Pre-service Teachers’ Use of Visualizations in the Science Classroom: A Case Study

Brooke A. Whitworth & Jennifer L. Chiu

Scientific visualizations of phenomena can enhance the way learners understand scientific concepts (Honey & Hilton, 2011). Scientific concepts can be abstract and difficult for students to understand and visualizations can help make these abstract concepts more concrete for students. For example, chemistry students often struggle with understanding how atoms bond since they cannot directly see atoms. Using a visualization to show students how the electrons are shared or transferred can help students understand these abstract concepts. In addition, many visualizations are freely available online and can be a key element to maintain quality science instruction with limited resources.

Creating Quality Science Programs in Preschools

Heather Newton & Jenny Sue Flannagan

Curiosity, along with a thousand questions, is the start to a preschooler’s journey as they begin to explore the world of science. As educators, it is our job to stimulate and provide experiences that will allow children to grow into emerging young scientists. One of the struggles early childhood programs face is budget constraints and the ability to provide resources on a “shoestring budget”. Early childhood teachers are left with minimal resources at times and thinking outside the box takes on a whole new perspective. All you want to do is deliver that amazing science lesson that is sure to capture the children’s hearts, but there isn’t any money left. Partnering with community organizations is a great way to supplement resources for providing a well-planned and exceptional unit on science that will leave children talking and asking a lot more questions.

Stone Soup Anyone? Using Service-Learning Pedagogy to Promote STEM

Erin Burke Brown, Lynn E. Pelco, Suzanne Kirk, Holly Houtz, Anne Wright, & John Speich

Service-learning provides opportunities for science educators to gain access to community resources, enhance student learning outcomes, and assist with providing solutions to community problems. This article will explore how GreenSTEM@VCU is training middle school teachers in Virginia to use service-learning projects to facilitate the effective implementation of STEM curriculum.

www.vsrn.org
An internet gateway connecting teachers and students with scientists across Virginia
**Changing Students’ Perceptions of Scientists: Ideas for Classroom Teachers**

*Peter Sheldon, Tatiana Gilstrap, & Peggy Schimmoeller*

Many have discussed problems in the way we educate students in the sciences as a reason that we have a shortage of scientists. Science is often perceived as the difficult, lonely pursuit of white males in lab coats. This study examined how children perceive scientists. Children ranging in age from 8 to 12 years old were asked to draw a picture of a scientist. Drawings were coded using criteria developed by Chambers (1993) in his *Draw-A-Scientist* test. Examination of the data revealed that similar to Chambers’ findings, children held very stereotypical beliefs about scientists and what scientists do. After a week-long science camp where teachers made efforts to refer to the students as scientists, where the children interacted with practicing scientists of both sexes from different fields, and where the children participated in hands-on science experiments, the drawings changed to show fewer stereotypes when compared to their pretest images.

**Implementing Engineering in Instructional Strategies: The NASA Simulation-Based Engineering and Science Teacher Professional Development Program**

*Lori Andersen & Behzad Raiszedah*

Engineering practices occupy a prominent position in the new *Framework for K-12 Science Education* (National Research Council, 2012); however, these practices are unknown to many science teachers. According to the Framework, science students must learn to understand and apply engineering practices (NRC, 2012). The major practice of engineers is product design, and this is best accomplished through computer-based modeling and simulation. The Simulation-Based Engineering and Science Teacher Professional Development Program and the CK-12 *Modeling and simulation for high school teachers* provide opportunities for teachers to learn how to incorporate modeling and simulation into instruction.

**Notes**

(Notes are not subjected to the peer review process and are limited by length.)

**Science and the Common Core State Standards**

*Marlow Ediger*

**Renewing a Cause for Public Schools and Those Who Teach**

*Philip Wishon*

Excerpt:

“Striving to connect in meaningful ways with every student, teachers perform small miracles every day. Surrogate parents to fifteen, twenty, twenty-five or more students, teachers coach, counsel, and console—whatever it takes to help instill in students the ability and will to think through what they care about most, to deepen their understanding of themselves as human beings, and to develop their capacity for moral deliberation and action.”

**Reviews of Current Publications Affecting the Teaching of Science**

**Book Review**

*Anne Mannarino*

*A review of The Magnificent Magnifying Lens* by J.S. Flannagan and H.L. Newton
From the Editor

This has been quite a year for science educators. The release of the Next Generation Science Standards (NGSS) in April, 2013 is a milestone that 26 states have embraced. There are new conceptual shifts found in the NGSS and A Framework for K-12 Science Education which include the following concepts:

1. The NGSS are not curricula but are student performance expectations.
2. The science concepts are built sequentially from K-12.
3. Engineering and science are integrated throughout the NGSS, K-12.
4. Science education from K-12 should reflect the interconnected nature of science as it is practiced and experienced in the real world.
5. The NGSS focus on an in-depth understanding of science concepts as well as application of content.
6. NGSS and Common State Standards (Mathematics and English language arts are fully aligned).

Virginia is not among the 26 states involved in the NGSS movement. However, it should be interesting to see where Virginia goes with this in the future. You can download the NGSS and find out more information on them and how NGSS may impact science teaching at www.nextgenscience.org.

Even though we as Virginia educators are not involved in the NGSS on a state level, I think all teachers have found that engineering has become a bigger part of our science curriculum than before. As I talk to teachers around the state, I hear that many are using and integrating engineering design into their lessons through design briefs, mathematical components, problem solving, modeling, and building engineered objects. I find this an exciting addition to science curricula if there is relevance in how the engineering concept is integrated into the science content.

Some of the papers in this journal discuss how science education is approached from even the preschool environment up to the college level. As always, we are ask you to think about submitting to the journal. Read our upcoming themes and consider contributing to the science community. If you have other articles that are not based on our themes, we will also consider those on an on-going basis.

Cheers,
Anne Mannarino
Call for Submissions

Fall/Winter 2013 – Getting Students Interested and Engaged in Science
Teaching is all about the children. As science educators we need to know what interests students and how to relate to them. If we can apply these concepts to teaching science, then we should find a way to engage all students. How do we make science relevant to students? What have you found that works for you? How do we maintain teaching based on strict content standards and still create an environment that allows creativity, problem solving, and learning to occur? What is the role of the teacher in getting students interested and engaged in science? How do we really know that the students have made connections and understand the science concepts? In this journal, we seek articles describing how science educators successfully managed to gain students’ interest and engagement in science.

The deadline for submission is October 31, 2013.

Spring/Summer 2014 – Creating a Science Classroom for All Children
Teaching science is not an easy task. The demands on teachers can be overwhelming. In addition to the daily administrative tasks, the dynamics of our classroom populations are forever changing. Students may come to us with different challenges and diverse backgrounds. As teachers, we are expected to support all students and teach science. How do you achieve that in your classroom? What challenges are you experiencing and how can you deal with students that learn in different ways? Diversity encompasses race, gender, socio-economic status, levels of background knowledge and experiences, learning styles, abilities, success with education, nationality, and much more. Reaching all children in such a diverse society is a challenge. How can we create a classroom for all children if they have different cultural backgrounds, language challenges, learning needs, behavioral issues, and family issues? In this journal, we seek articles describing how science educators manage to overcome these issues and create a science classroom for all children.

The deadline for submission is March 31, 2014.

Additionally, we are always accepting submissions outside the current call.

We are developing a more comprehensive list of upcoming themes for the Journal. If there are themes you wish to see highlighted, please develop a Call for Submissions and submit it for consideration to journal@vast.org.

If you have questions after reviewing the information on the web site, feel free to email Anne Mannarino at journal@vast.org.
Thank you to our reviewers

- Randy Bell
- Chris Carter
- Linda Chin
- Greg Corder
- Marilyn Elder
- Beth Folden
- Jean Foss
- Kathy Frame
- Wendy Frazier
- Debbie Hamilton
- Melissa Hamilton
- Sally Hurlbert
- Charles Jervis
- Jimmy Johnson
- Tim Johnson
- Bonnie Keller
- Suzanne Kirk
- Molly Logerwell
- Catherine Meechan
- Erin Peters
- David Slykhuis

- VAST is a comprehensive educational organization dedicated to the nurturing and advancement of science education.

- VAST is a nonprofit organization by educators for educators. It is affiliated with the Virginia Math and Science Coalition and is a State Chapter of the National Science Teachers Association.

- Consider making a tax-deductible donation to VAST to help continue to nurture and advance science education in Virginia. All donations to Virginia Association of Science Teachers, Inc. are deductible for income tax purposes. Fed ID# 54-1265890 Organization type 501c3. Contact / mail to: Jimmy Johnson, Treasurer, VAST, 12141 Winns Church Road, Glen Allen, VA 23059 treasurer@vast.org.
Science and the Common Core State Standards

Marlow Ediger

The common core state standards attempt to prepare a pupil from kindergarten up to college and career readiness. This is quite an undertaking in emphasizing the beginning of public schooling until entering college/career. This covers a fairly long span of years in which the pupil may experience a plethora of changes in life and in society. With continuous change occurring in the societal arena, the science curriculum must also change. New technology, inventions, and hypotheses accrue in science. Needs in society also change, requiring new applications for technology. Nearly all states in the union have signed on to giving the CCSS tests which harmonize with their instructional objectives.

It seems as if No Child Left Behind (NCLB) has just come into being (2002) and it has not been reestablished as of now. However, Congress is not able to agree on what needs modification and NCLB is still being mandated in school testing situations although a plethora of public schools are receiving waivers for the Adequate Yearly Progress (AYP) component of NCLB. The standards were set too high for AYP and many schools failed to meet their AYP criteria. Teachers were pressured to teach to the test and this eliminated several salient academic areas, science included. NCLB neglected the science curriculum until 2008 when it was added to the annual test, although science was still minimized in 2008 and succeeding school years due to heavy emphasis placed upon increasing reading and mathematics test scores. CCSS should ameliorate this situation with focus placed upon broader curriculum content areas, including science.

