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Teaching Science through Argumentation: An Outline for Virginia Science Teachers

Joanna K. Garner, Ph.D., The Center for Educational Partnerships, The Center for Educational Partnerships, Old Dominion University, 4111 Monarch Way, Norfolk VA 23508, jkgarner@odu.edu
Melani Loney Ed.S., The Center for Educational Partnerships, Old Dominion University
Victor Sampson, Ph.D., The Center for STEM Education, University of Texas at Austin

Abstract

In this article, we emphasize the relevance of scientific argumentation to inquiry-oriented instruction in science. Our aim is to provide teachers with an understanding of the components of a scientific argument, and an appreciation for how the use of scientific argumentation in the classroom can draw together a number of effective instructional practices. First, we identify the components of a scientific argument and interpret them for the classroom through an instructional model called Argument Driven Inquiry (ADI; Sampson, Enderle & Grooms, 2013). Then, we then present an example of an ADI lesson on potential and kinetic energy. We discuss developmental modifications for elementary and middle school students, and provide an example of how the ADI instructional model facilitates the integration of skills that are being taught across the curriculum. The example lesson is one of a suite of ADI lessons that we have developed for use in Virginia.

> ***"Argumentation draws as much on critical thinking and communication skills as it does on science content knowledge. It requires creativity, scientific literacy, and an understanding of science methods."***

What is scientific argumentation?

Argumentation is an essential part of scientific inquiry (Llewellyn & Rajesh, 2011). Through investigative processes scientists generate, interpret, and evaluate empirical evidence in response to one or more research questions, and then situate and communicate the evidence with reference to scientific theories, principles, and concepts. Their work leads to conclusions and claims which can be supported, refined, and even challenged by others (Norris, Philips & Osborne, 2007). Together, these processes lead to the development of a scientific argument—a question that guides inquiry, the design of an investigation; the collection and interpretation of data as evidence, the construction of a conclusion or claim from evidence; and the justification of evidence and its significance in reference to scientific theories, principles, and concepts (Sampson, Enderle & Grooms, 2013).

Scientific argumentation is by nature an iterative, investigative, and collaborative process. Scientists often work collaboratively throughout the entire investigative cycle, from the moment the research idea is conceived to the moment that the findings are published. For this reason, argumentation draws as much on critical thinking and communication skills as it does on science content knowledge. It requires creativity, scientific literacy, and an understanding of science methods. Scientific argumentation therefore embodies many of the principles of the Nature of Science (NOS; Lederman & Lederman, 2004).

Argumentation And Inquiry-Oriented Instruction

More than thirty years after landmark publications such as *A Nation at Risk* (National Commission on Excellence in Education, 1983), the release of national inquiry-oriented science standards including the Framework for K-12 Science Education (National Research Council, 2012) and the state's revised *Science Standards of Learning;* (SOL) (Virginia Department of Education, 2010), research shows that many teachers struggle to implement inquiry-oriented instruction (Capps & Crawford, 2013). One reason, we propose, is because teachers lack access to evidence-based instructional models that integrate science content with scientific inquiry processes and allow teachers and scientific argumentation allows classroom educators to embrace the process of scientific inquiry and the practices of science and engineering, which include asking questions, planning and carrying out investigations, analyzing and interpreting data, and engaging in argument from evidence (National Research Council, 2012; NGSS Lead States, 2013). For many years, science education researchers and policy makers have been calling for a more inquiry-oriented approach to classroom science teaching. Such an approach encourages the design of learning activities that approximate of the practices of scientists (National Research Council, 2012). When implemented by highly qualified teachers, inquiry-oriented instruction can be more effective than traditional, teacher-led methods that tend to emphasize memorization and the use of text, rather than experience, as a source of knowledge (Anderson, 2002). Inquiry-oriented instruction has been promoted as an approach that can help to increase science achievement across the United States because of its propensity to facilitate both cognition and motivation in science (National Commission on Excellence in Education, 1983). Through guided inquiry in particular, students experience scaffolding as they construct an understanding of content, and feel efficacious in allowing students to alternate in taking the lead..

The Argument Driven Inquiry Instructional Model

Instructional models, sometimes called teaching models, provide teachers with a road-map or blueprint for their teaching. They typically have specific goals, a sequence of phases, and a theoretical or research-based foundation (Eggen & Kauchak, 2012). Instructional models are not curricula, but instead act as a vehicle into which content, along with a variety of teaching strategies, can be inserted. Although not prescriptive, models do provide a helpful guide for teachers and offer an excellent template from which multiple lessons can be created.

In the fall of 2013, we were searching for just such an evidence-based instructional model for use in a Virginia Math Science Partnerships (MSP) project. The model needed to support the teaching of scientific discourse and argumentation as well as content, and provide for flexible movement between periods of teacher-led and student-led instruction. We identified Argument Driven Inquiry (ADI; Sampson, Grooms & Walker, 2009) because its goals, phases and foundations were well articulated, and easily aligned with the K-8 Virginia SOLs for science. ADI is also evidence based, and has shown promise in studies of high school and college students' learning with versus without the ADI instructional model (Walker, Sampson, Southerland & Enderle, 2016; Walker & Sampson, 2013). The model has been successfully used in four MSP projects since we began using it in the spring of 2014.

A major goal of ADI is to teach students how to formulate and critique scientific arguments, while at the same time making sure that they construct a deep understanding of science concepts. This goal is achieved through activities that include content area reading, investigation design, data collection and interpretation, and collaborative, constructive, and reflective discussion. Through these activities, students populate a generic template that serves as a conceptual organizer for their investigation and their scientific argument. *Figure 1*

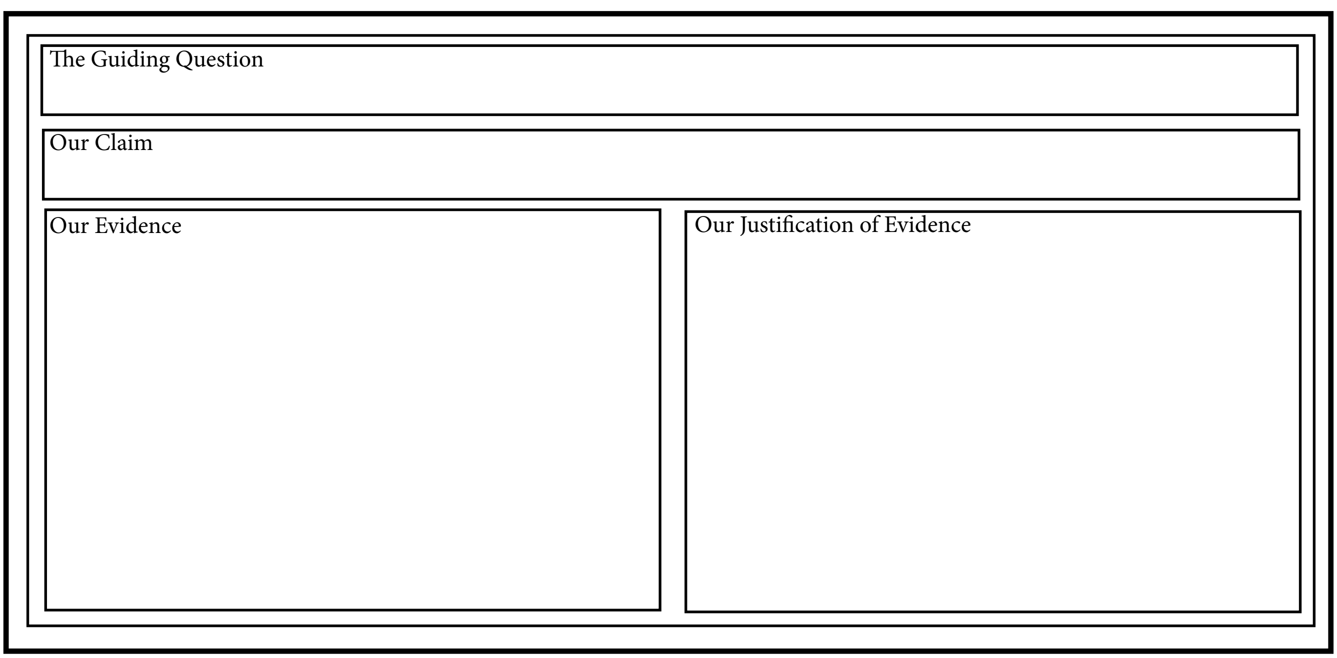

Figure 1 Generic structure of the ADI whiteboard

Example Lesson On Potential And Kinetic Energy

Guiding Questions And Claims.

Each ADI investigation centers on students' responses to a guiding question. This is usually phrased as a "Why…?" or "How…?" question that positions the students to generate a claim. A claim is a statement that responds to a guiding question; it can be thought of as an assertion, or conclusion, but it is best expressed at the conceptual level because ideally, the same basic claim will be generated by the class via several similar but not necessarily identical investigations.

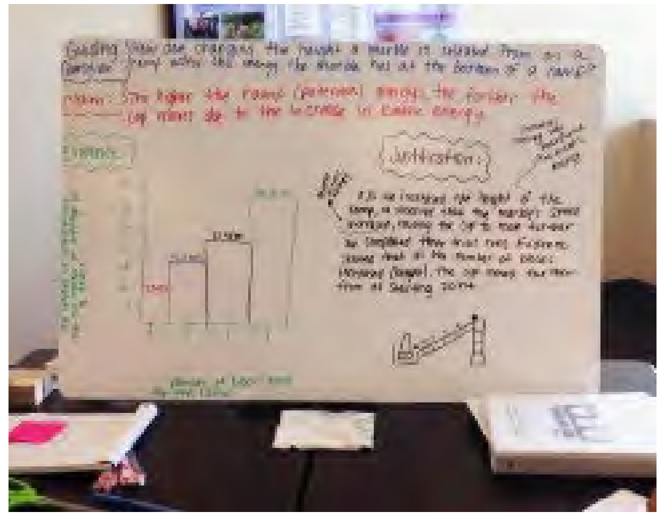

Figure 2: An example scientific argument created by elementary teachers

In our work, when designing an investigation, we draw from the curriculum framework for science so that guiding questions and claims can be mapped more or less directly. For example, we drew from specific components of SOL 4.2. and PS.6. *Figure 2:* An example scientific argument created by elementary teachers to design two variations on the same Guiding Question: What is the relationship between potential and kinetic energy?

Table 1. Excerpt from the Virginia Department of Education Science Curriculum Framework

SOL	Statement
4.2	The student will investigate and understand characteristics and interactions of moving objects. Key concepts include: a) Motion is described by an object's direction and speed; b) *Changes in motion are related to force and mass**; c) Friction is a force that opposes motion; and, d) *Moving objects have kinetic energy.*
PS.6	The student will investigate and understand forms of energy and hoe energy is transferred and transformed. Key concepts include: a) *Potential and kinetic energy*; and, b) Mechanical, chemical, electrical, thermal, radiant and nuclear energy.
	**Italics added to highlight objects within the example lesson*

Evidence and justification.

Evidence consists of the data or observations that were collected, and an analysis and interpretation of that data. It is positioned in the bottom left box of the whiteboard. *Figure 1* Often, this portion of the board includes an appropriately labeled graph or a table, and a brief written explanation of what the data show. For example, students may comment on trends or relationships that emerged, or differences that were apparent under various experimental conditions. On the right-hand side, students write a justification of the evidence, in which they relate their evidence back to the appropriate scientific theory or principle and make the case for their methodology. In colloquial terms, we often refer to this as why the evidence "matters."

ADI's eight stages.

How does this all fit together? The original ADI instructional model includes a sequence of eight stages:

Table 2. Summary of the stages within the ADI instructional model

Stage	Summary
1.	Students read and annotate a brief science text. Some hands-on exploration of a concept or principle may be included. Students consider the task that the lesson focuses on and the guiding question for their investigation.
2.	Students collaboratively design an investigation. They review materials that can be used in their investigation and create a plan. The teacher reviews and signs their plan.
3.	Students conduct their investigation and collect their data or observations. Students analyze their data and prepare an initial argument on a whiteboard.
4.	Students engage in an argumentation session. Each group of students divides so that some students visit other groups' boards, and one or two of the students remain at their board to explain their investigation to others. Students ask each other questions and provide constructive criticism. Afterwards, students regroup and modify their board.
5.	The teachers leads an explicit, reflective discussion. This stage may involve questions and answers, a review of whiteboards, an online activity or simulation, or a demonstration by the teacher.

6. Students prepare an individual report using a template and a rubric to guide writing.

7. Students work in groups to peer-review one another's work. The process is supported by the rubric, and is designed to provide an opportunity for constructive feedback.

8. Students revise their peer-review work and submit their final paper to the teacher. The teacher uses the rubric to grade the papers.

