselves on Howe High Adventures Ropes Course and aerial zip lines!

Howe Caverns was formed by the dissolving of limestone bedrock by underground water. Limestone is deposited on the ocean floor as soft slimy material (calcium carbonate) that later hardens into rock. The cave is located in the Helderberg Group of limestones, which was deposited from sea water on the ocean floor about 400 million years ago. These layers were later buried beneath younger rocks such as sandstone and shale (composed of hardened sand and mud). Much later they were uplifted above sea level as part of the Appalachian Mountains. The limestones were exposed at the surface in the Howe Caverns area a couple of million years ago as rivers eroded away the overlying rocks.

How old is the cave?
The caves are probably less than one million years old. We don't know for sure because most of the clues are missing. Deposits in nearby caves have been dated to more than 350,000 years ago. The rate of downward cutting of underground streams in some of these caves indicates an age of more than half a million years.

Cave Origin: Dissolving of limestone
Limestone dissolves easily in fresh water, especially if the water has picked up some kind of acid. The most common natural acid is carbonic acid which is formed when carbon dioxide gas in the air and soil is picked up by the water. The soil contains a lot more
filled it entirely (at least during high flow). The passage is about 30 ft wide and about 20 ft high with a canyon cut 8-15 feet deep in its floor. The stream in the passage is the same one that formed the passage in the first place. In the past there was more water because some of it has been pirated through other passages to more recent springs. The original passage was tube-like, but as the water table dropped, the stream cut the canyon in its floor. In places, this makes the passage cross section look like a keyhole. The Winding Way is a narrow canyon that formed above the water table. It once carried a stream that was a tributary to the main stream. Water still pours out of this passage during high flow, but during low flow it follows lower-level routes. Upstream from the elevator, the main passage can be followed a short distance to breakdown. This passage may have originally been the downstream continuation of a passage in McFail’s Cave which lies about 2 miles to the northwest. The Winding Way is the largest of several tributary passages and the only one that can be followed for any great distance. Like most of them, it enters the main passage from the up-dip side. At Titan’s Temple, the largest room in the cave, the lower level canyon branches off from the upper-level tube. The stream follows the lower level, which becomes more tube-like farther downstream, because it spent much time at a new, lower level of the water table. The upper level is clay-choked in the former downstream direction. Where the two passages diverge, the cave intersects a

**Interpretation Of Howe Caverns**
Howe Caverns is the largest Northeastern cave open to the public. The original entrance lies in the southeastern corner of the Howe Cave Quarry whose operation has removed the connection with the main part of the cave. The elevator leads directly into the main passage of the cave. The walls are composed of Manlius Limestone. The bottom of the next layer up, the Coeymans Limestone, can be seen in the highest ceilings.

**Passage types**
The main passage formed along the water table, and originally, the water...
LEAVE PAGE BLANK!
low angle fault. This is the same one that is exposed in the Howe Cave Quarry. Here the fault dips 14 degrees to the south southwest.

The fault can be seen in the chin of the Old Witch. The main passage continues a couple of thousand feet beyond the end of the tour. Its water drains out of a hole in the quarry wall and then down into a mine that underlies the quarry. The water eventually emerges at springs at the base of the quarry. The tours exit the cave through an artificial tunnel between the Winding Way and the elevators. Much of this tunnel is excavated through a fault zone containing white calcite veins.

**Glacial deposits**
Farther downstream the passage contains thick deposits of clay. These were deposited as very thin beds when Lake Schoharie ponded the water in the cave. They appear in all major caves in the Schoharie Valley but in almost no other caves in the state. The clay beds occupy the lowest part of the passage and the present cave stream has not even eroded down to their base. Therefore, almost the entire solutional history took place before the latest retreat of glacial ice about 14,000 years ago. Since they were deposited, much of the clay has been eroded away by the cave stream.