Science and its Relevancy

Much is written in educational literature about the need for engineers in society. Thus science educators have advocated a curriculum of Science, Technology, Engineering, and
Mathematics (STEM). This should aid in developing a high-quality curriculum of science education, kindergarten through grade twelve. A well-planned, integrated sequence of subject matter must then be in the offing. The scope of science units need to be broad enough to cover what is deemed needed subject matter to develop a scientifically literate person. Teachers need to be properly educated in teaching science at different grade levels. Elementary school teachers should have at least a minor in science with middle and secondary teachers possessing a science major from an accredited university. Science education should not stop here due to the necessity of upgrading one's own teaching; in-service education should be continuous and ongoing. Pursuing advanced university degrees in science teaching/subject matter is salient. The teacher also needs to communicate with other teachers in the school setting about improved teaching methods in science. Each public school should have a professional library for teachers which should make available the latest science journal articles and current science teacher education textbooks complete with research-based approaches for improved science instruction. In addition, science teachers should attend both national and statewide professional meetings which provide relevant ideas for assisting pupils to achieve more optimally (Ediger & Rao, 2011). Providing these resources would help many science teachers become enthused and motivated professionally.

Self-efficacy is important for science teachers in that feeling capable in teaching/learning situations is vital in aiding learner achievement and progress. Feelings of capability grow as teachers become more interested and desire to become more professional in their attitudes, pedagogical content knowledge, and instructional skills.

Teachers should reflect upon lessons taught to identify what was effective and where modifications are appropriate. Reflecting is not about focusing on weaknesses, but rather is a tool for strengthening the teaching profession. Quality attitudes need development and reinforcement
in all of life. Pupils, no doubt, observe teacher attitudes and might well model their own behaviors after them.

Science teaching methods need to incorporate how scientists work in the field. Quality science experiments should thus be a key component of a relevant curriculum. A quality experiment includes establishing a hypothesis, evaluating the hypothesis, and making necessary revisions. It is good to have an ample supply of commercial science equipment with provisions for the selection of some items on an as-needed basis per individual student projects and with teacher guidance. Computers which project large illustrations and subject matter on a white board, along with other updated technology/materials are inherently required in a modern science curriculum. Problem solving and critical and creative thinking are necessary ingredients in ongoing science units of study. Individual differences need to be considered when implementing holistic teaching and learning.

Textbooks and reading materials, basal or electronic, should be available for pupils to use in ongoing lessons (Ediger & Rao, 2009). Additional factors in instruction which must be tended to include the following:

* observing natural phenomenon carefully and accurately
* developing reading skills which encourage quality comprehension, synthesis of gathered information, and development of accurate conclusions
* writing which reflects thoroughness, standard English usage respective of background and ability level, appropriate sequence and syntax, and clarity in semantics
* speaking in a meaningful, coherent manner respective of background and dialects
* listening for a variety of purposes including answering questions and categorizing vital ideas in science as facts, concepts, and generalizations
Selected experiences in the classroom should involve collaboration. In society and in school, pupils must learn to work harmoniously together. Students should participate in small groups where the circulation and acceptance of others’ ideas is valued in an atmosphere of respect. Rudeness in all of its dimensions should be eliminated since it hinders more optimal pupil achievement and progress.

In Conclusion

Utilizing proper procedures in teaching is necessary for pupils to achieve under new CCSS criteria. Teaching methods emphasizing scientific inquiry are also relevant in developing science literacy. A classroom and school climate stressing achievement in science is conducive to teaching and learning.

Dr. Marlow Ediger is Professor Emeritus at Truman State University in Missouri. He has coauthored science curriculum for Discovery Publishing House, Inc. in New Delhi, India. Additionally, he has had several published manuscripts and been a speaker at state and national science conventions, including NSTA. He can be reached via email, mediger2@cox.net.

References

Renewing a Cause for Public Schools and Those Who Teach

Philip Wishon

In recent memory, academic testing and holding educators accountable for students meeting academic achievement standards has been the cardinal impulse of public schools. Teachers and administrators continue to face increasing pressure to respond to a high-stakes accountability movement that often forsakes much of what else is worthwhile in the curriculum. Accountability policies so narrowly conceived and implemented with a "blame and punish" mentality, reduce the education enterprise to a process that, in many instances, has become mechanical and cold. Such a pressure-driven enterprise fails to appreciate the inequitable impact of schooling and society itself on increasingly diverse child and youth populations.

While it is necessary for schools to improve the academic achievement of students, necessity quickly becomes vanity when it threatens to deprive students of the ecstasy of the arts, the wonder of scientific inquiry, and the grace of civilized discourse when the academic agenda is advanced in a climate in which there is little time or regard for matters of character, conscience, and interpersonal consequence. In a perfect world, there may be little need for schools to address anything other than basic academic standards. Sadly however, incidences of violence, poverty, family dysfunction, and social injustice serve as constant reminders that it's not a perfect world.

Over 700,000 Virginians live in poverty (The Commonwealth Institute & Voices for Virginia’s Children, 2009) over 39 million Americans nationwide (U.S. Department of Commerce & U.S. Census Bureau, 2012); almost a million American school children are homeless (National Center on Family Homelessness, 2011). Among western nations, America has the highest teen pregnancy, birth, and legal abortion rates (Hamilton, Martin, & Ventura, 2011). Three million American children are victims of abuse or neglect (U.S. Department of Health and Human Services,
2011). Because it is such a dominating theme of so much of popular youth culture, music, motion pictures, television programming, and video games, violence has become a primary language of the current generation of young Americans. Bullying and gang activity has reached epidemic proportions, and nearly twenty million youth report having experimented with illegal drugs (National Center on Addiction and Drug Abuse, 2012; Rattue, 2012). The majority of adolescents who suffer serious emotional or behavioral problems receive no treatment (Chorpita, 2012; Murphy, Vaughn, & Barry, 2013) — over a million of them enter the juvenile justice system yearly (The Substance Abuse and Mental Health Services Administration, 2012; Nelson, 2013).

Simply put, not all students arrive at school every day well-rested, well-nourished, fit, emotionally secure, in good health, and ready to learn. With countless young people struggling to manage deprivation and stress in their lives, professional educators step forward to provide support and guidance, not because it’s on some performance test — caring isn’t tested — but because it’s the right thing to do.

Striving to connect in meaningful ways with every student, teachers perform small miracles every day. Surrogate parents to fifteen, twenty, twenty-five or more students, teachers coach, counsel, and console — whatever it takes to help instill in students the ability and will to think through what they care about most, to deepen their understanding of themselves as human beings, and to develop their capacity for moral deliberation and action.

Teaching students representing richly diverse backgrounds and socio-economic circumstances is uniquely rewarding and challenging. The three R’s don’t make a life, and teachers should be recognized for helping to strengthen children’s resiliency as much as they are for raising children’s test scores. Just as we expect teachers to help students improve academically, we should encourage them to help students learn to think critically and creatively about events and
circumstances that imperil our relationships with others and with the earth that sustains us.

Teachers make easy targets when one is looking for where to place blame for why every student isn’t meeting or exceeding narrowly-focused academic standards. Teaching has become increasingly stressful as teachers bend to the weight of fresh concern about slashed budgets, limited resources, reductions in compensation, threats to contract status, and erosion in the level of respect they once received.

True, no teacher is perfect and some underperform. However, the small percentage of ineffective teachers should not indict the majority of educators, any more than the small percentage of ineffective employees in other professions, trades, or businesses should cast doubt on the vast majority of their peers. Persistently struggling teachers should be offered support with professional improvement. If adequate improvement is not demonstrated, a career transition plan should be implemented.

For one inclined to offer teachers a piece of one’s mind they’re easy enough to locate. When not in their classrooms or homes planning lessons or grading projects, teachers can be spotted at the discount store spending personal funds on materials to supplement classroom resources. Look for them after school at the park and ball field supporting their students’ teams, or at the car wash helping with school fund-raisers. Locate them in the audience supporting students’ performances, or volunteering with afterschool clubs. In the evenings, on weekends, and in the summer they can be found attending workshops and classes polishing and renewing their professional skills.

Schools should undertake a more heightened and consequential role in heeding Eudora Welty’s lifelong plea to humanity: helping to lift “the veil of indifference to each other’s presence, each other’s wonder, and each other’s human plight.” Renewed devotion to such a cause enriches human experience, and is as good for business and the workplace as is command
of any academic subject. Along with all that we demand of teachers, we should urge them to remain dedicated to helping prepare our students for a civic life in which they will engage with fellow citizens with differing views to develop policies and institutions that can advance shared aspirations. For their efforts, extending teachers a little gratitude on occasion would be nice, but unfortunately of late, certainly not expected.

Phillip Wishon is Dean of the College of Education at James Madison University.

References


Pre-Service Teachers’ Use of Visualizations in the Science Classroom: A Case Study

Brooke A. Whitworth

Jennifer L. Chiu

Introduction

Scientific visualizations of phenomena can enhance the way learners understand scientific concepts (Honey & Hilton, 2011). Scientific concepts can be abstract and difficult for students to understand and visualizations can help make these abstract concepts more concrete for students. For example, chemistry students often struggle with understanding how atoms bond since they cannot directly see atoms. Using a visualization to show students how the electrons are shared or transferred can help students understand these abstract concepts. In addition, many visualizations are freely available online and can be a key element to maintain quality science instruction with limited resources.

Scientific visualizations are meant to supplement, not supplant instruction. Teaching methods greatly impact the effectiveness of visualizations in the classroom (Kali & Linn, 2007). Teachers need to select accurate and appropriate visualizations, provide supporting instruction with the visualization, and help students reflect upon how the visualization connects to learning objectives (Kali & Linn, 2007). Teachers should discuss limitations and affordances of visualizations, making sure that students understand what visualizations do or do not represent (Gilbert, 2005). Therefore, understanding how teachers plan for and utilize visualizations in the science classroom is an important area for science education.