Stage 1, teachers and students identify the task and the guiding question for the investigation. Typically, this stage involves reading a short science passage, examining a diagram, and conducting some exploratory activities. (Appendix A)

Then, in *stage 2,* students work in groups to design an investigation and collect their data. Students select from an array of materials and work together to complete a proposal form, which the teacher then reviews and signs. (Appendix B)

Students then work collaboratively in groups to collect their data. *Figure 3* This involves selecting and organizing materials, and making sure that they follow the protocol they have developed.

Figure 3: Elementary teachers investigate potential and kinetic energy

After collecting data, students conduct their analyses and develop a tentative argument, which is then represented using the whiteboard. *stage* 3 In *stage 4*, students visit one another's boards in a round-robin style, leaving one or two students behind to represent the group. *Figure 4* Students question one another and typically note strengths and weaknesses in their own and each other's arguments.

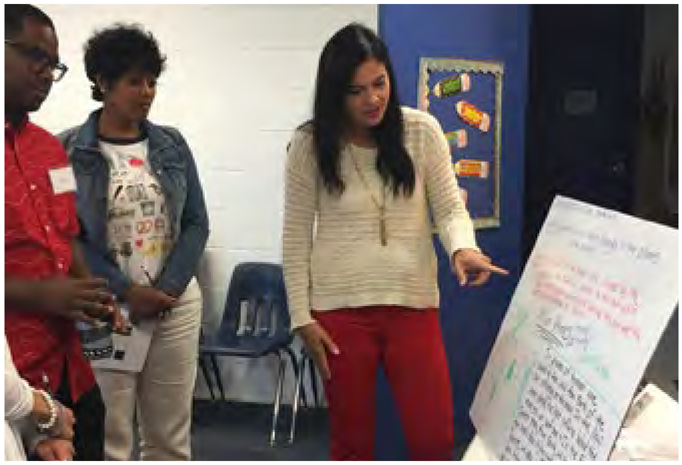

Figure 4: Teachers practice their argumentation skills

Following the argumentation session, students return to their boards and discuss what they have learned. At times, this stage becomes extended, with students revising their arguments or even collecting additional data. Then, in *stage 5*, the teacher leads an explicit, reflective discussion. This provides for an opportunity to teach or re-teach key information, and to tackle any remaining misconceptions. In *stage 6,* students prepare an individual written report, using a template. (Appendix C)

Once students have prepared a draft report, it is double blind peer reviewed (stage 7). In a manner that parallels the peer review process that scientists use, each student group reviews an anonymous set of papers, provides feedback using the rubric, and then subsequently receives their own work with feedback attached to it. Once they have revised the report, in stage 8 they submit the report for a grade. The teacher uses the rubric as a foundation for their grading. (Appendix D)

Potential And Kinetic Energy Adi Lesson

Perhaps the easiest way to demonstrate the ADI instructional model, and the modifications that have allowed it to be successfully integrated into elementary and middle school classrooms in southeastern Virginia, is to present an example. In the following sections, we highlight portions of an ADI investigation that focuses on energy and motion. We then call attention to specific modifications that, we have found, suit the developmental needs of the middle and elementary school students with whom teachers in our program work.

Energy is a concept that is revisited many times throughout the K-8 Virginia science curriculum. As shown in *Table 1*, it is important that students understand how energy can be transformed from one form to another, as well as the relationship between force, motion, and energy. This ADI investigation allows students to discover the relationship between potential energy and kinetic energy [1]. Through the opportunity to manipulate the height (gravitational potential energy) at which a marble is released, students observe changes in the speed (kinetic energy) of the marble.

Through an exploration of kinetic energy and force during *stage 1*, students construct a method to measure kinetic energy through force by measuring the distance that a cup travels when the marble rolls into it. In the advanced version of the lesson, students can also choose to vary the mass of the marble, which leads to the discovery that greater mass leads to greater kinetic energy, and greater force as the marble reaches the cup.

Students collect data once they have been approved to do so. Typically, students design an experiment consisting of multiple trials where the independent variable is the height of the marble release (or the mass of the marble) and the dependent variable is the distance that the cup moves. To complete the whiteboard argument, however, students must analyze and present the data using a table or graph. They must also write a brief explanation of what the table or graph shows, before they can legitimately point to their experiment as being supportive of their claim.

For the direct instruction portion of the lesson, which comes after the argumentation session, teachers may elect to show students an online simulation[2] of the relationship between potential and kinetic energy, and compare and contrast the simulation with the investigations that students designed and conducted. Students may also review the text that was included in *stage 1,* or complete an exit ticket in which they paraphrase their investigation and write their final claim.

Modifications To The ADI Instructional Model

Minor modifications to the ADI instructional model retain its most powerful elements but allow the model to be implemented in a manner that is sympathetic to the context (e.g. Chen, Wang, Lu, Lin & Hong, 2016). Successful adaptation of the ADI instructional model for Virginia's elementary and middle school students has involved the inclusion of additional scaffolds and prompts, and a modification to the individual paper requirement (*stages 6-8*). We now highlight these modifications for the middle and elementary school levels respectively.

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1 The lesson is available from the authors upon request.

2 https://www.pbslearningmedia.org/resource/hew06.sci.phys.maf.rollercoaster/energy-in-a-roller-coaster-ride/

Middle School

The ADI instructional model is used in the MSP funded project Knowledge through Experience for Youth in Science (KEYS; Loney, Garner & Whittecar, 2015). The KEYS project provides middle school science teachers with professional development which is focused on the design and incorporation of ADI in the middle school science classroom. Through this project teachers learn the 8 stage ADI process; methods for implementing lab and field-based ADI lessons in the middle school science classroom; and finally, means for designing their own ADI investigations that align to the grade six through eight Virginia middle school science standards.

Questioning is used as part of the investigation design process in *stage 2* to assist students as they create their investigation proposal. Questions presented in the ADI student materials prompt students to consider the design of the investigation and the collection and analysis of the data. Analyzed and interpreted data will comprise the evidence that the student will use to support their claim. Question complexity increases in the ADI document as the middle school grades increase, providing a gradual release of support for the student as their experience with designing scientific investigations become increasingly sophisticated. Appendix E shows an example of questions from a grade eight ADI document.

Support for writing is another area where scaffolding is incorporated in the middle school ADI process. Because students in grade six do not possess the same experience with writing a scientific report as students in grade eight, writing prompts are provided for students in the lower middle grades. Through the use of the writing prompts, students gain an understanding of the required report components as well as the order of their placement. As students graduate to grade seven and grade eight they transition from using the prompts to using the *stage 7* peer review rubric as a guide for the organization of their paper.

Elementary School

In another Virginia MSP project, *Building Bridges across the Elementary Curriculum using Argument Driven Inquiry* (Garner, Whittecar & Loney, 2015), we have incorporated a modified version of the ADI instructional model and created more than a dozen lessons that are aligned with the grade four and five science SOLs[3]. At the elementary level, we incorporate questions and prompts, but have also elected to make a modification to the stages of the instructional model. After discussions with teachers, division coordinators, and the ADI originators, we made the decision to omit *stages 7* and *8*. We replaced the *stage 6* individual report with an individual version of the whiteboard (used mostly at grade four), and at grade

[3] For examples of lesson plans and student workbooks aligned with the elementary Virginia Science SOLs, please contact the first author.

five use a structured report that included section headings, sentence starters, and blank axes or tables for students to complete.

In addition to questions that can guide students' thinking, we also made a modification to *stage 2,* during which students are examining materials and preparing a plan for their experiment. We renamed the proposal as the "Plan," and added structure to act as a guide for students, so that students would be prompted to articulate independent and dependent variables, and state a prediction or hypothesis. In the proposal, we also removed the prompt for a tentative claim, which is a feature within the secondary level ADI documents.

Classroom Management Strategies

At both the elementary and middle school levels, we developed additional class-room management strategies for teachers to use with their students. Icons were added to each workbook section in order to quickly orient students. Color-coded, visually appealing charts with movable clips were created for display to promote progress monitoring and time management within each group as well as for the class as a whole. Finally, to promote individual responsibility within each student group, we also added explicit roles such as materials manager, data recorder, explainer, and writer. Roles were designated through a reusable lanyard and badge system.

Gradual Release Of Responsibility

Many instructional models require several iterations before students are capable of working independently. We have found that students need more support during their first exposure to ADI, but that they quickly learn the sequence of the stages and the components of a scientific argument. For example, we have observed that students may need assistance identifying key terms that are useful for investigation design. However, once familiar with an annotation strategy, students become able to support each other throughout *stage 1* and *2* so that they can comprehend and apply the concepts in the science text. Similarly, during the first few opportunities to participate in an argumentation session, students may need support in the form of conversation starters and example questions. After becoming familiar with this type of format, however, students begin to offer and receive productive and constructive critiques.

Cross-Curricular Connections

One attractive feature of the ADI instructional model is that its structure provides students with an opportunity to practice skills from other areas of the curriculum. For example, during *stage 1,* students practice reading non-fiction text. During *stage 3*, students often need to apply their mathematical skills in order to accurately measure and then summarize and represent their data. During *stage 4*, students must practice oral communication skills. During *stage 6*, students have the opportunity to practice their non-fiction writing skills. An example of how the ADI instructional model can cross-walk with the Virginia SOLs is provided in Appendix F.

Reaching Diverse Learners

Although researchers have not investigated the potential impact of ADI on students with disabilities or English Language Learners, several features of the ADI instructional model are supportive of diverse learners. For example, ADI implementation builds on principles of cooperative learning. Specifically, it is recommended that teachers form heterogeneous groups, allowing students of varying abilities to work collaboratively and support one another in service of a common goal (Slavin, 2014). Second, ADI can be used to reach learners who require repetition of vocabulary and conceptual ideas with rich contextual support (Stevens, Van Meter, Garner, Warcholak, Bochna & Hall, 2008). In an ADI lesson, students read, discuss, act, speak, write, reflect, and compare their work for any given topic. Third, ADI provides built in extra practice of many cross-curricular skills in oral and written language that can benefit English Language Learners or students with disabilities (Francis, Rivera, Lesaux, Kieffer & Rivera, 2006). Finally, the varying templates we have developed to simplify the proposal and reporting stages of ADI may provide support for older students for whom planning, organizing, and writing prove to be difficult.

The Impact Of Teaching With Argumentation On Students And Teachers

The originators of the ADI instructional model took care to conduct rigorous research studies in order to provide evidence that the model was of benefit to students. They found that a condensed sequence of argumentation-focused steps not only improves students' content knowledge but also their abilities to plan and carry out an investigation, argue from evidence, and write in the context of science (Sampson, Enderle, Grooms & Witte, 2013; Sampson, Grooms & Walker, 2011; Sampson & Walker, 2012; Walker & Sampson, 2013a; 2013b). Their research also suggests that students enrolled in general sections of science courses make similar or larger gains than students enrolled in the honors section of the same courses when teachers used the ADI instructional model throughout the school year (Strimaitis, Southerland, Sampson, Enderle, & Grooms; 2017). These findings, when taken together, suggest that an instructional model that integrates science content with scientific inquiry processes and gives students more voice and choice in their learning, such as ADI, has the potential to help all students develop the knowledge, skills, and habits of mind that they need to be considered literate in science.

These findings have been echoed at the teacher level in our own work, which is focused primarily on providing professional development that equips teachers to implement the ADI instructional model (Garner, Whittecar & Loney, 2015; Garner & Whittecar, 2014; Garner & Loney, 2016; Loney, Garner & Whittecar, 2015). We have routinely administered pre- and posttests of scientific content knowledge and scientific argumentation skill to all participating teachers in our summer workshops and institutes. For example, over the course of a five day period, we have found that most (91%) of the participating teachers attending our summer institutes have demonstrated significant gains in their ability to formulate and critique a scientific argument, and more than half (61%) have also improved their scientific content knowledge (Garner, 2018). By doing multiple ADI investigations and by considering how they can teach with argumentation in their classroom, we have found that teachers, like their students, can also learn about argumentation and how it fits with investigative science practices.

Conclusion

Argumentation complements and reinforces scientific investigation skills, but we have also found it to be an effective vehicle for helping students to develop a rich understanding of science content. Use of argumentation within an instructional model that permits teachers to vary the degree of support they provide their students can promote the implementation of inquiry oriented instruction, thereby helping teachers meet the goals of enhancing students' science knowledge and 21st century skills in science and information literacy (Grooms, Enderle, & Sampson, 2015). We have used the ADI instructional model in southeastern Virginia through several MSP projects, and have found that critical steps towards ensuring successful implementation are the provision of professional development for teachers, and access to lessons that are aligned with the Virginia SOLs.

Appendix A

Text Used In ADI Stage 1 With Variations For Middle School

Physical Science Lab Investigation: Energy Transfer

How does a change in potential energy of an object affect the kinetic energy of the object?

Introduction

Energy is the ability to do work. Energy exists in two states, potential and kinetic energy. Potential energy is stored energy based on position or chemical composition. Kinetic energy is energy of motion. The amount of potential energy associated with an object depends on its position. The amount of kinetic energy depends o the mass and velocity of the moving object.