**Cave features**
The effects of water flow can be seen in the rock surfaces in the cave. *Scallops* are small hollows dissolved in the rock by flowing water. The smaller the scallops, the faster the flow. Scallopshave cross sections like small sand dunes, and like sand dunes, the steepest side points in the downstream direction. In the main passage there is no question what the flow direction has been. Do scallops in the Winding Way help to indicate the original flow direction? *Solution pockets* are random dead-end holes dissolved in the walls and ceilings by water that ponds up during severe floods. Most of them are located along joints or bedding planes in the limestone. The limestone shows *differential solution* - the more resistant beds stick out, while the less resistant beds and the bedding planes between them are dissolved inward. The most resistant beds are composed of sandy or clay-rich limestone which dissolves more slowly.

There are many mineral deposits in the cave (“cave formations,” more properly known as *speleothems*). These are almost all made of the mineral calcite (calcium carbonate), the same material that forms the limestone. Water that seeps through the overlying soil picks up lots of carbon dioxide. This water dissolves much limestone on its way down toward the cave. The cave air contains much less carbon dioxide than the soil, so when the water drips into the cave it loses enough carbon dioxide to precipitate much of the dissolved limestone. This doesn’t happen in large streams, because they do not contain enough dissolved limestone. *Stalactites* are formed in this way. They are icicle-like features that hang from the ceiling. *Stalagmites* grow
upward where drips hit the floor. Some stalactites and stalagmites fell into the stream thousands of years ago and have been pulled out and placed elsewhere, so, they are not necessarily in their original locations. Flowstone forms cascades of calcite where water drains downward over slopes. Rimstone has formed at the junction with the Winding Way. Rimstone consists of small dams that form at the edges of pools making the pools deeper with time. This rimstone is no longer active and has been moved during trail-building. Actively forming rimstone can be seen in the main passage.

Most speleothems are light brown, which contrasts to the dark gray of the bedrock. This is because the bedrock contains many impurities such as clay and organic carbon, while the speleothems are composed of purer calcite.

All of these features are thousands of years old and some are hundreds of thousands of years old. They form very slowly according to how much water is dripping onto them and how much dissolved limestone is precipitated by the water. Sand and gravel can be seen in the stream bed just as in a surface stream. This material consists mainly of sandstone pebbles that have been carried in from the surface. Breakdown blocks are seen in several areas. These are blocks of limestone that fell from the walls or ceiling, most of them in the remote past. Breakdown is very rare and very few cave explorers have ever seen a block fall on its own. Most breakdown takes place during severe floods, or when the water table is dropping rapidly.

Please check our website www.howecaverns.com for further information and supplementary lesson plans. Howe caverns is open all year!
Discovering And Analyzing Magnetic Fields With Solenoids

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Abstract
Understanding electricity and magnetism is difficult for introductory physics students partially due to a lack of familiarity, exploration and reflection upon electromagnetic phenomena. This activity was designed to help students experience and reflect upon magnetic phenomena and visualize magnetic fields around a current-carrying wire. Students constructed solenoids using a D-Cell flashlight battery, copper wire, a nail, and a straw. Students were guided through activities and explored the changes in intensity of magnetic fields at different distances away from the solenoid, and the effects due to introducing an iron core into the solenoid. Supplementing the qualitative conceptual experience, sample relevant calculations were also included for this activity.

My introductory high school physics students struggled with concepts associated with magnetic fields and the effects of electromagnetism. In order to help students anchor these ideas in concrete objects, it was important to provide my students the opportunity to gain visual and kinesthetic experience with electromagnetism (Arons, 1997). Visualizing magnetic fields in three dimensions is a significant challenge students face (Nguyen, 2005). The ability to fill in empty space with what a magnetic field may look like is a difficult task for students (Sawicki, 1997). Allowing students to construct models of a solenoid (or a wire wrapped in a coil) was beneficial for helping students with visualizing magnetic fields (MacIsaac, 2009) (Picture 1, Page X).