Pre-service teachers are new to teaching and to implementing the use of visualizations. Their experiences planning and teaching a lesson with visualizations for the first time may influence whether they chose to do so in the future. Therefore, understanding how pre-service
teachers plan for and utilize visualizations in lessons may help us understand how instruction in pre-service courses needs to be modified or changed. It could also help us determine if there are any mitigating factors that hinder pre-service teachers from using visualizations or certain types of visualizations. This study focuses on how pre-service teachers plan for and implement the use of visualizations in the science classroom. This case study answers the following questions:

1. In what ways do pre-service teachers plan for and utilize visualizations in the science classroom?
2. What types of visualizations do pre-service teachers use in a science classroom?
3. How do students respond to the visualizations used by pre-service teachers?

Rationale

Defining Visualizations

For the purpose of this study, we define five categories of visualizations commonly used by science teachers. The first visualization category is defined as “the systematic and focused visual display of information in the form of tables, diagrams and graphs” (Tufte, 2001). This type of visualization is categorized as a static image in this study. Examples of static images include digital images, graphs, tables, diagrams, etc. PowerPoints™, the second category, incorporate static images but differ in that they merge static images and text to create a presentation for students. Other types of visualizations may be dynamic in nature including animations, simulations, and videos. Animations and videos, the third category, are “computer-generated dynamic models that present theoretical or simplified models of real world components, phenomena, or processes” (Bell & Smetana, 2008, p.23). Animations and videos are sequences of static pictures that depict dynamic processes but do not enable user manipulation besides simple controls such as stop, play and rewind. Examples of animations and
videos include Brain Pop, videos found on YouTube, or the videos that often accompany curriculum. The fourth category, simulations, are similar to animations but have an interactive piece that allows the student to “observe, explore, recreate and receive immediate feedback about real objects, phenomena, and processes” (Bell & Smetana, 2008, p.23). Commonly used science simulations include PhET simulations (Perkins et al., 2006) and molecular simulations (e.g., Xie & Tinker, 2006).

**Visualizations in the Science Classroom**

While there are many forms and categories of visualizations, all can be used to support instruction in the science classroom. Science concepts are often abstract and difficult to understand for students. Visualizations have been shown to help students develop scientific conceptions (Bell, Gess-Newsome, & Luft, 2008; Flick & Bell, 2000; Hoffler & Leutner, 2007; Honey & Hilton, 2011). Visualizations can also be used to simulate data collection in situations where field-based data collection is not possible, too expensive, or dangerous (Winn et al., 2005). When a visualization is based on familiar experiences, built on prior knowledge or utilized in a manner that is student-centered, it can be effective and useful in helping students understand scientific concepts.

However, there are some limitations in using visualizations in the science classroom. When a visualization is isolated from prior knowledge or attempts to teach too many concepts it can be ineffective and even cause alternative conceptions. In general, visualizations are simplified models of a phenomena in the real world; thus, it is critical to emphasize the limitations of the model (Gilbert, 2005). If the differences between the visualization the reality is not explicitly discussed, students may develop alternative conceptions. Therefore, it is critical to implement visualizations effectively in the science classroom.
This study uses a constructivist approach to learning, which focuses on individuals actively making sense of their experiences (Cobb, 1994). This framework suggests the importance of building on prior knowledge, making instruction relevant and student-centered (Bransford, Brown & Cocking, 2000). In order for a visualization to be effective in helping a student construct new knowledge, a student needs to be actively engaged with the instruction featuring visualizations. Additionally, it is critical that teachers understand how students think about the concepts they are teaching with visualizations and integrate opportunities to refine, reflect and sort their ideas (Linn et al., 2010). This study explores how pre-service teachers create their lesson plans to incorporate prior knowledge, relevance, and student-centered instruction. Furthermore, it will investigate how students respond to the use of visualizations in the construction of their own knowledge.

**Best Practices for Instruction with Visualizations**

When visualizations are implemented in the science classroom, teachers need to recognize visualizations are tools to support learning. Bell & Smetana (2008) make the following recommendations when using visualizations to teach science:

1. Use visualizations to supplement, not replace, other instructional modes.
2. Keep instruction student centered.
3. Point out the limitations of simulations.
4. Make content, not technology, the focus. (pp. 26-28)

When these recommendations are followed, students’ ability to learn with the visualization may be increased.

It is critical pre-service teachers receive instruction about the best practices for visualization use. However, there is very little research to indicate what type of instruction is implemented with pre-service teachers. Flick and Bell (2000) recommend the following guidelines be used to prepare pre-service science teachers in using technology in general:
1. Technology should be introduced in the context of science content.
2. Technology should address worthwhile science with appropriate pedagogy.
3. Technology instruction in science should take advantage of the unique features of technology.
4. Technology should make scientific views more accessible.
5. Technology instruction should develop students’ understanding of the relationship between technology and science. (p. 40)

These recommendations are for using technology in general; however, they could also apply to visualization use.

Understanding the training pre-service teachers have to support instruction using visualizations in the science classroom sheds insight into how to develop effective pre-service programs and successful use of visualizations in classrooms. Few studies have investigated the use of visualizations in pre-service science programs. For instance, Ferreira and Arroio (2009) investigated the beliefs and practices of 24 pre-service chemistry teachers in one of the few studies on this topic. Results indicated that the methods courses only covered the use of visualizations superficially, which translated to pre-service teachers having some misconceptions about the use of visualizations. Specifically, some of the pre-service teachers believed visualizations could be used to supplant instruction or the reading of the text, while others viewed visualizations simply as entertainment or an opportunity to engage students. Results also suggested that pre-service chemistry teachers find value in the use of visualizations in the classroom, but feel they need more explicit training in order to use them effectively in their instruction.

**Methods**

**Interpretivism**

This study focused on how pre-service teachers planned for and utilized visualizations in the science classroom and on how students responded to teacher’s use of visualizations.
According to Schwartz-Shea and Yanow (2012) interpretive research is used to “understand what a thing ‘is’ by learning what it does, how particular people use it, in particular contexts…interpretive research focuses on context-specific meanings” (p.23). In this study, we were interested in what types of visualizations pre-service teachers used, what they did with those visualizations in the context of a science classroom. This study also focused on how pre-service teachers constructed lesson plans and how students constructed their knowledge as they responded to the use of visualizations in the lesson plans. Therefore, a qualitative case study approach taken from within constructivist and interpretive paradigms was most appropriate.

**Context and Participants**

This study occurred within the context of a science methods course and field placement assignment for pre-service teachers at a mid-Atlantic University. The first author served as the instructor for the field placement assignment. As part of the field placement, pre-service teachers were assigned in pairs to classrooms. They observed approximately 21 hours in their assigned classrooms, had two informal interactions with students and taught two formal lessons. Pre-service teachers consulted the classroom teachers to determine what topic they would teach for the formal lessons. Pre-service teachers submitted lesson plans for the formal lessons and co-taught the lessons with their assigned partner. After teaching the lesson, the field placement instructor debriefed the lesson with the pre-service teachers.

Six pre-service teachers who were enrolled in the methods course and field placement were selected as a convenience sample. They were assigned in pairs to three different classrooms in a small urban school district (see Table 1). Two classrooms were in elementary schools and one classroom was in a middle school. Two of the classroom teachers were female.
and one was male. Four of the pre-service teachers were male and two were female. All of the pre-service teachers had little to no experience in elementary and middle schools.

Table 1

<table>
<thead>
<tr>
<th>School</th>
<th>Classroom Teacher</th>
<th>Pre-Service Teacher Names</th>
<th>Grade Level Teaching</th>
<th>Lesson Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>James E. Lewis Elementary School</td>
<td>Ms. Jones</td>
<td>Don George</td>
<td>6th</td>
<td>Moon Phases, Solar System</td>
</tr>
<tr>
<td>James E. Lewis Elementary School</td>
<td>Ms. Smith</td>
<td>Brooklyn Matt</td>
<td>5th</td>
<td>Sound, Light</td>
</tr>
<tr>
<td>South Creek Middle School</td>
<td>Mr. Walker</td>
<td>Patrick Katherine</td>
<td>7th, 8th</td>
<td>Newton’s 2nd Law, Newton’s 3rd Law</td>
</tr>
</tbody>
</table>

Data Collection Methods

Over the course of seven weeks, data collection included observations of pre-service teachers’ science lessons, informal interviews and the collection of lesson plans. To understand how and what type of visualizations pre-service teachers utilized in science lessons, we used a combination of observations, informal interviews and document analysis. In order to gain an understanding of how students responded to the visualizations selected by the pre-service teachers, observations of the lessons and informal interviews were conducted to collect data (Table 2). Each of these methods is described more fully below.

**Lesson observations.** Observations of each pre-service teaching team were made on two formal and two informal occasions over the seven-week period. Each team was observed a total of four times. The informal observations occurred in the methods course as an opportunity to practice their formal lesson for the classroom. The formal observations took place when the

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1 School, teacher and pre-service teacher names have been assigned pseudonyms.
teaching teams arranged to teach their formal science lesson plan in the classroom. Lessons ranged from 20 minutes to 80 minutes in length.

During the observation, field notes were recorded on a computer using the Visualizations Observation Protocol (Appendix A). The Visualizations Observation Protocol was developed and based on a team of science educators’ and educational researchers input and ideas. It focuses on the type of instruction, type of visualization used, how it was used in the classroom and how students responded to the visualization.

**Unstructured, informal interview.** Unstructured interviews were conducted as needed as part of the lesson debrief with pre-service teachers. Questions were based on the lesson observed and followed up on the decisions made to use or not use visualizations. Questions also focused on how pre-service teachers perceived students to respond to the visualization. The interviews lasted a maximum of 15 minutes. Field notes were taken during the interview.