When you pull on a rubber band you apply a force to it and give it potential energy. Potential energy is energy that is stored as a result of position. For example the heavy ball of a demolition machine is storing when it is held at an elevated position. Similarly, a drawn bow is able to store energy as a result of its drawn position. A round object at the top of an incline has potential energy. The energy is based on position and gravity. When the object rolls down the incline the potential energy is changed to kinetic energy.

When you let go of 5the rubber band the potential energy you stored in the rubber band became kinetic energy as the rubber band flew. Kinetic energy is the energy of motion. An object that has motion has kinetic energy. There are many forms of kinetic energy. There are many forms of kinetic energy. We will focus upon the energy due to motion from one location to another. The amount of kinetic energy that an object has depends upon two variables: the mass (m) and the speed (v) of the object.

Kinetic energy ca be transferred between objects when one object is at rest and then is hit by a moving object. An example of this type of kinetic energy might be when an object is shot using a sling shot. If the sling shot is used to fire a projectile at a standing object, the object fired upon can be moved. The distance that the object is moved reflects the kinetic energy of the moving projectile. Another example of kinetic energy might be when a toy car at the top of a ramp is released. If an object is located at the bottom of the ramp, the car will move the object a distance when it makes contact. The distance can be measured to help determine the kinetic energy of the car.

Appendix A

Text Used In ADI With Variations For Elementary Students

Virginia Science SOL 4.2 Investigating and Understanding Characteristics and Interaction of Moving Objects
How is potential energy related to kinetic energy?

Introduction

Energy is what makes things change. Look at Figure 1. Image you are stretching a rubber band by widening your fingers. When you pull on the band you apply a force and give the band potential energy, which is energy that is stored in an object. When you relax your fingers or let go of the band, the potential energy stored in the rubber band changes into **kinetic energy.** You can observe this change because it causes the band to return to its starting position. **Kinetic energy** is the term used to describe the energy an object has because it has mass and it is moving in some direction. **Potential energy** and **kinetic energy** are in all objects that move.

Figure 1. Stretching and relaxing a rubber band demonstrates potential and kinetic energy.

Potential energy and **kinetic energy** can also be seen in objects that fall or roll down a slope. At the starting point above the ground, an object has potential energy. As it rolls or falls, potential energy is transformed into kinetic energy. Once the object stops falling or rolling it no longer has kinetic energy. If it can fall or roll further, it still has potential energy. Look at Figure 2 and imagine what happens if a ball was to roll down the slope. What might happen if a ball started higher or lower on the slope? What might happen if the ball had more or less **mass?**

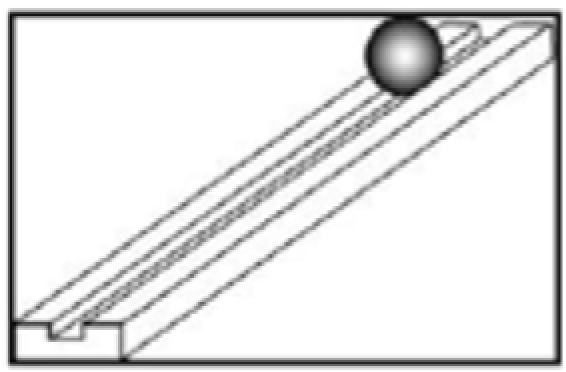


Figure 2. A ball rolling down a slope has potential energy that changes to kinetic energy.

You can observe the relationship between potential and kinetic energy by measuring how far a cup moves after a marble that has traveled down a ramp hits it. The distance the cup moves will represent the amount of kinetic energy in the marble because the marble will hit the cup with a force and forces cause objects to move. An object will move more when more force is applied to it. The height up the ramp that the marble starts, and the mass of the marble, will change the amount of potential energy in the marble.

Appendix B

Example Investigation Proposal Sheet For Elementary Students

Investigation Plan

Group members:

____

The Guiding Question:

Independent variable:

Dependent variable:

How we will set up the equipment:

Steps we will follow to make observations:

Data we will use to create evidence for our claim.....

We predict that our data will show:

I approve this Investigation.

______________________ ______________

Teacher's signature **Date**

Appendix C

Upper Elementary Template

Name: ______________________________

ADI Title: ______________________________

Final Report

Use the feedback you received to write your final report.

My goal of our investigation was to ______________________________

My guiding question was ______________________________

In order to gather the data, I needed to answer this question: ______________________________

I then analyzed the data I collected by ______________________________

Appendix C

Upper Elementary Template

Name: ____

ADI Title: ____

My claim is ____

____

____

____

The graph shows

____

____

____

____

____

____

____

____

This analysis suggests __________________________________

____

____

____

____

I think this evidence is important because ___________________

____

____

____

____

____

____

☑ **Submit your Final Report.**

Appendix D

Peer Review Template For Middle School ADI

ADI Investigation Report Peer Review Guide - Middle School Version

Report by: ________________________. Author: Did the reviewers do a good job? 1 2 3 4 5

Reviewed by: ____________ ____________ ____________ ____________

Name Name Name Name

Section 1. Introduction and Guiding Questions	Reviewer Rating	Instructor's Score
1. Did the author provide enough background information?	☐ No ☐ Probably ☐ Yes	0 1 2
2. Is the background information correct?	☐ No ☐ Probably ☐ Yes	0 1 2
3. Did the author make the goal of the investigation clear?	☐ No ☐ Probably ☐ Yes	0 1 2
4. Did the author make the guiding investigation clear?	☐ No ☐ Probably ☐ Yes	0 1 2
Reviewers: If your group made any 'No' or 'Partially' marks in the section please explain how the author could improve this part of the report.	**Author:** What revisions did you make in your report? Is there anything you decided to keep the same even though the reviewers suggested otherwise? Be sure to explain why.	

Section 2 Method	Reviewer Rating	Instructor's Score
1. Did the author provide a clear description of what he or she did during the investigation in order to collect data the method?	☐ No ☐ Probably ☐ Yes	0 1 2
2. Did the author describe how he or she analyze the data?	☐ No ☐ Probably ☐ Yes	0 1 2
3. Did the author use the correct form to describe his/ her investigation. e.g. Experiment, observations interpretation of a data set?	☐ No ☐ Probably ☐ Yes	0 1 2
Reviewers: if your group made any 'No' or 'Partially' marks in the section please explain how the author could improve this part of the report.	**Author:** What revisions did you make in your report? Is there anything you decided to keep the same even though the reviewers suggested otherwise? Be sure to Explain why.	

Appendix D

Peer Review Template For Middle School ADI

Section 3: The Argument	Reviewer Rating	Instructor Score
1. Did the author provide a clear and complete claim that answers the guiding questions?	☐ No ☐ Probably ☐ Yes	0 1 2
2. Did the author use evidence to support his or her claim?	☐ No ☐ Probably ☐ Yes	0 1 2
3. Did the author present the evidence in an appropriate manner by:		
• including a correctly formatted and labeled graph (or table).	☐ No ☐ Probably ☐ Yes	0 1 2
• using correct metric units (e.g. m/s, g, ml)	☐ No ☐ Probably ☐ Yes	0 1 2
• referencing the graph or table in the regular text?	☐ No ☐ Probably ☐ Yes	0 1 2
4. Does the evidence support the author's claims?	☐ No ☐ Probably ☐ Yes	0 1 2
5. Did the author use a scientific concept to justify the evidence? The justification of the evidence explains why the evidence matters?	☐ No ☐ Probably ☐ Yes	0 1 2
6. Is the justification of the evidence acceptable?	☐ No ☐ Probably ☐ Yes	0 1 2
7. Did the author use scientific terms correctly (e.g. hypothesis vs prediction, data vs evidence) and reference the evidence in an appropriate manner (e.g. supports or suggests vs proves)?	☐ No ☐ Probably ☐ Yes	0 1 2
Reviewers: if your group made any 'No' or 'Partially' marks In the section please explain how the author could improve this part of the report.	**Author:** What revisions did you make in your report? Is there anything you decided to keep the same even though the reviewers suggested otherwise? Be sure to explain why.	

Mechanics	Reviewer Rating	Instructor Score
1. Organization: Is each section easy to follow? Do paragraphs include multiple sentences? Do paragraphs begin with a topic sentence?	☐ No ☐ Probably ☐ Yes	0 1 2
2. Grammar: Are the sentences complete? Is there proper subject-verb agreement in each sentence? No run-on sentences.	☐ No ☐ Probably ☐ Yes	0 1 2
3. Conventions: Did the author use appropriate spelling, punctuation, and capitalization?	☐ No ☐ Probably ☐ Yes	0 1 2
Word Choice: Did the author use the appropriate word (e.g. there vs. their, to vs too, then vs than?	☐ No ☐ Probably ☐ Yes	0 1 2

Instructor Comments:

Appendix E

Questions In A Grade Eight ADI Student Document That Assist The Student Design Of Their Investigation.

To Determine What Type Of Data You Need To Collect, Think About The Following Questions:

- When does an object have an object have potential energy ?
- When does an object have an object have kinetic energy ?
- Can force be measured ?

To Determine How You Will Collect Your Data, Think About The Following Questions:

- What type of measurement will you use? (mass, length, height)
- How can you measure potential energy?
- How can you measure kinetic energy?
- How can you measure force?
- Will you need repeated trials?
- Do you need a control? If so, what will serve as a control?

In Order To Determine How You Will Analyze Your Data, Think About The Following Questions:

- What is the relationship between potential energy, kinetic energy and force?
- What type of graph can you make to help make sense of your data?

Appendix F

An Example Standards Cross-Walk For Adi At The Elementary Level

** Specific content standards (5.2-5.7) are addressed during specific laboratory investigations.*

Stage of ADI	Grade 5 Science	Reading	Writing	Speaking and Listening
1. Identification of the Task and the Guiding Question		5.6 a 5.6 g 5.6 b 5.6 h 5.6 c 5.6 i 5.6 d 5.6 k 5.6 e 5.6 l		
2. Design a Method and Collect Data	5.1 b 5.1 c 5.1 d 5.1 e 5.1 f 5.1 g			5.1 a 5.1 b 5.1 c 5.1 d 5.1 e
3. Analyze Data and Develop an Initial Argument	5.1 g 5.1 h 5.1 i 5.1 j			5.1 a 5.1 b 5.1 c 5.1 d 5.1 e
4. Argumentation Session	5.1 g			5.1 a. 5.2 c 5.1 b. 5.2 d 5.1 c. 5.2 e 5.1 d. 5.2 g 5.1 e. 5.2 h 5.2 a. 5.2 i 5.2 b
5. Explicit and Reflective Discussion	5.1 k			
6. Write an Investigative Report	5.1 g		5.7 a 5.7 e 5.7 b 5.7 f 5.7 c 5.7 g 5.7 d 5.7 i	
7. Double Blind Group Peer Review		5.6 a 5.6 g 5.6 b 5.6 h 5.6 c 5.6 i 5.6 d 5.6 k 5.6 e 5.6 l		5.1a 5.1b 5.1c 5.1d 5.1e
8. Revise and Submit the Report			6.7 h 5.8 f 5.8 a 5.8 g 5.8 b. 5.8 h 5.8 c 5.8 i 5.8 d 5.8 j	

References

Anderson, R.D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education* 13 (1), 1-12.

Capps, D.K., & Crawford, B.A. (2013). Inquiry-based instruction and teaching about the nature of science: Are they happening? Journal of *Science Teacher Education* 24 (3), 497-526.

Chen, H.-T., Wang, H.-H., Lu, Y.-Y., Lin, H.-S., & Hong, Z.-R. (2016). Using a modified argument-driven inquiry to promote elementary school students' engagement in learning science and argumentation. *International Journal of Science Education* 38 (2), 170-191.

Eggen, P. & Kauchak, D. (2012). *Strategies and Models for Teachers: Teaching Content and Thinking Skills*. (6th Edition). Pearson.

Garner, J.K. & Loney, M. (2016). Integrating Federal, State and local mandates for the benefit of teachers' professional learning: Examples from Southeastern Virginia. *Virginia Math Teacher* 43 (1), 53-58.

Garner, J.K., Whittecar, R. & Loney, M. (2015). Building Bridges across the Elementary Curriculum using Argument Driven Inquiry. *Virginia Department of Education Mathematics and Science Partnership award.*

Garner, J.K., Whittecar, R., Loney, M., Nelson, L., & Frank, G (2014). Project Discourse 'n' Argumentation: Building Blocks for Science Literacy. *Virginia Department of Education Mathematics and Science Partnership award.*

Grooms, J., Enderle, P, & Sampson, V. (2015). Coordinating Scientific Argumentation and the Next Generation Science Standards through Argument Driven Inquiry. *Science Educator,* 24(1), 45-50.

Lederman, N.G., and Lederman, J.S., 2004, Revising Instruction to Teach Nature of Science: The Science Teacher 71, 36-39.