My goal was to create an interactive activity for my students to help them understand how magnetic fields behave and to gain the hands-on experience that has been widely believed to help students understand magnetism. This simple activity, constructing low cost solenoids, provided students experience with magnetic phenomena and is designed to increase student spatial understanding of three-dimensional magnetic fields. This activity facilitated the exploration of the magnetic interactions of solenoids with different materials and the effects of different geometries of current-carrying wires on the magnetic fields created. By editing the associated mathematical examples, the activity could be modified (reduced or extended) as appropriate to meet the needs of a conceptual physics, AP physics, or even a calculus-based introductory college physics course.

Prior to this solenoid construction activity, my students read the basic theory of magnetic fields surrounding permanent magnets and current carrying wires using various activities (Knight,
2008; Modeling Curriculum, E&M Unit 4 Lab 1 v 3.0, available from <tiny.cc/modeling01>). In related activities understanding these concepts, students utilized a magnetic compass and iron filings (Diagram 2 and 3, Page X) to view the magnetic field around a vertical current carrying wire. The Modeling activities were designed to help students become familiar with magnetic fields as well as introduce them to the Right Hand Rule #2 (Diagram 4, Page X). Another activity used iron filings and a compass to view the magnetic field around permanent magnets. Students placed a compass at various distances from a single permanent magnet to observe how the magnet attracted and repelled the north and south poles of a compass. This was a great activity for students to see how the needle of the compass deflected greatly when close to the magnet and deflected only slightly when placed a foot away (Riveros & Betancourt, 2009). Other topics covered included magnetic fields created by a current running through a circular wire and work problems using the Right Hand Rules to determine the direction the magnetic field is pointing inside, outside, and around a current carrying wire in a loop (Knight, 2008). After I completed these introductions, I felt my students were prepared to construct a solenoid and predict its magnetic field.

Activity materials required were both inexpensive and readily available. For each student or team, the following materials were required: A plastic drinking straw, some magnet wire (enamel coated copper wire - about a meter per person), a steel (iron) nail (about 9 cm long), a D-Cell, a magnetic compass, and a few paper clips (Picture 1, Page X). Although magnet wire works best for winding solenoids, ordinary insulated solid copper wire is acceptable. These materials were purchased at a variety of local stores or on the Internet. Because compasses, paper clips and D-cells were readily available, the cost was roughly $10 for a class of 25 students (see product list), and many of these materials were able to be recycled for future classes.

Constructing the solenoids was quite straightforward. When I began the experiment, I made sure that both ends of the copper wire were stripped. I then asked my students to wrap the wire around the straw with the nail placed inside for support. I instructed my students to record the number of times they wrapped the wire loops around the straw for subsequent calculations. To elicit discussions between partners regarding the number of loops vs. the magnetic field strength, I asked my students to wrap their solenoids with different number of loops. Students were instructed to avoid wrapping the wire too tightly around the straw in order to permit easy insertion and removal of the nail; this allowed the solenoid to have either an open core (no nail) (Picture 3, page X) or an iron core (nail inside) (Picture 4, page X). It was also important to leave a few inches of unwrapped wire at both ends of the solenoid as leads so that there was enough room to
Place Here ALL DIAGRAMS AND PICTURES

Pictures 1-4

Diagrams 1-4
press the stripped sections of wire to the D-Cell terminals. With their solenoids completed, the students connected the two-stripped ends of wire to the D-Cell terminals, sending a current through the wire and creating a magnetic field around the solenoid (Diagram 1, page x). I encouraged the students to touch and tap and monitor the time the circuit is closed to prolong the working life of the D cell.

In this experiment, it was important to alert the students that the D-Cell would, in essence, be shorted causing the wire to become warm, and to call their attention to this phenomenon during and after the activity. I explained to the students that the wire has a low resistance, thus creating a very large current, which heated up the wire. Students were instructed to open the solenoid circuit every few seconds to allow the D-Cell and wires to cool down. Allowing the D-Cell to rest every few seconds also greatly increased both the life of the cell and the accuracy of the results. Note that my students were not in danger of actual burns from the wire, though this is a faint possibility with thinner wire.