**Lesson plans.** Lesson plans for each of the science formal lessons were collected two days prior to the lesson. The purpose of lesson plan collection is to analyze how pre-service teachers planned for visualization use and to determine the types of visualization used.

**Analysis of the Data**

An analytic induction (Erickson, 1986) approach to data analysis was used in this interpretive study. This approach is used to identify the structure or the organization of meanings in the data through a two-step process. In the first step, the first author spent time studying the data holistically in order to inductively generate assertions. Throughout the seven weeks of fieldwork in this study, the entire data set was read and re-read. Assertions were generated through this process.
In the second step of the analytic induction model, the first author searched for evidence to warrant the assertions. Data confirming and disconfirming the assertions were searched for during the reading and re-reading of the evidence. In this study, NVivo qualitative research software was used to code the data for the incidence of confirming and disconfirming evidence. These instances of evidence in the data were used to revise and support the assertions. Support for the assertions developed is provided in the form of quotes and observational notes.

Table 2

Research questions, data sources and analysis plan

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Data Source</th>
<th>Analysis Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>In what ways do pre-service teachers plan for and utilize visualizations in the</td>
<td></td>
<td>• Code plans for visualization use</td>
</tr>
<tr>
<td>science classroom?</td>
<td>Observation</td>
<td>• Confirm coding with observation and interview field notes</td>
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<tr>
<td></td>
<td>Interview</td>
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<td></td>
<td>Plans</td>
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<tr>
<td>X</td>
<td>X</td>
<td>• Code lesson plan for type of visualizations</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>• Confirm coding with observation field notes</td>
</tr>
<tr>
<td>What types of visualizations do pre-service teachers use?</td>
<td></td>
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<tr>
<td>X</td>
<td>X</td>
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<tr>
<td>How do students respond to the visualizations used by pre-service teachers?</td>
<td>X</td>
<td>• Code observation field notes for student response</td>
</tr>
<tr>
<td></td>
<td>X</td>
<td>• Confirm coding with interview field notes</td>
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</tbody>
</table>

Findings

The pre-service teachers all received explicit instruction on the use of visualizations and digital resources during science methods class. The second author served as the instructor for the methods class. The total instructional time lasted around 3-5 hours where the instructor went over best practices for use of visualizations. Instructed consisted of a whole-class discussion, activities where the pre-service teachers used simulations in pairs to learn about certain science
concepts, and then another instructor-led discussion to reflect upon what they saw as additional benefits or difficulties using visualizations in science classrooms. Pre-service teachers were assigned to find ten visualizations to use in their specific content areas (chemistry, physics, earth science, biology) as part of class homework. The assignment also forced the pre-service teachers to describe how each visualization would be integrated into instruction, making explicit learning goals and student support strategies. In a subsequent lesson, students shared their visualizations with peers in their same domain area and then presented their top ten visualizations to the class. The pre-service teachers went into their school placements after this instruction.

The four assertions generated in this study through analytic induction are presented in relation to the research questions (Table 3). These assertions are presented and then discussed in detail with supporting examples from the data.

Table 3

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Assertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. In what ways do pre-service teachers plan for and utilize visualizations in the science classroom?</td>
<td>Assertion 1</td>
</tr>
<tr>
<td>2. What types of visualizations do pre-service teachers use in a science classroom?</td>
<td>Assertion 3</td>
</tr>
<tr>
<td>3. How do students respond to the visualizations used by pre-service teachers?</td>
<td>Assertion 4</td>
</tr>
</tbody>
</table>

Assertion 1: In planning and implementing lessons, pre-service teachers use teacher-centered visualizations because it seemed less intimidating.

All of the visualizations planned for and utilized by pre-service teachers were teacher-centered. When asked why they did not use a student-centered visualization, Brooklyn said:

This is the first time we’ve tried out teaching so I wasn’t sure how it was going to go and I wanted to try something more hands-on than doing something with computers. Our topics had a lot of good hands-on activities too, so it didn’t seem necessary to do a simulation with students. Also, I wasn’t sure how much access our class would have to
computers because our teacher doesn’t like technology very much, so I wasn’t sure how that would go over. (Informal Interview, 11/30/2012)

The use of computers in the classroom to implement a more student-centered visualization was intimidating to the pre-service teachers for several reasons. Like Brooklyn, the other pre-service teachers indicated they were unsure of the technology available at the school and weren’t sure how to procure it if it wasn’t in the classroom. They also indicated it was overwhelming to think about monitoring students on computers as it was one of their first or second times to teach a lesson. Finally, pre-service teachers indicated they preferred trying to engage students in hands-on activities or demonstrations rather than student-centered visualizations.

Assertion 2: Pre-service teachers planned for and used visualizations to help explain abstract or difficult concepts.

The pre-service teachers used visualizations when they needed help explaining difficult or abstract concepts. The visualizations were used to add to their discussion and to aid them in their instruction. Don and George utilized a simulation to illustrate and explain the phases of the moon. This is a very difficult concept to explain with students and Don and George chose a simulation to help students understand where the moon and sun were in relationship to Earth during each phase of the moon. During their second lesson, Don and George utilized static images to help students visualize the distance between and the relative sizes of the planets in the Solar System. Relative size is an abstract concept for students and the images Don and George chose to use provided concrete images to help students understand the differences.

Brooklyn and Matt showed a static image of sound waves during their first lesson. They used this image to help students understand why they heard different pitches when the level of water was lowered or increased in a bottle. Students can hear the difference in pitches but understanding how sound waves are related to the pitch they hear can be difficult and abstract.
In their second lesson, they used static images to help students understand what was happening to light waves during reflection and refraction. These concepts are abstract as light waves cannot be seen; thus, using the static images helped students to understand what was happening to the light waves.

In both of Patrick and Katherine’s lessons, they used static images to help students understand the forces that were acting on an object. These images helped students understand where the force was being applied and what effect the forces would have on an object. Again, force is an abstract concept for students and the visualizations used helped make the content more concrete for students. During the second lesson, Patrick and Katherine also used a static image that showed how to set up the activity. This image helped students understand what and how they needed to set up their materials as they engaged in the activity. It is clear from these observations that in every lesson, the pre-service teachers chose visualizations to help students understand difficult or abstract concepts; none were used to engage or explore a topic.

Assertion 3: Pre-service teachers planned for and used mainly static images and were influenced by classroom teachers when choosing the visualizations they used in the science classroom.

The main type of visualization used by pre-service teachers in the science classroom was static images. As this is the first or second lesson for most teachers, it may be that using a static image is easier than using a type of visualization that requires more interaction or attention during instruction. Other types of visualizations included a video, simulation and PowerPoint. Table 4 describes the visualizations pre-service teachers planned to use and the visualizations they actually used.
Table 4

*Types of visualizations planned for and used in the science classroom*

<table>
<thead>
<tr>
<th>Pre-Service Teachers</th>
<th>Lesson Topic</th>
<th>Visualizations Planned For</th>
<th>Visualizations Actually Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don George</td>
<td>Moon Phases</td>
<td>Simulation, Static Image</td>
<td>Video, Simulation, Static Image</td>
</tr>
<tr>
<td></td>
<td>Solar System</td>
<td>Static Images</td>
<td>Static Images</td>
</tr>
<tr>
<td>Brooklyn Matt</td>
<td>Sound</td>
<td>Static Images</td>
<td>Static Images</td>
</tr>
<tr>
<td></td>
<td>Light</td>
<td>PowerPoint, Static Images</td>
<td>Static Images</td>
</tr>
<tr>
<td>Patrick Katherine</td>
<td>Newton’s 2$^{\text{nd}}$ Law</td>
<td>Static Images</td>
<td>Static Images</td>
</tr>
<tr>
<td></td>
<td>Newton’s 3$^{\text{rd}}$ Law</td>
<td>Static Image</td>
<td>Static Images</td>
</tr>
</tbody>
</table>

The types of visualizations planned for use by pre-service teachers was different from the visualizations actually used. This change was influenced by the classroom teacher’s ideas or everyday practice in the classroom. For example, Don and George added a BrainPop video to their lesson based on the everyday practice and resources of Ms. Jones. George said:

> Ms. Jones often shows BrainPop videos to introduce a topic. She showed us some that applied to moon phases and so we decided to include a video in our lesson. The students are used to them and there is a lot of good information in the video. (Informal Interview, 11/12/2012)

Brooklyn and Matt were planning on using a PowerPoint in their light lesson, but they decided not to because Ms. Smith never uses them in her classroom. In the case of Patrick and Katherine, they planned to use only one static image in their lesson on Newton’s Third Law, but ended up using multiple images based on feedback they received from Mr. Walker. It is clear the classroom teacher’s practices and input had influence over what types of visualizations the pre-services implemented.
Assertion 4: Students were engaged with the visualizations and respond to questions asked by the pre-service teachers; however, they did not ask any questions regarding the visualizations.

Students were highly engaged, as evidenced by their attention and participation, during the use of visualizations. When using visualizations, the pre-service teachers asked questions of the students in every instance. These questions ranged in purpose. Some of the questions were meant to focus student attention on certain aspects of the visualization, others were problem questions and some were higher reasoning questions. Students responded quickly and with enthusiasm to these questions, but despite being given the opportunity to ask questions, students did not ask any questions regarding the visualizations. In fact observations show there was very little student questioning during the lessons in general. This may be attributed to the fact that pre-service teachers are “guest teachers” and students are not as comfortable with them. However, given that not one question was asked by a student during visualization use, it is important to note this as a finding of this study.

Limitations

Pre-service teachers were observed a total of four times, twice informally and twice formally, for a total of twelve observations, but students were only present for six of these. An increased number of observations in the field would help in understanding the student response to the visualizations utilized. Furthermore, pre-service teachers were only interviewed informally following lessons. The development and implementation of a formal interview protocol would further understanding of the pre-service teachers’ thinking and planning process. Finally, only 3 pre-service teacher teams were observed. Increasing the number of hours in the field, implementing a formal interview protocol, and observing more pre-service teacher teams would help to increase the validity of this study.