Llewellyn, D., & Rajesh, H. (2011). Fostering argumentation skills: What doing what real scientists really do. *Science Scope* 35 (1), 22-28.

Loney, M., Garner, J.K.& Whittecar, R. (2015). Knowledge through Experience for Youth in Science. *Virginia Department of Education Mathematics and Science Partnership award.*

Marx, R. W., Blumenfield, P. C., Krajcik, J. S., Fishman, B., Soloway, E., Geier, R. & Revital, T. T. (2004). Inquiry-based science in the middle grades: assessments of learning in urban systemic reform. *Journal of Research in Science Teaching*, 41(10), 1063-1080.

National Commission on Excellence in Education, (1983). *A Nation at Risk*. Washington, DC: United States Department of Education.

Norris, S.L., Philips, L.M., & Osborne, J.F. (2007). Scientific inquiry: The place of interpretation and argumentation. In J. Luft, R. Bell, & J. Gess-Newsome (Eds.), *Science as Inquiry in the Secondary Setting*. Arlington, VA: NSTA.

Sampson, V., Enderle, P. & Grooms, J. (2013). Argumentation in science education: Helping students understand the nature of scientific argumentation so they can meet the new science standards. *The Science Teacher* 80 (5), 30-33.

Sampson, V., Enderle, P., Grooms, J., & Witte, S. (2013). Writing to learn and learning to write during the school science laboratory: Helping middle and high school students develop argumentative writing skills as they learn core ideas. *Science Education*, 97(5), 643-670.

Sampson, V., Grooms, J. & Walker, J. (2009). Argument-Driven Inquiry: A way to promote learning during laboratory activities. *The Science Teacher* 76 (8), 42-47.

Sampson, V., Grooms, J. & Walker, J. (2010). Argument-Driven Inquiry as a way to help students learn how to participate in scientific argumentation and craft written arguments: An exploratory study. *Science Education* 95 (2), 217-257.

Sampson, V. and Walker, J. (2012). Argument-Driven Inquiry as a way to help undergraduate students write to learn by learning to write in chemistry. *International Journal of Science Education*, 34(10), 1443-1485.

Strimaitis, A., Southerland, S., Sampson, V., Enderle, P., & Grooms J. (2017). Promoting Equitable Biology Lab Instruction by Engaging All Students in a Broad Range of Science Practices: An Exploratory Study. *School Science and Mathematics*, 117(3-4), 92-103.

Virginia Department of Education (2010). Curriculum Framework for Science. Retrieved from *http://www.doe.virginia.gov/testing/sol/standards_docs/science/index.shtml*

Walker, J. & Sampson, V. (2013a). Argument-Driven Inquiry: Using the laboratory to improve undergraduates' science writing skills through meaningful science writing, peer-review, and revision. *Journal of Chemical Education*, 90(10), 1269-1274.

Walker, J. & Sampson, V. (2013b). Learning to argue and arguing to learn in science: Argument-Driven Inquiry as a way to help undergraduate chemistry students learn how to construct arguments and engage in argumentation during a laboratory course. *Journal of Research in Science Teaching*, 50(50), 561-596

Integrating Technology into Science Field Investigations

Sarah Nuss, M.S., Education Coordinator,
Chesapeake Bay National Estuarine Research Reserve in Virginia (CBNERR)

Abstract

One of the most valuable results of environmental education is the clear association between understanding of STEM (science, technology, engineering, and math) concepts after participation in outdoor programs, as outlined in the National Science Foundation's Environmental Science and Engineering for the 21st Century report (NSF, 2000). One component of STEM is technology. Technology can assist in "problem solving, consensus building, information management, communication, and critical and creative thinking", the main goals and missions of environmental education as stated by the NSF report. These tools allow students to participate in science as a scientist would. By using appropriate technology, and developing technological skills along the way, students will be better prepared for career paths to be created in the future that will inevitably utilize technology. In order to maximize potential gains of using both technology and environmental education, technology must be used in concert with outdoor hands-on experiences, and not just as an afterthought (Willis, Weiser, & Kirkwood, 2014). This paper aims to share best practices of methodology for field investigations, along with examples of technology integration for each portion (preparation, action, and reflection).

Figure 1: Salt Marsh Investigation

Figure 2: Side by side in the lab

Figure 3: Refractometer use

In The Field

A class of students is split into groups, and is exploring a salt marsh within the Chesapeake Bay's watershed. Each small group is focused intently on the task at hand, to conduct a transect study of the marsh, determining what plants and animals can call it home. Students are using tools such as hand-held Global Positioning Systems (GPS), transect lines, quadrats, and digital cameras to document their work. With each student assigned a specific task, they work together to collect their data, and then back in the classroom, share the information about their area with the entire group in order to create a habitat map of the entire marsh. While conducting real-world science in an outdoor setting, with common and new technologies, students are engaged and interested in the topic at hand.

The benefits of students participating in environmental education are vast, and have been studied in great detail (Bartosh, 2004; Louv, 2005; US Senate, 2011). One of the most valuable results of environmental education is the clear association between understanding of STEM concepts after participation in these outdoor programs, as outlined in the National Science Foundation's Environmental Science and Engineering for the 21st Century report (NSF, 2000). In the report, NSF cites similar learning goals and missions in environmental education and in STEM programs, thus strengthening students' understanding of these concepts such as "problem solving, consensus building, information management, communication, and critical and creative thinking" during participation in both. Outdoor experiences foster these skills as well as added benefits such as a sense of stewardship and appreciation for nature (Broussard, Jones, Nielsen, & Flanagan, 2001), and additional opportunities for students to interact with technology (Hougham, Eitel, & Miller, 2015).

The North American Association for Environmental Education (NAAEE) partnered with Stanford University to review 119 studies on the impacts of environmental education. The 2017 Stanford study presents several key findings including:

- 98% of studies that examined whether students gained knowledge from environmental education saw a positive impact,
- 90% reported increased skills; and,
- 83% reported enhanced environment related behaviors.

Lead researcher, Dr. Nicole Ardoin from the Stanford University Graduate School of Education and Woods Institute for the Environment, stated "There is a mountain of evidence that suggests environmental education is a powerful way to teach students. Over 100 studies found that it provides transformative learning opportunities. There is no doubt that environmental education is one of the most effective ways to instill a passion for learning among students" (Ardoin, 2016). The research shows the many benefits of environmental education in addition to science knowledge, including academic performance, critical thinking, civic engagement, and personal growth.

Technology can also provide benefits to environmental education programs. The Virginia Standards of Learning (SOLs) state that "one must expect to 'do as a scientist does' and not simply hear about science if they are truly expected to explore, explain, and apply scientific concepts, skills and processes" (VDOE, 2010). Interactive technology, when used appropriately in order to accomplish learning goals, can support and enhance the project by allowing for the development of technology skills, addressing different learning styles, engaging students in more personal work, and supporting multidisciplinary learning

(Willis, Weiser, & Kirkwood, 2014). Technologies used in place-based education programs allow students to collect local observations both in physical locations and digitally, generate their own research and information, and connect their local environment with others (Hougham et al., 2015). Technology must be used in concert with outdoor hands-on experiences though, in order to reap the benefits of both it and environmental education, while also preparing students for the future (Willis et al., 2014).

MWEEs

In the Chesapeake Bay region, much of the effort in providing students with outdoor educational experiences has taken the form of MWEEs. The term MWEE, meaningful watershed educational experience, was coined by the Chesapeake Bay Program Education workgroup, in part due to the creation of the Chesapeake Bay Agreement in 2000 (Chesapeake Bay Program Education Workgroup, 2014). The Agreement tasked schools with providing a meaningful Bay or stream-focused outdoor experience for every student in the watershed prior to their graduation from high school (Chesapeake Executive Council, 2000). In 2014, the Chesapeake Agreement was reauthorized, and an environmental literacy goal was added, specifically increasing the MWEE requirement to one MWEE for every student during each phase of their education — elementary, middle, and high school (Chesapeake Executive Council, 2014).

MWEEs support classroom teaching and learning by involving students directly in field investigations, through development of a research question, collection of data, and analysis of results. The MWEE process is not a one-day event, but rather a year-long process involving the Standards of Learning (SOLs) as well as other education initiatives such as the Next Generation Science Standards. To achieve this standard, organizations and schools must fit the following requirements (Chesapeake Bay Program, 2014):

First, students must decide on an environmental issue or question to research, setting up experiments, and reviewing background information. Then, during the action phase, students participate in outdoor field experiences to collect data and participate in project to address environmental issues. Finally, during the reflection phase, students compile and analyze data, make conclusions, and participate in projects to address environmental issues. When done properly, MWEEs bridge together multiple disciplines, increase student knowledge, and increase positive behaviors and attitudes regarding the environment (Chesapeake Bay Program Education Workgroup, 2014).

CBNERR

The Chesapeake Bay National Estuarine Research Reserve in Virginia (CBNERR or Reserve), located at the Virginia Institute of Marine Science (VIMS), was designated in 1991 as one of 29 NERR sites established to promote informed management of the Nation's estuaries and coastal habitats. A critical aspect of the National Estuarine Research Reserve System (NERRS) mission is to enhance public awareness and understanding of estuarine areas and provide suitable opportunities for public education and interpretation. Reserve educators have created an established education program, coordinating many informal science programs for K-12 students, teachers, and the general public. CBNERR educators use technology to enhance field investigations with K-12 students through the use of many different tools (Figure 4). Students participating in field investigations may use the technology in any or all of the three phases of a MWEE, and by using the same tools as scientists, are gaining exposure to possible careers in the future.

Technology Use in the Preparation Phase

In the preparation phase of a MWEE, students develop their investigative question and complete background research to prepare for the main outdoor field experience. This component could involve outdoor experiences, but typically takes place in the classroom and prepares students for outdoor investigations. For students that may not be comfortable in the field, it is beneficial to introduce them to the location as much as possible. This allows students to focus more on data collection in the field, and decreases the distraction of being in a new environment.

Students may not be familiar with particular estuarine habitat types, and it may not be possible to take students to research locations. Therefore, we prepare students for field experiences in part through the use of videos and virtual reality. Videos and virtual reality can transport students virtually to a location they otherwise would not be able to visit. There are endless opportunities for this, but we recommend several that relate very well with Chesapeake Bay MWEEs. For general estuary information, we suggest the NERRS Estuary Education website (https://coast.noaa.gov/estuaries/). This site provides introductory videos on topics such as watersheds, estuaries, animals and plants, food webs, etc. In addition to watching videos, students could make their own informative video to share with their classmates, or students could contact local experts who can video chat and answer questions in order to shape their investigation.

A further step would be to use virtual reality, transporting students virtually to key habitats they are discussing in class through the use of Google Cardboard (https://vr.google.com/cardboard/) or similar technology. Educators or field staff collects video while conducting research in the field, and then we share those videos, including sound, with our students. Being transported to the salt marsh in this way, with the ability to hear the birds, and explore the habitat as if you were standing there, impacts students for a very low cost. We suggest using the Google Cardboard virtual reality viewers, and cell phones (or iPod touches) that schools or students may already have to view the content.