In order to learn about different designs of solenoids and gain a better idea of the magnetic fields they create, students constructed their own solenoids. Throughout the activity I instructed my students to try a variety of different solenoid designs in order to compare the different effects with their partners. Before the activity, I cut the straws into different lengths. Not only did this
reduce straw waste but also it guaranteed that the students would wrap their solenoids with a different number of loops. This was important for demonstrating the relationship between the number of loops and the magnitude of the magnetic field of the solenoids (Picture 2, page x).

My students readily calculated an approximate value of the strength of the magnetic field created by their solenoid given the standard equation: \[ B_{\text{solenoid}} = \mu_0 \frac{N}{l} \] where \( B_{\text{solenoid}} \) is the magnitude for the magnetic field in Teslas, \( N \) is the number of loops in the solenoid, \( l \) is the length of the solenoid in meters, \( \mu_0 \) is the permeability constant depending on the material of the core which is equal to: \[ \mu_0 = 4\pi \times 10^{-7} \text{ Tm/A} \] for an air core (no nail inside solenoid) solenoid, or \( 2000 \times \mu_0 \) stronger: \[ \mu_{\text{iron-core}} = 8000\pi \times 10^{-7} \text{ Tm/A} \] The permeability constant for the iron nail is much higher because iron will ferromagnetically respond to a magnetic field. This produces an enhanced magnetic field strength. The more responsive a material is to an induced magnetic field the higher the materials permeability constant or magnetic susceptibility. Exempting the differences in the current in each D-Cell from consideration, for a given type of solenoid (open core or iron core) the only significant variable that was not the same for each student was \( n \) (and the amount of iron for the iron core solenoids). Thus, it became apparent to the students that the greater number of loops per unit of length resulted in an increased magnetic field created by the solenoid.

I began the activity of experimentally measuring the magnetic field by instructing the students to connect the D-Cell to their open core solenoid (without the nail inside the straw) and observe the interactions between their solenoids, a compass, and paper clips. One approach to find the magnitude of the magnetic field was to see how many paper clips the solenoids would lift up. If a solenoid lifted more paper clips than another student’s solenoid, a reasonable prediction was that the solenoid that picked up more paper clips was stronger. A more accurate approach I had my students explore was to see how far away their solenoids would deflect the compass 10°, 45°, or 90° and alternatively to compare the solenoid distance from the compass necessary to exactly deflect the needle by 45°. I instructed the class to make sure that there were no other steel items or magnets on the desktop while measurements were being taken to avoid interference to the compass needle. The instructor also must check the desktops for steel beams and screws and try to avoid these when comparing magnetic
field strengths with a compass. Students measured the distance between the solenoid and a magnetic compass (the latter being deflected by the predetermined number of degrees) using a meter stick and a protractor. Students were given time to discuss their results with a partner to see what similarities and differences they measured. Then I had the students try to explain why their results were different or similar. We then discussed the relationship of the deflecting force of the magnetic field and compared it to Coulomb’s law. I explained that the magnetic field created by the solenoid deflects the compass needle by the inverse square of the solenoid’s distance away from the compass (Knight, 2008). For example, if two solenoids both deflect a compass needle 10° but one solenoid is twice as far away from the compass than the other, then the magnetic field of the farther solenoid is four times as strong as the closer solenoid.