Discussion & Implications

The purpose of this study was to investigate how pre-service teachers plan for and use visualizations in the science classroom. The evidence clearly shows pre-service teachers used teacher-centered visualizations to help explain difficult or abstract concepts. It is also clear the classroom teacher influenced the choice of visualizations used and that pre-service teachers mainly used static images. Finally, students were engaged by the visualizations pre-service teachers use, but did not ask questions about the visualizations.

These findings warrant further study to determine if these results are similar to other pre-service teacher teams. There are also implications for educators of pre-service teachers. Educators may need to consider how to support pre-service teachers’ use of visualizations using student-centered methods. This is critical in order to support the learning of science more effectively (Bell & Smetana, 2008). Furthermore, educators may need to model how to teach with all different types of visualizations, not just static images. Finally, educators may need to think about how to help pre-service teachers promote more student questioning in the science classroom. The findings are significant in terms of the increasing availability of visualizations to support science instruction. Even though the findings of this case study should only be generalized to other settings with caution, they support future efforts to investigate how pre-service teachers use visualizations in the science classroom.
References


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Appendix A

Visualizations Observation Protocol

Teachers: Date:
Time:

1. In what ways do pre-service teachers plan for and utilize visualizations in the science classroom?
2. What types of visualizations do pre-service teachers use in a science classroom?
3. How do students respond to the visualizations used by pre-service teachers?

<table>
<thead>
<tr>
<th>Time in minutes</th>
<th>0-5</th>
<th>5-10</th>
<th>10-15</th>
<th>15-20</th>
<th>20-25</th>
<th>25-30</th>
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<tbody>
<tr>
<td>Instruction</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Organization</td>
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<tr>
<td>Student Attention</td>
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<tr>
<td>Visualization Use/Type</td>
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<tr>
<td>Questions Asked</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Time in minutes</th>
<th>30-35</th>
<th>35-40</th>
<th>40-45</th>
<th>45-50</th>
<th>50-55</th>
<th>55-60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instruction</td>
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<td>Organization</td>
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<td>Student Attention</td>
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<td>Visualization Use/Type</td>
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<td>Questions Asked</td>
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</table>

How do students interact with each visualization?
Is it student centered or teacher centered?
What is the purpose of each visualization? (to illustrate or to get at understanding)
Do teachers address the affordances/limitations of the visualization?
What type of questions do students ask?

Notes:
Creating Quality Science Programs in Preschools

Heather Newton, M. Ed.

Jenny Sue Flannagan, Ed.D.

Curiosity, along with a thousand questions, is the start to a preschooler’s journey as they begin to explore the world of science. As educators, it is our job to stimulate and provide experiences that will allow children to grow into emerging young scientists. One of the struggles early childhood programs face is budget constraints and the ability to provide resources on a “shoestring budget”. Early childhood teachers are left with minimal resources at times and thinking outside the box takes on a whole new perspective. All you want to do is deliver that amazing science lesson that is sure to capture the children’s hearts, but there isn’t any money left. Partnering with community organizations is a great way to supplement resources for providing a well-planned and exceptional unit on science that will leave children talking and asking a lot more questions.

Growing science in preschool!

Week one: the chatter around the science lab is filled with questions and curiosity as the children sit down and observe the items lying in the middle of each table. There are pipe cleaners, colored beads, and books. “Are we doing art in science class?” one little voice mutters. Week two: the tables are now piled with bags of dirt, packets of sunflower seeds, plastic cups, and bottles of water. “I can’t wait to grow my very own sunflower” explains an anxious four year-old girl. Three months later and finally week twelve: it is time to cut down the sunflowers and begin to explore and investigate them even more. One little girl looks up from sitting on the floor and examining her sunflower and says, “Is it my turn to look at the seeds with that thing that makes them really, really big?”

From May until early August, the children at our preschool were engaged in a unit on sunflowers with several different lessons and experiences. The final products from this unit were mammoth sunflowers that stood on average 8 feet tall and had sunflower faces ranging from 10 –
12 inches in diameter. The excitement of the children each week as they charted, measured, and took photos while learning about their sunflower was priceless.

**A Successful Lesson**

Our preschool conducted a lesson on sunflowers that extended over several months. Our belief is that students need to experience science lessons through a hands-on approach and then build on those lessons each week. We started the lesson by introducing the children to the lifecycle of the sunflower. Through the use of two books, *A Sunflower’s Life* by Nancy Dickmann and *The Life Cycle of a Sunflower* by Linda Tagliaferro, the children were able to study the cycle from seed, to sprout, to bud, to flower. Next, the children were able to use beads and make bracelets representing the order of the life cycle. For example, the first bead was black for dirt, the second bead was brown for the seed, the third bead was blue for water, the fourth bead was green for the sprout and the fifth bead was yellow for the flower. Children were then given a pipe cleaner and instructed to put the beads in the correct order of the sunflower lifecycle starting with the dirt and progressing to the final stage of the flower. Having a hands-on lesson allowed the children to recall the order of events through proper representation of the colors and then sequencing the sunflower lifecycle.

Next, the children were provided seeds, soil, and cups to plant their own sunflower seed. Each cup was labeled with the child’s name and they assisted with watering their seed for the next several days. Within five days, many seeds had sprouted and were ready to plant outside. The children had a choice to either plant their seed at school or take it home. The decision was split down the middle and approximately half of the children planted their seeds at school and the rest took their seeds home to plant. The seeds used for this lesson were Martha Stewart “mammoth seeds”, which as previously mentioned, grow to exceptional heights and have faces
up to a foot in diameter. The sunflowers were planted along our playground fence and then reinforced against the pickets as they grew larger, helping to support the stalks. We enjoyed the sunflowers after they bloomed for several weeks and then we began to cut them down. The children had an opportunity to dissect the sunflower face and pull out the new sunflowers seeds that had matured.

During the closure of this unit, the children were able to use a ProScope to explore all the parts of the sunflower. The ProScope magnifies objects 300 times the normal size and projects the images on a laptop screen for the children to view and make observations. The children explored and asked many questions when using the ProScope on the sunflower face. “Look how big the seed just got,” exclaimed one child. Another quickly stated, “Can we put it on the petals, too?” Of course, our quick response was, “absolutely!” At the conclusion of dissecting the sunflowers for a few days, the children placed the remaining sunflower faces in our back field and we watched the birds feed on them for several more weeks. It was an amazing lesson which stimulated the children’s language and communication skills; they still talk about it! We look forward to conducting this lesson again next spring and engaging the children in even more exciting hands-on experiences.

Assessing a Quality Science Program

Just within the last ten years, researchers have begun to define and develop assessment tools for preschool science programs. There are several components one needs to consider when trying to define and evaluate what makes a quality science program. First, teachers need to address an experiential approach to teaching. Children need to make real-life connections to the science they are learning and teachers need to make meaning of the content so it will last. Second, a quality science program will have assessment tools that allow for observation and
documentation of conversations that are occurring between the teacher and the student and also among the students themselves. Activities and lessons need to be documented by the teacher as well as the students. Students can learn to write and draw their observations and ideas into journals with the assistance of teachers. A good assessment tool does not just evaluate what the child knows based on a checklist, but allows the child to talk through what they have learned and make connections to the real world. A quality science program will provide time to allow preschoolers to have open discussions, ask questions, solve problems, and think critically.

The National Association of the Education of Young Children (NAEYC) has developed a checklist outlining the top 10 standards of a high-quality early education program (2006). It is important when developing lessons and units within a curriculum to also address these standards and implement them into lessons. For example, NAEYC’s quality program standard 2 states, “implement a curriculum that fosters all areas of child development – cognitive, emotional, language, physical and social” (NAEYC, 2006, para. 4). Teaching a unit on the lifecycle of sunflowers engages the child emotionally, allows for language looping and opportunities for children to ask questions, which are derived from the child’s natural curiosity about science. Additionally, children are physically planting and sowing the seeds in a social environment with their peers and/or parents if they choose to take their seed home to plant.

Head Start preschool teachers were asked what they felt the top ten benefits of teaching or witnessing quality science programs were, and they are:

1. Science responds to children’s needs to learn about the world around them.
2. Children’s everyday experience is the foundation for science.
3. Open-ended science activities involve children with a wide range of developmental levels.
4. Hands-on science activities let teachers observe and respond to children’s individual strengths and needs.

5. The scientific approach of trial and error welcomes error and interprets it as valuable information, not as failure.

   - Nonfiction books become a powerful foundation for conversations with adults and peers.
   - Vocabulary growth is supported by children’s prior knowledge and experience of the everyday world, coupled with observation and hands-on activities.
   - Receptive language (listening comprehension) is fostered as children listen to the teacher read aloud and talk about the science activity.
   - Expressive language is fostered as the teacher leads children through a cycle of scientific reasoning and especially as the teacher supports the children in developing a report of their findings.

7. Science helps children with limited language to participate in the classroom and learn English.

8. The problem-solving skills of science easily generalize to social situations.


10. Science connects easily to other areas, including center-based play, math, artistic expression, and social studies (NAEYC, 2002, p. 1).

**Forming Partnerships**
A major issue that faces many preschool programs is the concern of how to fund a quality science program when there may be financial and budget constraints. One option is to look to the community and form partnerships to assist with the cost concerns. In order to be rated a high quality program by the NAEYC, in fact, community partnership should be formed. With this criterion in mind, our preschool reached out to Regent University for assistance with setting up our preschool science program. The partnership initially developed three years ago and stemmed from a mother with two children attending our preschool who was the director of The Martinson Center for Mathematics and Science at Regent University. At first, “the science lady”, as the children called her, would visit once a month to do fun and engaging hands-on lessons with the children. The more we did the science lessons, the more we noticed the children were talking about science and asking for “the science lady” to visit the preschool again. It was at that moment we realized there was something really fantastic developing between the Martinson Center and our school.