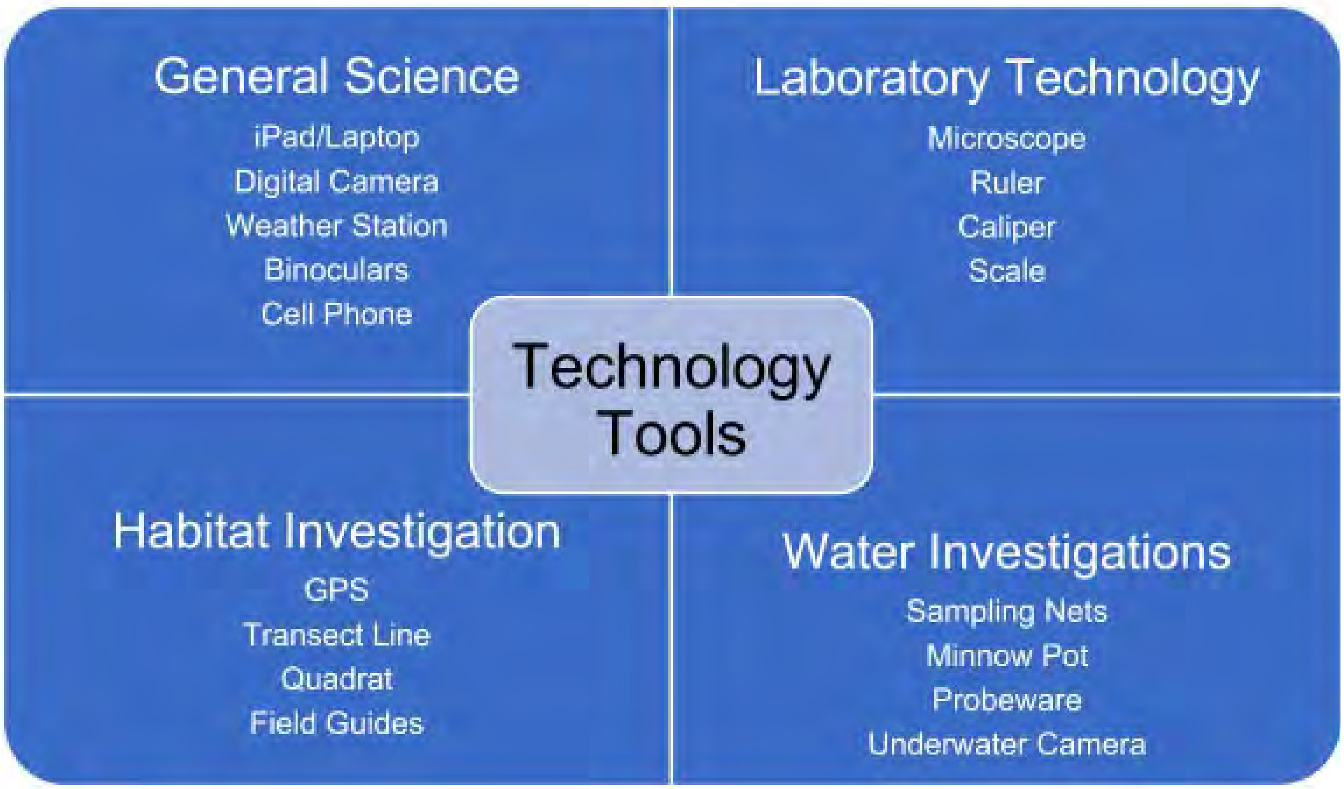


Figure 4: Example of technology used by CBNERR educators

Action Phase Technology

During the action phase of a MWEE, students conduct field science investigations, just as a scientist would. Students participate in one or more outdoor experiences where they make observations, collect and analyze data, and participate in restoration projects to better their local environment. Technology is an easy fit during the action phase, and is typically used to capture both qualitative (images, sounds, interviews of experts in the field, etc) and quantitative (measurements, distances, time, etc) data.

Figure 5: Overview of the process

Throughout the Virginia SOL's, there are several key references to technology to support science investigations. Field experiences at the Reserve typically focus on the SOL's that coincide with our own mission, including:

- 4.6 The student will investigate and understand how weather conditions and phenomena occur and can be predicted. Key concepts include use of weather measurements and weather phenomena to make weather predictions.

- 6.7 The student will investigate and understand the natural processes and human interactions that affect watershed systems. Key concepts include water monitoring and analysis using field equipment including hand-held technology.

- LS.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, and probeware are used to gather data.

Water quality testing is likely the most common type of field investigation conducted by teachers in Virginia. However, the collection, analysis, and sharing of this data needs to be highly structured, and requires background preparation. Time should be allotted to prepare students to use the equipment and parameters prior to time in the field. Students may be new to reading graphs, creating data tables and graphs, or analyzing data. A good first step is the National Oceanic and Atmospheric Administration

(NOAA) Data in the Classroom website (https://dataintheclassroom.noaa.gov/). The Water Quality module steps students, and teachers, through the basics of reading one parameter in graphical format, understanding how different water quality factors influence each other, and finally ending in creating personalized investigative questions.

As students are more familiar with graphing and the common parameters typically collected in an estuarine setting (pH, temperature, dissolved oxygen, salinity, and turbidity), students can collect their own data in support of their research question. At CBNERR, water quality data is collected using a variety of tools, as well as structured data sheets to keep students on task and organized. (Appendix 1). While we use Pasco probeware (https://www. pasco.com/GLX), all field data can be collected with lesser expensive technology such as thermometers, hydrometers, and tablet tests, typically revealing similar results to the more expensive technology.

Finally, it is important to ensure a feeling of purpose with students collecting water quality data. The data must be used to answer their investigative question, which may require repeated water quality testing throughout the year or at various locations. Another way to make data collection more meaningful is to share the data with others, also typical of what scientists would do. We suggest Chesapeake Bay FieldScope, a National Geographic tool (http://www.fieldscope.org/), or any other citizen science monitoring project, such as World Water Monitoring Day (http://www.worldwatermonitoringday.org/), to submit data collected by the students for use and comparison by others. Advanced students may also benefit from comparing their data to that collected by scientists or to data from other locations, using websites such as (www.vecos.org, https://coast.noaa.gov/swmp/, and https://buoybay.noaa.gov). Several of these websites also contain curriculum that accompany the data.

Technology for Reflection Phase

In the reflection phase, students refocus on the question, problem or issue; analyze the conclusions reached; evaluate the results; and assess the activity and student learning. Reflective thinking is part of the critical thinking process, specifically the process of analyzing and making judgments about what has happened (Lin, Hmelo, Kinzer, & Secules, 1999). Through reflective thinking, learners may assess what they know, what they need to know and how to bridge the gap. Using the research by Lin et al. (1999), the University of

Figure 6: Students reflect on their findings

Hawaii produced a Reflective Thinking document which states the importance of reflective thinking in middle school students as being particularly valuable as it can support them in their transition between childhood and adulthood (http://www.hawaii.edu/intlrel/pols382/Reflective%20Thinking%20-%20 UH/reflection.html). Reflective thinking can provide middle school students with the skills to mentally process learning experiences, identify what they learned, modify their understanding of the topic based on new information and experiences and transfer their learning to other situations. Warner, Eames, and Irving (2014) suggest that social media may be the best venue for this reflection, in order to allow for the continuation from learning about the environment and having positive attitudes about the environment, to taking action, which is something that CBNERR also strives to promote.

To support reflective thinking on CBNERR field experiences, students complete a number of different activities based on age group. For example, elementary students studying the salt marsh complete a mural of the habitat studies, with each student responsible for one animal or plant on the mural. (Figure 7) Students write one fact that they learned on the inside of the image, and one thing they enjoyed about the experience on the outside edge of the image, and then add to the full mural. Murals are displayed at the school to share with other students. In another example of reflection products, high school students present their findings on sea level rise impacts to their community both to their classmates and potentially to local stakeholders.

Figure 7: Students make a mural based off their findings

For some students, technology can be used specifically in their reflection phase. Technology allows students to focus on actions post-field experience, which may not happen otherwise (Agyeman, 2006). For example, students can present their findings of a year-long MWEE regarding the Chesapeake Bay's health and how to help through social media. Twitter provides a platform for each student to create a concise message of what they have learned and how they plan to help the Bay. *Figure 8* Students can even tag many federal and state agencies, local non-profits, and even their local representatives to draw attention to the issues (and solutions) to help the Chesapeake Bay.

Figure 8: Student prepare Tweets

Students use a common hashtag in order to track the messages, and CBNERR educators create a Storify (www.storify.com) of images, tweets, and background information about the entire process. An example from 2013 can be found here: https://storify.com/cbnerr/queens-lake-bwet-twitter.

The results from participation in this program can be seen in their post-assessment. Of the seven schools participating in the same program in 2013, this school was the only school to do this type of reflection, and was also in the top three for the highest average post-assessment score. They also had the greatest percent increase of all the schools at 58% between pre and post-assessments. Giving the students time to reflect on the MWEE allowed for very powerful responses, even encouraging teachers and administration to look for funding to continue this project. One 7th grade student wrote,

> ***Yes, I definitely feel that other students should have the opportunity to participate in this program. I really liked it, because we are learning about the Bay, not just in our classroom, but in real life, hands-on, experiencing it. I think that this program could also make more people more interested in/worried about protecting the environment, and especially the Bay (which is something I am very passionate about). Plus it was a lot of fun!***

Best Practices

The examples described above show different options for integrating technology into the phases of a MWEE. It is also likely that common technology, such as digital photography, mobile devices, apps, webcams, GPS, and probeware, can support field investigations, no matter the location or topic. For more ideas on technology options, review Technology for Field Investigations: Scientist-Driven Technology Practices (http://www.fishwildlife.org/files/Technology_for Field_Investigations-CE_Strategy.pdf), a product of the Association of Fish and Wildlife Agencies' North American Conservation Education Strategy.

Lastly, remember that technology should directly support your learning goals, and should only be used if it is adding to your program in some way, either through efficiency or by completing a task that could not done another way. In summary, our best practices for technology integration for field investigations are:

- Start small
- Practice makes perfect
- Each student has a role,

continued

- A student“reporter”role can document your MWEE for future sharing
- Check out the options along the budget spectrum
- Technology can be used to differentiate
- Select your learning goals first, and your technology last
- Have fun

Appendix 1

Example Student Data Sheet

Field Data – VIMS Eastern Shore Lab, Wachapreague, VA – TEAM 1

SITE: ____________________________ Vessel Name: ____________________________

DATE: ____________________________ Data Recorder: ___________________________

LOCATION DESCRIPTION

Time: ____________________________

Latitude: ____

Longitude: ____

Physical Description of Site: ____

ATMOSPHERIC CONDITIONS

Air temperature (^oC) ____

Estimated cloud cover (%) ____

Current weather conditions ____

WATER CONDITIONS

Total depth (m) ____

Salinity (refractometer, ppt) ____

Salinity (hydrometer, ppt) ____

Temperature (^oC) ____

PH ____

DO (mg/l) ____

Turbidity (cm) ____

BIOLOGICAL DATA – ORGANISMS COLLECTED

____________________	____________________	____________________
____________________	____________________	____________________
____________________	____________________	____________________
____________________	____________________	____________________
____________________	____________________	____________________
____________________	____________________	____________________

References:

Agyeman, J. (2006). Action, experience, behaviour and technology: Why it's just not the same? *Environmental Education Research*, 12(3-4), 513-522.

Ardoin, N.M., Bowers, A.W., Roth, N.W., & Holthuis, N. (2016). Environmental education and K-12 student outcomes: A review and analysis of research. Manuscript submitted for publication. Retrieved from: *https://cdn.naaee.org/sites/ default/files/eeworks/files/k-12_student_key_findings.pdf.*

Bartosh, O. (2004). Environmental Education: Improving Student Achievement. Unpublished Master's Thesis, The Evergreen State College, Olympia, WA.

Broussard, S., Jones, S., Nielson, L., & Flanagan, C. (2001). Forest stewardship education: Fostering positive attitudes in urban youth. *Journal of Forestry*, 99(1), 37-42.

Chesapeake Bay Program Education Workgroup. (2014). The meaningful watershed educational experience. Chesapeake Bay Program, Annapolis, MD. Retrieved from: http://www.chesapeakebay.net/content/publications/cbp_12136.pdf.

Chesapeake Executive Council. (2000). Chesapeake 2000. Chesapeake Bay Program, Annapolis, MD. Retrieved from: http://www.chesapeakebay.net/channel_files/19193/chesapeake_2000.pdf.

Chesapeake Executive Council. (2014). Environmental literacy goals and outcomes. In Chesapeake Bay watershed agreement. Chesapeake Bay Program, Annapolis, MD. Retrieved from: http://www.chesapeakebay.net/documents/FI- NAL_Ches_Bay_Watershed_Agreement.withsignatures-HIres.pdf.

Hougham, R., Eitel, K., & Miller, B. (2015). Technology-enriched STEM investigations of place: Using technology to extend the senses and build connections to and between places in science education. *Journal of Geoscience Educatio*n, 63(2), 90-97.

Lin, X., Hmelo, C., Kinzer, C., & Secules, T. (1999). Designing technology to support reflection. *Educational Technology Research and Development,* 47(3), 43-62.

Louv, R. (2005). Last child in the woods: Saving our children from nature-deficit disorder. Chapel Hill, NC: *Algonquin Books*.

National Science Foundation. (2000). Environmental science and engineering for the 21st century (NSB 00-22). Arling- ton, VA: National Science Board Office. Retrieved from: www.nsf.gov/pubs/2000/nsb0022/start.htm.

The U.S. Senate, Office of the Press Secretary. (2011). Reed & Kirk introduce bipartisan "No Child Left Inside Act" [Press Release]. Retrieved from https://www.reed.senate.gov/news/releases/reed-and-kirk-introduce-bipartisan-no-child-left- inside-act.

Virginia Department of Education. (2010). Science standards of learning for Virginia public schools. Retrieved from: http://www.doe.virginia.gov/testing/sol/standards_docs/science/index.shtml.

Warner, A., Eames, C., & Irving, R. (2014). Using social media to reinforce environmental learning and action-taking for school students. *Journal of Environmental Education*, 4(2), 83-96.

Willis, J., Weiser, B., & Kirkwood, D. (2014). Bridging the gap: Meeting the needs of early childhood students by integrating technology and environmental education. *International Journal of Early Childhood Environmental Education*, 2(1), 140-155.