After a discussion about the interactions between their solenoid, paper clips, the compass needle, and their partner’s solenoid, my students created a sketch of the solenoid including the direction of current flow and polarity of the solenoid’s ends (Diagram 1, page X). Though my students had examined the magnetic fields of permanent bar magnets already, this was still a difficult task to complete. When students determined the polarity of their solenoid, I had them use a compass to establish which side of the solenoid attracted the north seeking end of the compass (solenoid’s magnetic south pole) and which end of the solenoid attracted the south seeking end of the compass (solenoid’s magnetic north pole). Attempting to determine the polarity of the solenoid using a bar magnet was difficult. The solenoid’s magnetic field (especially with the iron core inserted) is much stronger than the weaker magnetic field of most bar magnets and, when the solenoid was in contact with the iron bar magnet, the solenoid usually magnetized the iron permanent magnet overwhelming the usual magnetization and attracting both ends of the bar magnet. To see repulsion with the bar magnet required carefully starting out with the solenoid and the bar magnet separated and closely observing their behavior as they were gradually brought close to one another. To determine the polarity correctly, my students were instructed to always use a compass and initially have the (open core) solenoid a foot or so away, slowly moving the solenoid towards the compass until they could determine which ends of the solenoid attract the different ends of the compass. Then the students put the nail back into the middle of the solenoid, creating an iron core solenoid, so they can see how the interactions with the compass and paper clips compared to their open core solenoid. Students would see that the iron core solenoid was much stronger than the air-core solenoid. They may not have known how much the magnetic field had increased but they soon noticed that they were able to pick up more paper clips and that the solenoid with iron core deflected the compass needle.
The magnitude of the magnetic field (Knight, 2008).

Other extensions to this activity included encouraging exploring modified designs and comparing the magnetic fields produced. For example, students who doubled the number of loops on the solenoid by putting another layer of wire on top of the previous layer without making the solenoid any longer, found the solenoid magnetic field stronger, as predicted by Equation 1. When the number of loops was doubled, \( N \) was twice as large for a given length. This lead to \( n \) being twice as large and consequently \( B_{\text{solenoid}} \) doubled in magnitude. I found that allowing free time for students to alter their solenoids’ design was a great way for students to explore how different changes affect the solenoids magnetic field. The changes to the magnetic field were observed from the solenoid picking up more paper clips or deflecting the compass needle a greater amount when held at the same distance. My students found that some solenoid designs create a larger magnetic field than other designs. Other modifications I had my students experiment with included wrapping the solenoids less tightly, wrapping the solenoid in different directions around the straw, and putting loops of wire on top of one another while always recording the number of loops they wrapped around the straw. Wrapping the wire less tightly and putting loops of wire on top of one another decreased and increased the magnitude of the magnetic field respectively, changing the direction the
wire was looped around the straw so as to create partial or complete cancellations did not have as obvious an effect. Changing the way the wire was wrapped around the straw, say from clockwise wrapped to counter-clockwise wrapped around the straw, would change the solenoid’s polarity. However, if the students reversed the D-Cell terminals while rewrapping the solenoid, this would have a compensating effect resulting in no change in polarity. Because the number of different solenoid designs is virtually endless, I encouraged my students to experiment with different ideas.

After my students completed their solenoids and observed how different designs created different magnetic fields, I showed them examples of commercially designed solenoids. These are available through most science material magazines, such as science kit (http://sciencekit.com/), or online for around $100.00. My students were impressed that their solenoids were so similar to the ones that cost hundreds of dollars. I discussed how these solenoids were constructed and worked the same way as their solenoids. I had access to a “ring flinger” (an electromagnetic ring launcher) (Hall, 1997; McAlexander, 2005) (PASCO) so I amazed my students by demonstrating how strong a solenoids’ magnetic field can get. I then showed my students how solenoids play a major role in our everyday lives. I explained that solenoids are used in MRI machines, car starters and alternators, and doorbells, which use solenoids to strike chimes and make music.

To further supplement this activity, I found it beneficial to introduce students to the simulations found on The University of Colorado at Boulder’s PhET website (http://tiny.cc/PhET). Specifically, the simulation Generator 2.02 (Frankel, 2009) has interesting solenoid diagrams that allowed my students to visualize the magnetic field created by the solenoid as well as what factors affect the magnitude of the magnetic field. I found these applets to be helpful for students trying to understand the interactions between magnetism and current flow in their solenoids. The simulation added visual effect while the physical experiment allowed students to reliably and consistently take numeric measurements and calculate the magnetic field created. Both the strongly numeric simulation and the more qualitative real world experiment complemented one another to create a more complete experience on magnetism.