Forming the partnership with Regent University allowed our preschool to utilize expensive hardware and software, like the ProScope, that we did not previously have at our school. We also were able to foster a working relationship with the university faculty to train our preschool teachers in a six-hour workshop covering topics of early childhood science and how to effectively implement science activities into our current curricula. This training is a prime example of NAEYC’s standard 6 which states, “Employ and support qualified teaching staff”. This is clear evidence that partnerships within the community can directly support teachers. Another great outcome of infusing NAEYC’s quality program standards into the unit on sunflowers was the relationships that were formed within the school’s community. Standard 8 states, “establish and maintain relationships and use resources of the community” (NAEYC,
The relationship that had formed between the school, Dr. Flannagan “the science lady”, and Regent University was invaluable.

Dr. Flannagan was able to instruct me and my staff on how to take general science content and make it age appropriate for classes being taught. Although, the greatest successes were observed in pre-k and kindergarten, we have seen levels of curiosity grow with our two year-old children. Science is introduced to our toddlers in a very limited fashion, but it does allow for them to ask questions, play, and be engaged with science at a very young age.

The first year we did science lessons monthly and the following year we chose to do the lessons every other week. These lessons were in addition to the science that was already incorporated into our preschool curriculum. With the university math and science center being largely grant funded, we were able to receive some materials to assist with the lessons during our second year of instruction. Year two was extremely successful and we included take-home extension lessons with each activity based on suggestions from our parents. It was so fulfilling to see the parents getting involved and wanting to do more with our science program. Parent involvement is also a criteria set by NAEYC in rating a quality preschool program.

Dr. Flannagan and I had such a positive response from our parents and students, we decided to take our lessons and create a basic science curriculum and provide training to other preschool teachers. The driving factor in the decision to train other teachers was the impact we had witnessed with my preschoolers, their love for science, and their desire for more science lessons. The university math and science center funded the first training; 60 preschool teachers attended and it was extremely successful. The registration fee was $35.00 and included a resource box of materials worth $400.00 that each teacher got to take back to their classroom. Our intent was to instruct 12 lessons and provide the teachers with all of the materials to “hit the
ground running” when they returned to their schools. As teachers, we are aware of tight budget constraints and minimal salaries; therefore, by providing the teachers with the materials necessary for doing lessons, our hopes were they would implement the lessons right away. The feedback from the teachers and the reactions of their students were phenomenal. We got many emails and requests to conduct additional trainings, so we did another training the following year. It is wonderful to know that we are providing quality best-practice instruction to preschool teachers who might not normally have the opportunity to attend training with the benefits that come from a grant funded program. This is a testament to the power of creating community partnerships. Finally, Dr. Flannagan and I were so excited to witness teachers who thought they didn’t know how to teach science, or were uncomfortable teaching science, now realize they did have the skills and they did have the knowledge; they just needed guidance on how to deliver the material age-appropriately.

Dr. Flannagan and I are extreme advocates for teaching appropriate science content at an early age. In our efforts to keep the momentum going with the preschool science program, we renovated our preschool this past year and developed an actual math and science lab that children can visit daily during open centers in addition to their weekly classroom lessons. The children ask constantly to visit the lab and there is nothing better than sitting with a child and listening to them explain and talk about what they have created, built, imagined, and learned.

In addition to the partnership formed with Regent University, we have also partnered with The Virginia Beach Technical and Career Education Center and the Early Childhood Program. Through this partnership with a local high school, early childhood resources, which include materials like books, manipulatives, etc., are loaned to our preschool based on our thematic units and lessons being conducted. Additionally, the faculty from the high school offers
to train our teachers and we, in-turn, open our doors to their high school students who conduct nine-week internships at our preschool. The effective collaboration of resources between our two schools allowed us to be recognized as a 2009-2010 Model Partnership by the Virginia Beach City Public Schools and our preschool was awarded the *Making a Difference* Community Award in April 2010.

The Virginia Beach Technical and Career Education Center offers two-year vocational programs in many fields with certifications and licensures upon graduation. Our partnership with the high school provides assistance from turf management, early childhood, dental hygiene, and building and construction. The turf management program provides our school with flowers and plants; the early childhood program provides materials and student interns; and dental hygiene students visit the preschoolers and teach dental hygiene lessons. Finally, the building and construction program built our shed to store our lawn equipment at the preschool. Forming these partnerships has saved our school thousands of dollars as well as provided us countless hours of volunteer work. I encourage preschools to network with community organizations that can greatly benefit your school when there is a financial constraint and when you are looking for good quality resources.

In conclusion, research is showing that making an investment in quality science programs will benefit children in the long run and is well worth the cost. Quality programs can directly influence academics and social development within preschool children. Teachers and schools need to get involved with the community and form lasting partnerships that will directly affect the learning outcomes of young children. Tap into the monetary resources available to create quality science programs and watch children develop into young scientists.
Heather Newton is Co-Owner and Director, Bullfrogs and Butterflies Preschool and Kindergarten. She is also a doctoral student with the School of Education at Regent University. She can be reached via email at heatnew@regent.edu.

Jenny Sue Flannagan is Director, Martinson Center for Mathematics and Science Education and Assistant Professor for the School of Education at Regent University. She can be reached via email at jennfla@regent.edu.

References


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**Stone Soup Anyone? Using Service-Learning Pedagogy to Promote STEM**

Erin Burke Brown, M.P.A., Lynn E. Pelco, Ph.D., Suzanne Kirk, Holly Houtz, Anne Wright, & John Speich

Service-learning provides opportunities for science educators to gain access to community resources, enhance student learning outcomes, and assist with providing solutions to community problems. This article will explore how GreenSTEM@VCU is training middle school teachers in Virginia to use service-learning projects to facilitate the effective implementation of STEM curriculum.

In the well-known folk tale *Stone Soup* a town of stingy villagers is unwittingly persuaded to share their food with hungry travelers with the promise of preparing the tastiest soup they have ever had made using only stones. Of course, in the end, all enjoy a hearty soup made of contributions from each family demonstrating the power of giving and cooperation in the midst of scarcity. In challenging financial times, it is important for teachers to be creative in their efforts to provide the best education possible with limited resources. In essence, today’s teachers are being asked to make stone soup. For the past two years, teachers participating in Virginia Commonwealth University’s (VCU) GreenSTEM@VCU have been doing just that.

With funding provided by the Corporation for National and Community Service, GreenSTEM@VCU offers training and grant funding to middle school science, technology, and math teachers who serve low-income populations. The Division of Community Engagement at VCU coordinates the project and, in collaboration with VCU Life Sciences and the VCU School of Engineering, provides much of the GreenSTEM training and support. What has made VCU’s program different from others in the STEM field is its use of service-learning, a fairly new teaching pedagogy that has been shown to engage learners and benefit communities (Stott & Jackson, 2005).
Exploring the Benefits of Service-Learning in K-12 Education: Lessons from the Field

During service-learning, students reflect upon and connect community service projects and experiences to classroom curriculum and Standards of Learning (Cress, Collier, & Reitenauer, 2005). Service-learning is a form of experiential learning in which teachers encourage students to use creativity and classroom knowledge to address real-world problems within their community (Skinner & Chapman, 1999). Students and teachers pool resources from members of the community and businesses to achieve more effective solutions to local problems.

Evidence from various studies shows a correlation between service-learning participation and students’ sense of social and personal responsibility (Billig, 2000). According to the recent publication, The Crucible Moment, by The National Task Force on Civic Learning and Democratic Engagement (2012), current students graduating from colleges and universities are disengaged citizens that are unconcerned with the public good. Employers and communities alike are finding that these recent graduates know content, but lack an ability to connect their academic skills with real-world issues. These findings about higher education serve both as a wake-up call and cautionary tale to educators at all levels to begin the process of blending academic curriculum with real-world application to prepare students to handle the challenges of society outside of the classroom. Middle school STEM teachers using service-learning pedagogy have an opportunity to impact students’ lives by providing them not only with academic content, but with a sense of civic responsibility that they will carry with them regardless of their chosen field.

While some educators have embraced service-learning for its innovative and creative approach to education, some are uncomfortable with service-learning pedagogy because it runs counter to the traditional view of education, where teachers lecture and students listen. In
service-learning the learning is expanded beyond the walls of the school and into the larger community where community members serve as co-instructors with the classroom teacher (Stoecker & Tryon, 2009). Students are encouraged to view learning in a holistic way, understanding that knowledge learned from a local farmer is just as credible as what they learn in a textbook.

Research has shown service-learning to be an effective method of instruction that reduces the achievement gap, increases graduation rates, improves academic performance, and develops students’ critical thinking skills (Dary, Prueter, Grinde, Grobschmidt, & Evers, 2010; Scales, Roehlkepartain, Neal, Kielsmeier, & Benson, 2006; Seitsinger, 2005). Service-learning can particularly benefit students in inner-city and rural schools that may face challenges related to poverty, that impact their academic engagement (Soslau & Yost, 2007). Students participating in service-learning are often more engaged because their everyday lives are not divorced from the classroom in an effort to deify middle class norms and values. Rather, the classroom becomes a place that students can learn new skills that can positively impact the realities they face in their communities. Service-learning has been a natural fit for GreenSTEM@VCU because it engages low-income students in meaningful service activities related to STEM facilitated by teachers, and community partners.

GreenSTEM@VCU: Linking STEM with Service

As a service-learning initiative, GreenSTEM@VCU recognizes that many teachers face a metaphorical stone soup tale laced with challenges in obtaining the resources they need to effectively teach STEM subjects. Finding equipment, materials, and specialized expertise becomes even more difficult for teachers that serve a high proportion of students from low-
income families. *GreenSTEM@VCU* shows teachers how to contribute their knowledge and experience to a cauldron seasoned with student energy and community resources.