Integrating Inquiry into Informal STEM Experiences

Robbie L. Higdon, Ph.D, Assistant Professor, Department of Middle, Secondary, and Mathematics Education, James Madison University
Amanda Sawyer, Ph.D., Assistant Professor, Department of Middle, Secondary, and Mathematics Education, James Madison University

Abstract

Informal STEM (Science, Technology, Engineering and Math) experiences can very powerful and engaging encounters for K-5 students. However, these onetime events do not typically allow students to translate these encounters into deeper learning experiences. In addition, these learning experiences potentially enable students to develop misconceptions will limit their construction of long-term conceptual understanding of key scientific ideas. Therefore, we propose that meaningful STEM experiences can be implemented within any time period allotted by employing the components of the 4E x 2 Instructional Model (Marshall, 2007). We can also maximize the use of instructional time through the induction of multiple content areas shared across common themes such as measurement or properties of matter. The world does not operate in isolation; therefore, we cannot promote instruction that is presented in isolation. As we are stretched to achieve learning goals within the limits of the school day, teaching integrated content using a learning cycle model such as the 4E x 2 allows us to achieve these goals.

Integrating Inquiry into Informal STEM Experiences

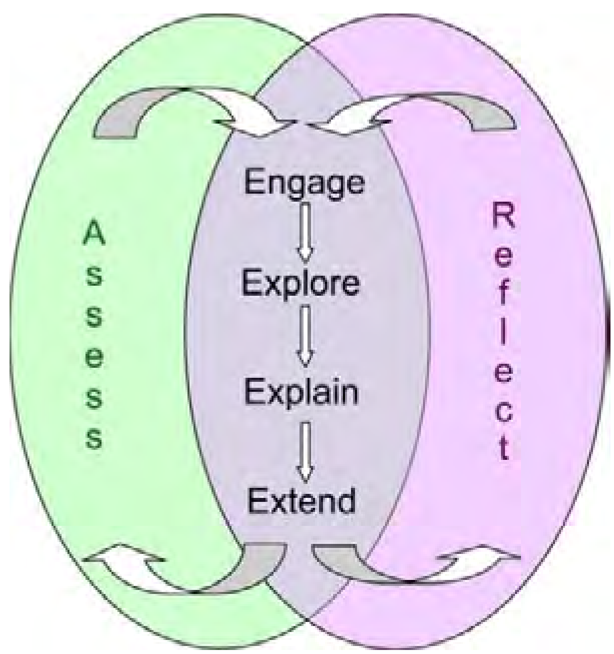
In our work with pre-service math and science teachers, we are often recruited to have our students present at informal science events such as STEM days or STEAM fairs. These events are typically a school day dedicated to STEM in which presenters provide mini-lessons multiple times to varying groups of students within a classroom setting or an after-school event in which families can rotate through learning stations. In order to provide a memorable experience for students within the given time restraints, presenters often provide flash-in-the-pan activities that immediately engage student interest such as watching the launch of bottle rockets, making slime, or dissecting owl pellets. However, these onetime events do not allow students to translate their encounters into a deeper learning experience as well as promotes STEM in isolation. In addition, these learning experiences potentially enable students to develop misconceptions will limit their construction of long-term conceptual understanding of key scientific ideas. Therefore, we propose that meaningful learning experiences can be implemented within any time period allotted by employing the components of the 4E x 2 Instructional Model. In essence, the model promotes students exploring their ideas before constructing an explanation for their concept allowing the development of deeper understanding and connections with cross-cutting science concepts.

The 4E x 2 Model-A Learning Cycle Approach

The lesson featured here uses the 4E × 2 instructional model (Marshall, 2007), which integrates three major learning constructs in an effort to foster deeper conceptual understanding: inquiry-based instruction, formative assessment, and reflective practice at each step of the pedagogical process (Dong, Marshall, & Wang, 2009). The 4E x 2 model builds upon previous research on existing models of learning that propose creating disequilibrium experiences for students in order to resolve misconceptions and promote full understanding. The core of this inquiry model is based on the premise that solid inquiry instruction necessitates that students are provided an opportunity to explore major ideas before an explanation from students or teacher occurs (Marshall, Crenshaw, & Higdon, 2013).

The implementation of the 4E x 2 Instructional Model gives teachers a concrete approach to routinely incorporate inquiry-based methods into any instructional exercise. The first step in the model is Engage, during which the learners' prior knowledge is activated and misconceptions are uncovered about the big ideas being presented in the lesson. The next step within the model, Explore, involves giving learners opportunities to investigate their ideas and conceptions uncovered in the previous phase in order to construct one's own understandings. The following step is Explain in which both the students and the teacher work in conjunction to construct meaning of the ideas formulated in the previous step. The final step is Extend, which involves students applying their recently constructed conceptions in new situations. This approach guides students to become more active participants in their learning resulting in deeper understanding and higher levels of mastery.

Figure 1: The 4E x 2 Instructional Model (Marshall, 2007)



The Activity

From this activity presented during a K-2 STEM day event, students were expected to gain an understanding that liquids flow to take shape of their container and how to distinguish between liquids and solids. These learning goals aligned with various math and science Virginia standards of learning within grades K-2. For example:

Content Area:	***SOL***	
Math	**K-9**	The student will compare two objects or events, using direct comparisons, according to one or more of the following attributes: length (longer, shorter), height (taller, shorter), weight (heavier, lighter), temperature (hotter, colder), volume (more, less), and time (longer, shorter).
Math	**1.10**	The student will use nonstandard units to measure and compare length, weight, and volume.
Science	**2.3**	The student will investigate and understand basic properties of solids, liquids, and gases.

Table 1: Aligned Virginia Standards of Learning

The activity began with the facilitators asking questions to the entire group to engage in the lesson. Students were shown four containers of varying heights and/or volume such as a 100 mL graduated cylinder, a 250 mL flask, and a 400 mL beaker. Each of these containers were filled with 100 mL of water tinted using food coloring. Students were asked, “Which container has the most liquid?” Students were then directed to vote by raising their hands for the container they chose. Then, the contents of each container were then poured into separate 400 mL beakers. Students were given the opportunity to explore their ideas as they were shown how each container actually held the same amount of liquid. Students were asked to share their observations of the liquids now being displayed in identical containers and then being poured back and forth between the original containers and the identical 400 mL beakers. They were asked questions such as “What did you observed when the liquids were poured into the different containers?” “What changes did you observe?”

At this point, the lesson transitioned into guiding the students towards the explanation that liquids flow to take shape of their container. Therefore they can be at different levels depending on the shape of the container. Students were asked, “So does each container have the same amount of liquid? Then why were they not on the same level in the first containers?” Students were asked to speculate and offer their explanations for their observations. At this point, students could articulate an understanding of the concept that liquid flows to take the shape of its container. Then, students were asked to extend their knowledge about the properties of a liquid and apply this during an activity. Students were given clear, plastic bags containing various substances such as rice, marbles, buttons, honey, and water. The instructor demonstrated how to move the bag around to show students how the substance flows in the bag. Students were asked to determine if it is a liquid or solid and then place the bags on different sides of the table accordingly.

The Promotion of Conceptual Understanding

This instructional activity provides students with concrete learning experiences rather than having them be passive recipients of the abstract world. Students are allowed explore concepts before having to construct their own meanings about the concept. Finally, students are given opportunities to apply their knowledge of the concepts and skills to new situations. From this experience, students are able to gain a richer understanding of the interactions of matter by manipulating concrete representations of abstract, microscopic processes. (Higdon, Marshall, and Taylor, 2014).

Student Responses

Throughout the lesson, the students energetically responded to questions posed by the pre-service teachers. When asked if the substance displayed in a clear, plastic bag was s a liquid or a solid, the K-2 students were able to correctly classify the substances. They were shown a bag containing dice followed by a bag of water and asked to explain the differences between the two substances. Students were able to respond that they could "pick up one of the dice but not the water." Next the students were shown a bag containing oil and asked to describe what they observed. Students were able to correctly label it as a liquid. Then, students were shown a bag containing honey and asked to describe how the honey differed from the other liquids. Students responded that it "moved differently than the other [liquids.]" Then students were asked, "Is this bag still a liquid?" They were able to state that it was a liquid because "it flowed in the bag."

Conclusion

For many pre-service teachers, it is very tempting to fall into the trap of "just doing a demonstration" when feeling pressed for time. However, meaningful learning experiences can be implemented in within any time period allotted by employing the components of the 4E x 2 model. In essence, having students explore their ideas before constructing an explanation for their ideas allows for the development of deeper understanding and connections with held conceptions. We can also maximize the use of instructional time through the induction of multiple content areas shared across common themes such as measurement or properties of matter. The world does not operate in isolation; therefore, we cannot promote instruction that is presented in isolation. As we are stretched to achieve learning goals within the limits of the school day, teaching integrated content using a learning cycle model such as the 4E x 2 allows us to achieve these goals.

References

Dong, L, Marshall, J, & Wang, J. (2009) A web-based collaboration environment for K-12 math and science teachers. Paper presented at the ASEE/IEEE Frontiers in Education Conference, San Antonio, TX.

Higdon, R., Marshall J., & Taylor, S. (2014). What's the matter? Looking beyond the macroscopic. *Science Scope*, 38(1), 80-85.

Marshall, J. (2007). 4E x 2 Instructional Model [Electronic Version]. Retrieved from *www.clemson.edu/iim*

Marshall, J., Crenshaw, K., & Higdon, R. (2012). Sunlight and seasons. *Science Scope*, 36(1), 54-60.

Vocabulary and Literacy Instruction Strategies

Janine D'Elia, M.Ed., NBCT, Physical and Earth Science Teacher Science, Department Chair, Salem Church Middle School
Rachel Hill, M.Ed., Life Science Teacher, Salem Church Middle School

Abstract

This paper highlights the various strategies for middle school science vocabulary usage, as presented at the Virginia Association of Science Teachers (VAST) conference in November of 2017. Strategies shared are: Mission Definition, a sorting card game; Vocabulary Bags, a strategic way of grouping vocabulary so that students make connections between the words; Vocabulary Circuits, an interactive way for students to practice vocabulary that is self-checking; Pre-teaching vocabulary with images- choosing images that will allow students to think critically and use inquiry when creating definitions. The strategies presented have been teacher-tested, student-approved and have shown to promote retention of terms.

Choosing Words

Science is a vocabulary-heavy content area. Many students struggle with the acquisition and retention of vocabulary. Teachers may have trouble finding engaging and relevant ways to teach or reinforce the language of science. We, the presenters- Janine D'Elia, a 17-year veteran science teacher, and Rachel Hill, a 4-year veteran, have come up with many strategies in our teaching experience that have increased our success in the classroom. In the three years that we have implemented these strategies, our Standards of Learning (SOL) scores in science have increased by over 10 percentage points. We have seen that students who are familiar with and can appropriately use content vocabulary feel better prepared for assessments, and can understand science at a deeper level. The strategies highlighted in detail are Mission Definition, Vocabulary Bags, Circuits and Pre-Teaching Vocabulary with Images.

Mission Definition

The first strategy that we implemented was Mission Definition. In Mission Definition, the teacher creates a set of cards with a vocabulary word and a definition in a matching set. Definitions are printed on separate cards from the vocabulary word or phrase. For example, a card would say "mitochondria", and the match would say “the organelle that makes energy; the power plant of the cell”. Other organelle cards would be made as part of the unit.

Teachers could use the vocabulary card set in many ways. If the teacher chooses to hand out one card per student, pairing up with the correct partner is encouraged by walking around the room. Make the activity more challenging by not allowing students to see what is written on their own card. One paired, teachers can have students physically sort themselves into groups or sequences based on how they think the words are related. Teachers can also make many sets of the cards and have the students work as cooperative teams. One could also have a vocabulary station as a review for an assessment, with the cards that had previously been matched as a whole class.

Once the cards are made, they can be laminated for long term use. Donohue & Buck (2017) described similar experiences with vocabulary and found that sorting contextual definitions helped students’ vocabulary acquisition and retention. Mission Definition would not be used as a way to teach the words the first time. We would use this strategy to review or reinforce before an assessment.

Vocabulary Bags

A second strategy that we use is Vocabulary Bags. We make vocabulary card sets much like the ones described above, but we group them in brown bags as complementary sets. We provide students with worksheets that have missing words or definitions that they then have to fill in using the bags. For example, the words ecosystem, community, population and organism would be in one bag with their matching definitions. Students have to sort the cards to identify the correct term and definition to fill in their worksheet. A second example would be a bag with work, force, speed, and velocity. We choose groups of words that students have trouble differentiating. Showing students that they are related, since they are in the same bag, but different because all of the words mean different things, has been rewarding. This technique builds students’ confidence by allowing them to use prior knowledge and context clues to match the definitions. Teachers can set a timer for each bag, so that students pass the bag, or rotate to a new bag every 3 to 4 minutes.