Entering the electromagnet tab under the simulation Generator 2.02, the students were able to visualize the magnetic field created by the solenoid. The students were instructed to select a DC current source, show the field meter, and change the number of loops to one. Using the field meter, students observed that the magnetic field becomes larger the closer to the middle of the solenoid they get. Because the field meter measured the magnetic field in units of G, or Gauss, instead of Tesla, it was necessary to provide my students
this experiment to be quite versatile, allowing me to explore many different facets of magnetism inexpensively. An important additional benefit to performing the experiment with my students is that they enjoyed constructing their own solenoids and learning about the interesting magnetic fields surrounding them. The feeling of empowerment experienced by students with this activity was evident. This activity provided students with confidence in their work and positively affected their attitude, not only towards magnetism and physics but towards science in general. Arons observed noticeable improvement in students’ attitudes toward magnetism following concrete experience measuring the magnetic field of a source, such as a solenoid (Arons, 1997). If sufficient supplies are available, students can enjoy taking their solenoids home and showing them off to their peers and parents. With the construction of simple solenoids and the use of these supplemental diagrams and applications, students are afforded a visualization of this topic while exploring some of the properties and calculations associated with magnetic fields.

Constructing solenoids is a simple and low-cost activity that allowed my students to see first-hand how the different properties of a solenoid affect the magnetic field surrounding it. This activity heightened my students understanding of magnetic fields associated with current-carrying wires as well as more difficult magnetic field setups. Aside from being inexpensive, I have found constructing solenoids with students can be taught through whiteboarding (MacIsaac & Falconer, 2004) and the objectives provided in Table 1 below helped guide the students through the experiment as well as guided instructor’s discussions with the students (MacIsaac, 2009).
Product List (prices and availability will vary)

* Note: You only need to buy one type of wire. Home Depot or other building supplies stores may be a lot more convenient but the enameled copper wire will make better electromagnets.

<table>
<thead>
<tr>
<th>Material</th>
<th>Item #</th>
<th>Source</th>
<th>Price</th>
<th>Amount</th>
</tr>
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<tbody>
<tr>
<td>Straw, Plastic, Pkg/250</td>
<td>WW21924M70</td>
<td><a href="http://sciencekit.com/">http://sciencekit.com/</a></td>
<td>$ 2.85</td>
<td>1 package makes approximately 500 electromagnets</td>
</tr>
<tr>
<td>Small Magnetic Compasses</td>
<td>WW61180M12</td>
<td><a href="http://sciencekit.com/">http://sciencekit.com/</a></td>
<td>$ 11.95</td>
<td>1 package makes 12 electromagnets</td>
</tr>
<tr>
<td>Paper Clips, Regular</td>
<td>WW65207M00</td>
<td><a href="http://sciencekit.com/">http://sciencekit.com/</a></td>
<td>$ 0.75</td>
<td>1 package can provide for 33 groups</td>
</tr>
<tr>
<td>Energizer Max D 12-Pack Batteries</td>
<td>A 250 859</td>
<td>Home Depot</td>
<td>$ 11.59</td>
<td>1 package makes 12 electromagnets</td>
</tr>
<tr>
<td>Nails Bright Common, 10D 3”</td>
<td>A 229 253</td>
<td>Home Depot</td>
<td>$ 3.24</td>
<td>1 package makes 68 electromagnets</td>
</tr>
<tr>
<td>* Enameled Copper Magnet Wire, 18 Gauge</td>
<td>WW63641M18</td>
<td><a href="http://sciencekit.com/">http://sciencekit.com/</a></td>
<td>$ 16.70</td>
<td>1 lb makes approximately 62 electromagnets</td>
</tr>
<tr>
<td>* 14 Gauge Solid THHN Wire</td>
<td>A 589 241</td>
<td>Home Depot</td>
<td>$ 0.18 / foot</td>
<td>3 foot per electromagnet</td>
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References:

MISSING BIOGRAPHY?

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