Teachers who initiate and build relationships with individuals and groups in the community are often rewarded with newfound allies that contribute a wealth of knowledge, materials and networks to their classrooms. Initially, teachers may find the task of approaching a community partner and asking for assistance daunting, but most teachers participating in *GreenSTEM@VCU* found their fears to be unfounded. Once community members were made aware of a project with which they could assist, they were more than willing to share their resources. The community-classroom collaboration that results from a service-learning partnership provides benefits for not only the students, but also for the teacher, school, community partner, and community as well.

On the surface, it would appear that service-learning in a field like STEM is relatively easy. Science, technology, engineering, and math are best taught and learned using experiential learning techniques that actively engage students. In addition, service projects can be relatively easy to do with energetic young people and a willing community. Service-learning differs from community service because it is not solely focused on helping the community. Service-learning that is done well is strategically aligned with academic curriculum. Community partners are intentionally sought out based on their ability to fit with the curriculum and address a *community-identified* need as opposed to a need that the students perceive exists.

According to Billig (2011), using the K-12 Service-Learning Standards for Quality Practice is the best way for teachers to ensure that they are providing a quality academic experience for students and the community. These include an emphasis on duration and intensity, meaningful service, link to curriculum, reflection, diversity, and progress-monitoring
(Billig, 2011). It is highly important that teachers do not jump into service-learning without appropriate planning and preparation to ensure success.

The GreenSTEM@VCU program provides middle school science and math teachers with an opportunity to plan their service-learning curriculum prior to the start of the school year. Teachers participating in the program have a four-day on-site training at VCU where they work with scientists and engineers on projects they can replicate in their classrooms. Everything is taught through the lens of service-learning and experiential education as a method to engage students and aid the community. During the workshops, teachers are provided with multiple opportunities to reflect on what they are doing and how it will impact their teaching, students, and community. Teachers are encouraged to collaborate and work together on project ideas and curriculum development with the goal that they will fully develop and implement a unit using service-learning pedagogy when they return to their schools. An online course facilitated by the GreenSTEM@VCU coordinator provides consistent feedback and follow-up throughout the school year to ensure that teachers stay committed to their project goals and have appropriate support.

GreenSTEM@VCU Success Stories

An award-winning middle school science teacher from Richmond participated in GreenSTEM@VCU with the hopes of getting her students more engaged in science and with the community, specifically on topics of agriculture and sustainability. The teacher was introduced to the community partner, Backyard Farmer (http://www.backyardfarmer.us/), by a parent. The class worked with the partner to create indoor and outdoor learning gardens by taking what was once an underused greenhouse on school grounds and constructing low-cost “hoop houses” to cultivate vegetables and plants. Backyard Farmer generously contributed its time and expertise
in sustainable agriculture and assisted the class with acquiring material and supplies for free or reduced costs. The partnership with Backyard Farmer connected the teacher to a network of community resources that provided additional materials, expertise, and “people-power” to support the school’s project. The students learned about the science of plant reproduction, process, agriculture, and sustainable practices. Math and engineering concepts were applied to construction for the project, aligning traditional curriculum with real-world situations. The implementation of the project addressed a variety of Career and Technical Education Competencies that reinforce 21st century skills such as critical thinking and problem solving, communication, collaboration, creativity, and innovation (Eyler, Giles, Stenson, & Gray, 2001).

The service component of the STEM project took learning a step further when students decided to make donations to local community soup/food kitchens, transplant seedlings from the hoop houses to community gardens, and gift plants to teachers and community members. As a result, students were empowered by civic engagement and responsibility. The culminating lesson yielded far-reaching outcomes that resonated with students who saw needy parts of their community literally enjoy the fruits of their labor.

More than three hundred miles away, another GreenSTEM@VCU participant from Southwest Virginia was using similar strategies to teach middle school science. Through a collaborative service-learning project involving students from the local middle and high school, the teacher began a school recycling initiative that would not only impact her students, but her entire community. The teacher learned about the Environmental Control and Recycling Coordinator from reading the local newspaper and bravely decided to contact the coordinator about a potential partnership. The coordinator agreed to serve as an advisor for the students’ recycling initiative. The environmental office provided the students with valuable advice,
donations, and connections to local business with similar recycling goals. The coordinator visited the school and spoke to students about sustainability, emphasizing that the students’ efforts in their school was very important to county-wide recycling efforts.

Students at the school continue to participate in large-scale recycling initiatives that positively impact the campaign to ‘Keep Southwest Virginia Beautiful.’ The evidence of their work is seen not only in the brim-filled bins of recyclables lining the halls of the school, but also in the use of sustainable items in their county with many of the students encouraging their families to recycle at home as well. The environmental coordinator has cited the school’s initiative as a driving force in spreading the word about recycling in the community with its youngest citizens serving as catalysts for change. Throughout this process, the classroom teacher capitalized on the many teachable moments that linked the students’ service project activities to the academic concepts within science, math and technology that she teaches. Establishing relationships with community-based partners and working collaboratively to impact real environmental problems in the local community makes STEM subjects more meaningful for middle school students.

The projects described above serve as shining examples of how teachers can create engaging STEM instruction using service-learning despite resource limitations. The classroom teachers intentionally took steps not to reinvent the wheel, but to reshape it to fit the needs of a changing educational environment where teachers are continually asked to do more with less. By reaching out to their communities for support and assistance these teachers were able to find partners willing to help them meet their educational goals through the development of service projects that benefitted their respective communities. Utilizing service-learning pedagogy to teach STEM can provide science educators with valuable resources that can help them meet their
academic goals and turn what some might call a tasteless stone soup into something delectable and satisfying.

For more information about GreenSTEM@VCU visit http://greenstem.vcu.edu/.

References


Changing Students’ Perceptions of Scientists: Ideas for Classroom Teachers

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Many have discussed problems in the way we educate students in the sciences as a reason that we have a shortage of scientists. Science is often perceived as the difficult, lonely pursuit of white males in lab coats. This study examined how children perceive scientists. Children ranging in age from 8 to 12 years old were asked to draw a picture of a scientist. Drawings were coded using criteria developed by Chambers (1993) in his Draw-A-Scientist test. Examination of the data revealed that similar to Chambers’ findings, children held very stereotypical beliefs about scientists and what scientists do. After a week-long science camp where teachers made efforts to refer to the students as scientists, where the children interacted with practicing scientists of both sexes from different fields, and where the children participated in hands-on science experiments, the drawings changed to show fewer stereotypes when compared to their pretest images.

Children frequently are asked what they want to be when they grow up, and they dream of future careers based on the things that they find fun and interesting. As they grow older, they begin to look more pragmatically at their career choices. Working environment, salary, and job status are some criteria that begin to attract students to various professions. Moreover, students make choices based on the job skills they think they are capable of learning and being successful at throughout their lives. Very few students choose to become scientists, this is due in part to the stereotypes children gather from a young age: the unattractive view about what scientists do, the “genius” status often applied to scientists, and the stereotype that scientists are males. Research studies have reported that children of all ages have negative images of scientists (Chambers 1993; MacCorquodale 1984). Children’s ideas about scientists are influenced by the media, by teachers, by parents, and by their peers. It is essential for educators to realize that when teachers possess stereotypical images of scientists, these images transfer to their teaching.
in a negative way (Rosenthal, 1993). Stereotypical and unflattering images of scientists influence students’ career aspirations (Beardslee & O’Dowd, 1961; Odell, Hewitt, Bowman, & Boone, 1993; Smith & Erb, 1986). Researchers report that female and minority students who have low self-concepts with respect to science are less likely to enter science programs in college (MacCorquodale, 1984; Ross 1993). Not surprisingly, students choose to pursue science careers when encouraged by teachers and parents, when exposed to role models, and when they expect to succeed in the study of science (Burton 1979; Casserly 1975). Chuck Gallo, in a letter published in *Physics Today* (July, 2010), posited that students need to see the relevance of science education (p.9). In Gallo’s opinion, this is particularly true for low-income students whom he claims, “do not see any correlation between success in school and success in life” (2010, p.9).

Research on children’s images of scientists started in the 1950s with a study conducted by Mead and Meatrux (1957). Their work focused on thousands of high school students and used essays to measure students’ perceptions of scientists. The results showed that students held “an overwhelmingly negative” view of scientists. Students viewed science as something good for society – science is important for improving health, national defense, etc. – but when it came to making a personal choice (i.e. choosing to become a scientist, or to marry a scientist) the response was very negative (Mead & Meatrux, 1957). Chambers (1983) attempted to define the age at which students first develop distinctive images of scientists. He introduced the Draw-A-Scientist test and tested nearly 5000 students from kindergarten through grade five. He discovered that stereotypical images of scientists were present among children as young as kindergarten. Moreover, as children grew older, their images of scientists became more and more stereotypical. A widespread public image of scientists is that of somebody difficult, cold,
abstract, and largely masculine. As mentioned before, many students in public school classrooms portray an image of a scientist that is influenced by social constructs: the media, their friends, their teachers, their parents. The image is defined as a mental representation held by a person, which is based on past experiences and associated with beliefs, attitudes and ideas about who can be a scientist, and what a scientist does (Lim, 2002). A stereotypical image might be a scientist is a Caucasian male with eye glasses, facial hair, and a white lab coat, working in isolation to create magic potions.

In this study we analyzed drawings by students who participated in an interactive science camp. The hands-on and inquiry-based instructional interventions used during the camp were developed so that teachers could use them during the typical school day to help change students’ stereotypical beliefs about what scientists do and who can become a scientist.