Freeing up the teacher to facilitate and engage individual or small groups of students in relevant scientific discourse is an effective way to have students practicing vocabulary. You can even use this technique to introduce vocabulary to students. If you choose to introduce new vocabulary, stick with two to three pairs per bag. Vocabulary bags are an excellent way of reviewing life and Earth science content for the Eighth Grade SOL test. Teachers can challenge students to sort an entire unit of cards at a time throughout the year for a spiral review.

Circuts

Figure 1

Vocabulary circuits are a fun way to practice vocabulary in an active way. Each circuit card has a vocabulary word at the top and a non-matching definition at the bottom. The student reads the bottom of the card and circulates the room for the card with the appropriate word at the top. For example, if a student started with the card "Thermometer" on top, and "Measures mass in grams" on the bottom, the student would look for the next card that would have "Triple beam balance" at the top. The bottom of card 2 would tell the student where to go next. The purpose of a circuit is to get back to the seat at which the student started. The student referenced above would end the activity with a card that has the definition "Measures temperature" and he would return to his seat. While the student searches the room for the matching definition he leaves the printed card on his desk. The only thing a student walks around with is his answer sheet. The student should get back to his seat in as many moves as there are cards, and the teacher can easily assess who understands the newly acquired vocabulary and who ends up at the wrong seat. *Figure 1* is an example of how a teacher would structure circuit cards on laboratory tools.

Pre-Teaching Vocabulary

The strategies above discuss ways to reinforce known vocabulary. What about a creative way to teach new vocabulary? We have developed ways to pre-teach vocabulary before a unit which in turn makes students feel more successful as the unit progresses. A fun way that has shown great success is using pictures and diagrams to teach words. When teaching heat transfer, we hand out a set of cards with diagrams and images on them that convey radiation, convection and conduction. *Figure 2* The images are chosen intentionally with a purpose in mind. The convection cards all have circulating arrows. The radiation cards all have electromagnetic waves demonstrating heat transfer. The conduction cards all have two objects in close contact. Students are told that there are a certain number of cards for each of the three topics and that they have to sort the images into piles using commonalities. The students use inquiry to create a definition of the three vocabulary words, before the lesson is taught. When students are given ownership and the freedom to create answers, they tend to recall the information better on assessments and performances. This builds student efficacy and confidence in scientific literacy, which can lead to better performance.

Pictures and images provide cues for all learners. When one of our teachers had a visually impaired student, he had the cards labeled in Braille with Braille labeling tape to ensure access for all students. A 3-D pen can also be used to make basic drawings of the concepts for a visually impaired student. Using pictures to help students learn and use vocabulary assists all students but would allow greater access of the materials for students with disabilities and English-language learners. Gersten & Baker (2000) noted that adding visuals for ELL students encourages retention of vocabulary. Concept maps and other diagrams could be provided in addition to the images.

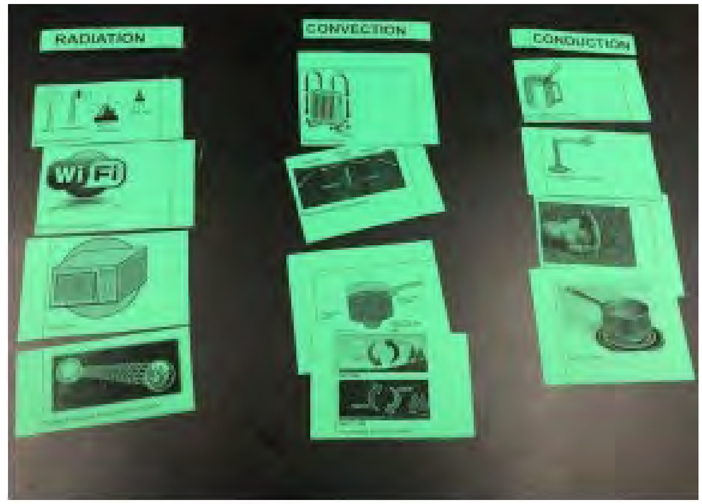


Figure 2

Conclusions

Students learn vocabulary best by making connections among the words (Nagy, 1988, as cited in Nixon & Fishback, 2009). Students given multiple experiences with many words have greater success (Graves, 2016). The above strategies help science teachers teach, reinforce and review science vocabulary with all levels of students. The greater the access to material, the more likely the student will retain and be able to use scientific vocabulary which leads to greater scientific thinking.

The strategies listed above will encourage collaboration and group work. Teachers can decide if strategies would work best in pairs or groups, but all allow cooperative thinking which facilitates student learning. The field of science is almost a different language, and can be difficult for all readers to understand, especially struggling readers. Allowing students to discuss, and work hands-on with vocabulary to make connections and visualize concepts is one way that we can strengthen students' literacy in science.

References

Donohue, K., & Buck, G. 2017. Swimming in new vocabulary. *Science and Children*, 55 (3), 32-37.

Gersten, R., & Baker, S. 2000. What we know about effective instructional strategies for English-language learners. *Exceptional Children*, 66(4), 454-470.

Graves, M.F. 2016. The vocabulary book: *Learning and instruction*. New York: Teachers College Press.

Nixon, S., & Fishback, J. 2009. Enhancing comprehension and retention of vocabulary concepts through small-group discussion: Probing for connections among key terms. *Journal of College Science Teaching*, 38(5), 18-21.

The Magic of Science:
Using Disequilibrium to Engage Learners

Robert M. Ellis, B.A., Physical Science Teacher, South County Middle School, Lorton, VA

Have you ever thought about using magic tricks to explain science principles in your classroom? You don't have to be a "magician" to learn and use a few tricks that can arouse curiosity, stimulate critical thinking, and increase student engagement. At the Virginia Association of Science Teachers (VAST) 2017 Professional Development Institute (PDI), I showed 15 magical affects you can use in your classroom. Some were demonstrations, and some allowed "hands on" student explorations. All effects correlated to scientific principles, the Virginia Standards of Learning, and followed laboratory safety rules.

Figure 1: Robert Ellis

The compatibility of science and magic is not new. Magicians routinely employed scientific principles long before the general public realized their deceptions were in fact the application of science. For example, in the 1850s electromagnetism was used by the famous magician, Jean-Eugène Robert-Houdin with his "Light and Heavy Chest" (England, J. 2015). One of my treasures is a book written in 1920 on "Chemical Magic". Some of those demonstrations are still used, and you may have seen some in your college chemistry courses.

> ***I only do magic in class when it provides a graphic example and safely teaches the content goals. If I don't see a clear link to the Science Standards of Learning, I don't perform the effect.***

Teachers have used magic to capture attention and build critical thinking for years. There have been many ideas published on magical effects for the classroom by magicians like Martin Gardner, Robert Friedhoffer, and Walter Gibson. One of the best books for educators is "Magic and Showmanship for Teachers", by Alan J. McCormack. It is a wonderful resource on how to perform and when to use tricks, and includes a wealth of student activities. Of course, another resource for learning to use magic in the classroom is online. Today, a search on the Internet for "teaching science magic" will turn up an extensive number of hits. If you are lucky enough to be close to a real magic shop, visit! You can talk with magic experts, buy magic tricks, and learn how to perform like a professional.

There are two ways I use magic in class: demonstrating a science principle, and providing "hands-on" experience. I only do magic in class when it provides a graphic example and safely teaches the content goals. If I don't see a clear link to the Science Standards of Learning, I don't perform the effect. Outside of class, I use magic to build relationships and entertain. During lunch duty, I perform magic tricks to reward good student behavior such as cleaning tables. These can include card or mind reading tricks which are not "standards-based".

Here are some recommendations for any demonstration. When I decide to use an effect, it must reinforce the Standards of Learning, and follow our school system's safety protocols. I practice in front of a mirror until I'm satisfied the effect will work for the students. Practice what you will say, and be aware of how much time you have. Doing this will give you confidence, and make you a legend.

I find all students enjoy and can learn from magic. Magician and educator Kevin Spencer wrote and produced a magic course for students called Hocus Focus. He wrote it for all students, including those with special needs. A few years ago, I purchased the course with a small grant from my Parent Teacher Student Organization. Since then I have used it with my after school Magic of Science Club which is open to seventh and eighth graders. Kevin produced eleven easy to follow lessons in video and text. When students master the lessons, I present them with a certificate.

Our school has a self-contained program for students with intellectual disabilities. Students may have autism, cognitive impairments, or other severe disabilities. When The Magic of Science club members have mastered four or five of the effects, we visit our low incidence students to demonstrate and teach some basic tricks. It's very rewarding to see the kids interacting. As students work through procedures and overcome obstacles, their confidence and self-esteem increases. Kevin's program is data driven, and his research documents how magic can benefit all students (Spencer 2012).

Before I show you some effects, here are some facts. To begin, there really is a magician's code of ethics. It states magicians are not allowed to expose magic secrets to the public. It doesn't mean you can't use "Fortune Fish" moving on your hand to teach about polymers. But, you shouldn't spoil the delight of the audience by telling them how a trick works. It's also important to protect professionals who make a living performing, inventing, and building magic tricks.

Keep something in mind as you do magic. If you do tricks to fool people, then you are probably making people feel foolish. Magic is a wonderful tool that can either excite a student's curiosity, or cause embarrassment in front of peers. So when you do magic, please use it to bring enjoyment to your students as you embark on your own journey of teaching the Magic of Science.

Here are two of the 8th grade level effects I taught at the 2017 VAST PDI. These are not meant to replace a student laboratory experience. They do allow you to share the fun of applying scientific principles, while developing reasoning skills and focusing attention. I summarized some concepts, but you may want to review the essential knowledge, skills and processes for your program.

Please, remember to follow all the safety rules when doing any demonstrations or lab activities.

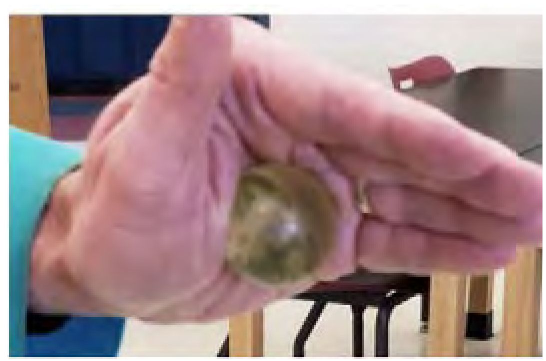
Gravity Defying Erlenmeyer Flask

Virginia Standard of Learning PS.10 Force/Motion gravity/friction
Skill level: Beginner

Materials: flask, ruler & ball

Overview: As you walk around the room explaining gravity, you hold up an empty, 1 liter, opaque flask, and a ruler. To add mystery and grab students' attention, I might start by saying there are certain areas of the room where "gravity is acting weird". I place the ruler in the flask, and carefully release the flask while holding the ruler. This is where a little showmanship goes a long way. Try to convey your own surprise as you see the flask remaining in the air. Students will be amazed! The secret is to surreptitiously place a bouncy ball into the flask. The ball should be a little smaller than the opening so the ruler gets stuck when both are removed at the same time.

Materials: 1 Liter flask (covered in tape or painted), ruler, bouncy ball.



Step 1: Palming and holding the flask

Step 1) Palm the ball in the hand holding the flask. Show the flask and ruler. Palming is a basic magician skill. Place the ball in your open palm and partially close the hand. The ball will remain held, even when you turn your hand over or hold other objects.

Step 2) Drop the ball into the flask, making sure no one sees the ball go into the flask. Place the ruler in the flask and turn it upside down. Gently tug on the ruler to "lock" it with the ball using friction. The clear flask is shown below so you can see how it works.

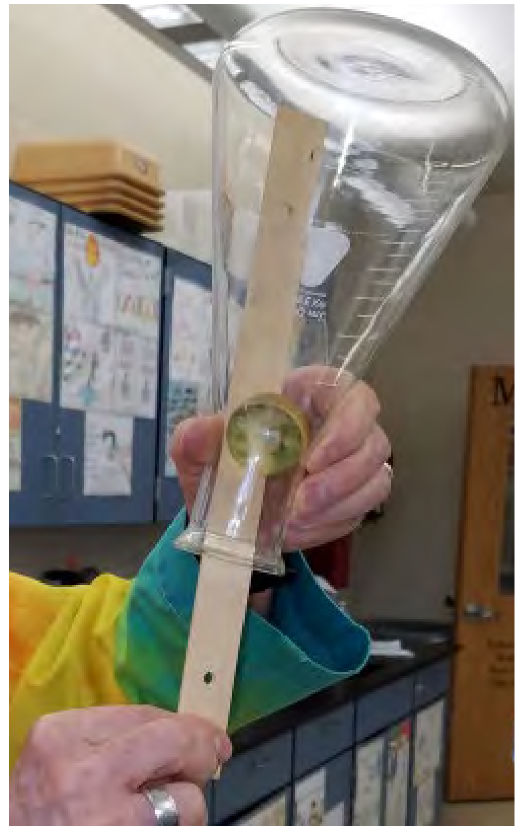
Step 3) Turn the flask upright and carefully let go while holding the ruler. Proclaim your astonishment at overcoming the force of gravity!

To retrieve the ball:
Step 4) Hold the flask while pushing the ruler down to release the ball. Remove the ruler. Turn the flask upside down and re-palm the ball.

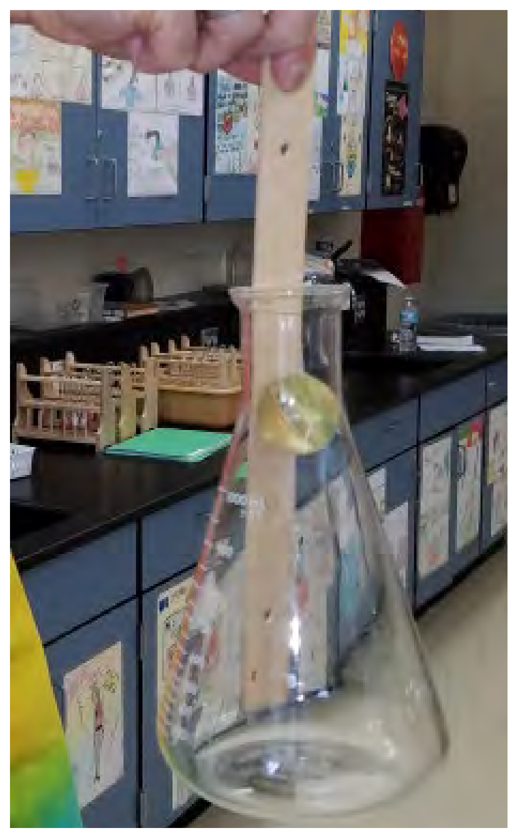
Step 5) Hand the flask and ruler to a student, but keep the ball hidden. Let the student(s) try to replicate the trick. Remember to practice proper safety when using glassware.

Your entire class will be mystified! When students say there is something inside the flask, I let them inspect it while I keep the ball hidden in my hand. I guide the discussion by asking questions about some force (friction?) which is opposite and equal to the gravitational force pulling down on the flask.

Concepts/activity: I got this idea over 20 years ago from an old trick with various names like The Genii Vase, Prayer Vase, or The Floating Bottle. It's suitable when reviewing or introducing forces (a push or a pull), or Newton's Laws. The force pulling the flask toward Earth is gravity, and is



Step 2: Locking the Ball and ruler



Step 3: Overcome gravity!

measured in Newtons (N). You might have students calculate the flask's weight before or might have students calculate the flask's weight before or after your demonstration. A one liter flask has a mass of about 0.3 kilograms. Newton's second law of motion says F=ma. So you can convert kg to N by multiplying by Earth's acceleration, 9.8 m/s2. Example: 0.3 kg x 9.8 m/s2 = 2.9 N. You can also discuss how Newton's laws tell us that the flask should be falling when you let go. A force (gravity) is pulling down, therefore there must be an opposite & equal force present. You can let students brainstorm in lab groups on how the force stopping the fall is created. I have heard answers like "glue", "magnets", "hooks", "Velcro", and very uncommonly, "a ball"!


Step 5: Re-palm the ball and allow inspection

In over 20 years I never had a student drop it, but just in case, I am always prepared to catch the flask. If you are concerned about breakage, cover the flask in tape, or use an unbreakable bottle.

Appearing 4 Foot Long Pencil

Virginia Standard of Learning PS.5 **Physical changes/conservation of mass**

Skill level: Beginner

Overview: The teacher reaches into a box or bag and unbelievably produces a 4 foot long pencil which is much larger than the container.

Materials: Box or bag about the size of a lunch-box, 3 dozen pencils, 4 feet "Appearing Pencil"
This is a commercial trick, so I won't reveal the secret. But, it is affordable and creates a big visual impact. I will give you a hint that it is hollow. There are various sizes, even an 8 foot long pole I use for stage shows.

In the lab I show a wooden box on a table. I say how disappointed I am that some students don't bring pencils to class, and don't return the ones I loan them. I say "I have one in this bag no one will be able to take out of the room". As I'm speaking, I pull out a couple of handfuls of regular pencils, and then pull out a huge 4 foot long pencil. To purchase the "pencil", do an Internet search for appearing pencil, or staff, or pole. The best way to buy the pencil is to visit a real magic store. There, you can buy the trick, and the sales person will teach you how to perform the effect.

Concepts/activity: Matter is anything with mass and volume. Volume is a measurement of space. The atoms and molecules in matter can be rearranged in a chemical change, resulting in new chemical properties. A physical change results in a different form, and the chemical composition remains the same. The law of conservation of mass tells us that matter, (like the giant pencil), could not have been created in a physical or chemical change, (thanks Lavoisier!). After the demonstration have student groups answer the following three questions: 1) Why might it seem like "magic" when the big pencil appears? 2) What is volume and what role does volume play in the trick? 3) Could the material of the "pencil" have gone through either a chemical or physical change?

Over the years, I have complied dozens of effects aligned to 6th through 8th grades science standards. I am looking forward to sharing more of them at the 2018 and future VAST PDIs. For questions, please contact me via email at rmellis@fcps.edu.

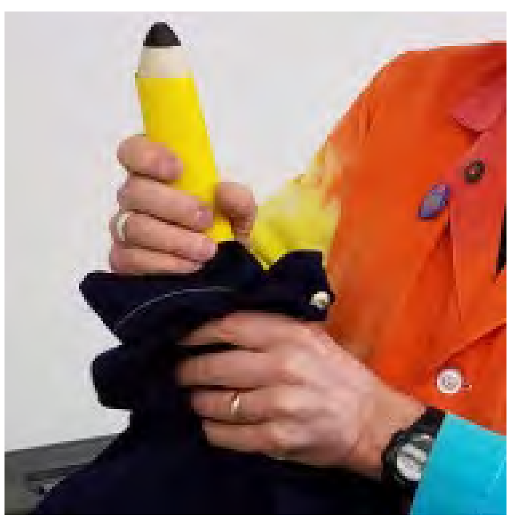


Figure 7: The appearing 4' long pencil

References

England, J. (2015, May). The Magic of Magnets. *Cosmos.* Retrieved from https://cosmosmagazine.com/technology/magic-magnets

McCormack, A.J. (1990). *Magic and Showmanship for Teachers*. Louisville, KY: Showboard

Spencer, K. (2012). Hocus Focus: Evaluating the pedagogical implications of integrating magic tricks in classroom instruction. *Journal of the International Society for Teacher Education*, 16(2) 45-54. Retrieved from http://www.hocusfocuseducation.com/wp-content/uploads/2013/01/JISfTE.pdf

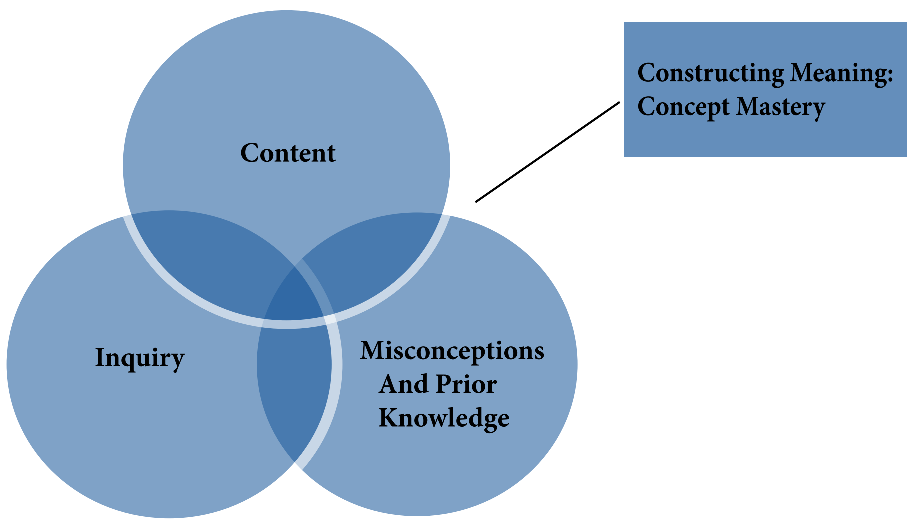
Developing Student Understanding in Science: The Three Rings of Learning

Anne Petersen, Ph.D., Science Coordinator at Virginia Department of Education

At the beginning of the year, a teacher is handed a list of student names, a curriculum, and some materials and tools. Nine months later, it is expected the product will be a room full of students that have mastered the mandated science content and are conceptually ready to move on to the next grade. If only it were so easy.

Developing students in science can be a three-ring circus that includes juggling content, prior learning, misconceptions, and science process skills. At the same time, teachers must maintain a safe but engaging learning environment that encourages inquiry learning. With many heterogeneously grouped science classrooms that have a large number of students, this can be a challenge. In order to meet this challenge, teachers must first determine what the students already know and the misconceptions that exist concerning the topic at hand in order to help students construct an understanding of new concepts (Campbell, Schwartz, & Winslow, 2016). New content, steeped in the correct foundation of prior knowledge and taught through the lens of inquiry learning, can lead to all students obtaining content knowledge in the classroom.

Figure1: The Three Ring Circus Of Student Mastery.



In order to help students, construct conceptual understanding the teacher first must determine where each student is at in terms of prior learning for each concept area. Unfortunately, depending on the students' prior experiences in elementary school, some may come in with science process skills and a rich content knowledge while others may have been exposed to science process skills and science content on a very limited scale (Petersen, 2014). In the 2011-12 school year, the average elementary class and teacher responsible for teaching all core subjects spent 2.6 hours per week on science education (Institute of Education Sciences, 2012). With the increased accountability of elementary schools in the areas of language arts and mathematics, science instruction has experienced a drop in the average instructional time allotted to teachers during the regular school day (Fulp, 2007). Gaps in student understanding of concepts and science process skills exist in many classrooms.

As educators, how can enable a very diverse group of students, in terms of science background, in a way that will enable all to succeed? First, the teacher needs to determine prior misconceptions. These misconceptions are ideas that students have developed about the natural world that are based on incorrect information. The teacher's role is to help the student reconstruct their ideas in a way that makes sense of the phenomena versus just telling the student the correct concept and expecting students to build understanding (Campbell, et al, 2016). How can a teacher do this?

- Engage students in their own ideas and experiences with a phenomenon
- Allow students to discuss and support the ideas
- Offer your ideas of the concept

Once the teacher has a clearer picture of the misconceptions, the students can investigate the concept using inquiry learning. Informing students of the misconception and the corrected version of the concept does not allow many students to develop and internalize the correct conceptual understanding. Instead, students need to use evidence built on science content to develop a foundation for understanding. Inquiry learning, with the teacher as a facilitator, allows students an environment to develop the concepts. Inquiry learning is the scientific process of active exploration by which students use critical, logical, and creative-thinking skills to study the natural world. This is done by generating questions, choosing a course of action and carrying the procedures of an investigation, and gathering and recording data through observation and instrumentation to draw appropriate conclusions. In the classroom, inquiry learning can be done through developing:

- Laboratory investigations
- Discrepant events
- Data analysis

After the student has been introduced to the concept through the inquiry learning laboratory or activity, the teacher facilitates the process of constructing meaning. Constructing meaning is the process of connecting prior understanding to new experiences through modifying and accommodating previously held beliefs and conceptual knowledge to construct new knowledge. There are many methods for providing new content for students to augment what was learned through inquiry. This may be direct instruction, student research opportunities, videos, or the use of literature; the methodology for providing new content to your students depends on the grade level and the learners. Once the content has been taught, the role of the teacher is to help students reshape their misconceptions to create an accurate science conceptual foundation. This can be accomplished as students:

- explain the information in one's own words, comprehend how the information is related to other key facts, and suggest additional interpretations of its meaning or importance;

- apply the facts and principles to new problems or situations, recognizing what information is required for a particular situation, using the information to explain new phenomena, and determining when there are exceptions;

- analyze the underlying details of important facts and principles, recognizing the key relations and patterns that are not always readily visible;

- arrange and combine important facts, principles, and other information to produce a new idea, plan, procedure, or product;

- make judgments about information in terms of its accuracy, precision, consistency, or effectiveness; and

- help students construct a model of the concept through discourse and through investigation.

Developing concept mastery with students in the classroom goes far beyond exposing students to new information. Teachers must become jugglers as they juggle prior knowledge, misconceptions, and new content in a way that leads to student understanding and concept mastery.

References

Cambell, T., Schwartz, C., and Windschitl, M. (2016). What we call misconceptions may be necessary stepping-stones toward making sense of the world. The Science Teacher, 69-74.

Fulp, S. (2007). 2000 Survey of science and math education: The Science Of Elementary School Teaching.

Institute of Education Sciences (2012). Schools and staffing survey. Retrieved from http://nces.ed.gov/surveys/sass/.

Petersen, A. (2014). Females and STEM: Determining the K-12 experiences that influenced women to pursue STEM fields.