Method

Setting. This science education project took place at a college-sponsored summer science camp at the Jubilee Family Development Center in Lynchburg, VA. The Jubilee Center offers educational programs and services to assist in academic and social skill development of local youth. The Jubilee Center is located in a low-income housing neighborhood. The facility includes classroom space, a cafeteria, gymnasium, and recreation center. Each summer, the Science Education Group from Randolph College offers a five day science camp for two hours each day at the center.

Participants. The children involved in our study were elementary and middle school children aged 8-12 years (n=35). For data analysis, we included only children who completed both the pretest and post-test drawings. Children who live near the center typically attend the summer
camps. Though the students are not required to attend every day, most of the children attend on a daily basis.

**Instrumentation.** The Draw-A-Scientist Test (DAST) was administered as a pretest and a post-test. The DAST was administered on the first day, as the first activity. The children were given a piece of paper and colored pencils, and the following directions:

“On one side of the paper, write your name, your age, and F (if you are a girl) and M (if you are a boy). For the next part, you are going to work by yourself. Do not talk to anyone around you about what you are drawing. These ideas are going to be your own ideas. Draw a picture of a scientist. You are to draw whatever you think a scientist looks like.” Students were given 15 minutes to complete their representational drawing.

**Procedure.** The children participated in hands-on and inquiry-based science lessons as part of the five day camp. Not all of the same children attended every day; however, about 90% of the children attended for all five days. Only the pre and post-test drawings for those who attended all five days were included for analysis.

Each day, teachers focused on a separate science topic. The typical week included a chemistry day, a biology day, an environmental science day, and two physics days. In addition to learning content knowledge and doing fun and interesting experiments, the camp was designed to dispel stereotypes about science and scientists, both about how science is done and who does it. The goal was to help boost children’s interest and achievement in science. The entire camp was about discovery and the exploration of scientific concepts through hands-on exercises. Each morning started with a guest speaker, a college science faculty member, who presented an interactive lecture on the topic for the day that lasted no more than twenty minutes. These college scientists were purposely chosen to represent a mix of genders, races, and ages. The
children were then divided into smaller groups according to grade, and they participated in discovery-based science activities guided by teachers. No textbooks or worksheets were used, and the children were encouraged to have fun while exploring science through acting like a scientist. Throughout the lessons, teachers made statements to the children that they were scientists and that they “did” science in their everyday lives, often not realizing that they were doing science.

On the fifth and last day, after the activities were over for the week, the DAST was administered again in exactly the same way it was on the first day of the camp. The DAST was scored according to the Chambers’ (1983) rubric by two researchers, and reliability was checked.

Results

When the students were asked to draw a picture of a scientist on the first day, prior to any participation in the science activities, two categories emerged as the most typical type of drawing: very stereotypical drawings and nature drawings. The majority of the students drew pictures that depicted the stereotypical male scientists similar to Figure 1 and Figure 2.

![Figure 1. Pretest Student A. This drawing includes 7 stereotypical traits: crazy hair, facial hair, glasses, indoors, male, Caucasian, symbols of science research (beakers).](image)

![Figure 2. Pretest Student B. This image scored 7 points on the DAST: indoors, male, Caucasian, symbols of research (beakers), glasses, facial hair, lab coat.](image)
Many of the female participants drew what were categorized as nature drawings. These nature-type images included rainbows, trees, flowers and butterflies. In addition, the nature images often included self-portraits of the female artists as part of the picture. Usually, there were no signs of science being done in the nature images. Figure 3 is a typical example of a nature image.

![Image of a nature drawing](image)

**Figure 3.** Nature Image. Drawing that depicts the student outdoors but does not seem to portray the student engaged in science; this would be scored a 0 based on the omission of any of the stereotypical traits.

Not only did the student participants draw the nature pictures during the pretest, students also drew these types of pictures during the post-test session. It is important to note that we did not have an opportunity to ask the students to describe these types of drawings. For future research, interviews will be conducted to better understand the ideas behind these nature drawings.

The figures were scored to measure common stereotypes. The scoring rubric was created from Chamber’s (1983) recommendations. The higher the score a drawing receives, the more stereotypical the drawing. Both Figure 1 and Figure 2 received a score of 7 out of 10. Both representations included white, male, facial hair, glasses, indoors, and stereotypical symbols of
research (beakers). Figure 1 scored another point for “crazy hair”, and Figure 2 scored another point for the lab coat.

Following five days of instruction, the same two students (Student A and Student B) drew the following representations (Figure 4 and Figure 5).

**Figure 4. Post-test Student A.** This student’s stereotypes decreased over time; this second drawing scored a 4 on the DAST: male, white, facial hair, glasses, a decrease of 3 points.

**Figure 5. Post-test Student B.** This student’s drawing decreased in stereotypical representations scoring a 2 on the DAST: male, facial hair, a decrease of 5 points.

Student A and student B drew males; however, both omitted the symbols of research. The glasses in Student A’s post-test drawing were much more contemporary than in his pre-test drawing, and the person in the post-test appears younger in the second drawing than in the first. Student B added color to both the skin tone and the shirt, wrote “Dr. Cool” in the upper right hand side, and added a sun in the upper left. The total score for Student A decreased 2 points for a total score of 5 out of 10, while student B’s score decreased 5 points for a total of 2 out of 10.

Based on examinations of the pictures, we concluded that what is said to students and how science concepts are presented are very important in the way children develop view scientists, and more importantly, how they come to view themselves as scientists.

One drawing highlighted the influence the camp had on how a child viewed science and the role of scientists. Figure 6 is a post-test drawing created by an eight year old girl. On the last
day of the science camp, instructors conducted the very popular Egg Drop experiment. The students were very engaged with and excited about this activity. Dr. S., a physics teacher from a local college who had given the introduction on the science behind the egg drop was the person who dropped the eggs from a ladder. The girl’s picture is a representation of this activity which she drew when asked to draw a picture of a scientist.

Figure 6. Post-test drawing. This student made a drawing of the Egg Drop contest: It shows the student and Dr. S on the ladder that was used to drop the egg containers

In comparing the pre and post-test drawings, the students’ reliance on depicting scientists as “working indoors in a sterile lab setting conducting dangerous experiments” is the result of students’ lack of clear understanding of what scientists do and what constitutes science as a career. Moreover, media influences like television and the internet and the attitudes of the adults that work with students on a daily basis strongly influence these perceptions.

Suggestions for Teachers

Teachers have an opportunity to explore how their students view scientists prior to instruction, and they can reduce the stereotypes if they use hands-on and engaging scientific investigations as part of instruction. Teachers must carefully frame what they say and how they teach if they are to avoid reinforcing the negative stereotypes children hold about science. Teachers can collect information on student perceptions of scientists in their own classrooms. It
is important for elementary, middle, and high school science teachers to have an understanding of how the students they teach perceive science and scientists. These beliefs influence how children feel about their own abilities in studying science. Reading about scientists in textbooks or watching science shows may only reinforce the stereotypes commonly held about scientists.

What images of scientists do the children in your classroom hold? Try the following activity with your students to discover what they are thinking and to help you plan lessons to change negative stereotypes that they may hold.

1. Draw a picture of a scientist. Write about your scientist. What is the scientist doing? Where is the scientist working? Do this activity at the beginning of the year or at the beginning of a unit of science study and then again at the end of the experience. If you have not used hands-on experiments in the past, compare pre and post-test drawings.

2. Have the students ask their parents and friends to draw a picture of a scientist and explain the role of that person.

Once you have an idea of how students view scientists, begin to interject statements about how the students are already scientists. Always refer to them as scientists. Typical examples might include: “I see that you are setting up your experiment in a very scientific way,” or, “Today when we collect leaves from the area around the school, we are going to be scientists. We are going to look carefully for different types of leaves and observe where the leaves were when they were collected. These are the kinds of things that scientists do when they are gathering data.” Teachers must provide frequent opportunities for students to actively engage with science. Avoid demonstrations, as the students are passive learners when they are only observing, and provide experiments that the students carry out on a weekly basis. It is better that
students talk about science problems, generate ideas on how to solve the problem, design experiments to test their ideas, collect data, analyze data, and report their findings.

During this study, students were not asked to write descriptions of their pictures; however, having them do so would provide teachers with additional information on what they are thinking. In addition, we recommend interviewing the children and asking them the following questions: What do you think scientists do while at work? Could you see yourself working as a scientist? Would you marry a scientist? Future research will include these ideas to provide researchers and educators with additional data to enrich this study’s interpretations.

*Jubilee Science Camp schedules and lesson plans can be found at the Randolph College Science Education Group’s website resource for teachers (The New Science Teacher).*

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**References**


Engineering practices occupy a prominent position in the new *Framework for K-12 Science Education* (National Research Council, 2012); however, these practices are unknown to many science teachers. According to the *Framework*, science students must learn to understand and apply engineering practices (NRC, 2012). The major practice of engineers is product design, and this is best accomplished through computer-based modeling and simulation. The basic components of simulation-based engineering and science practice are illustrated in this article. The Simulation-Based Engineering and Science Teacher Professional Development Program provides an opportunity for teachers to learn how to incorporate modeling and simulation into instruction. This program was developed by NASA to train teachers in the use of innovative engineering practices and to develop resources for the use of these practices in the classroom. Lessons created by the participants of this program and other resources for science teachers have been published in a freely available, online book called *CK-12 Modeling and simulation for high school teachers*. Videos in which the lesson plan authors describe their lessons are available on Youtube.

On August 6, 2012, the Curiosity rover landed on Mars. This amazing event was the culmination of nearly a decade of design work by NASA engineers. A very critical part of this mission was the Entry, Descent, and Landing (EDL) phase. Every detail of the EDL had to be thought about in advance. Of all the variables that play roles in EDL, engineers had to decide which variables were important and build a mathematical model to characterize the system behavior. Using computer modeling to simulate the entire landing sequence, the EDL was practiced millions of times before the rover actually entered the Martian atmosphere. Possible variations in environmental or system parameters were analyzed via Monte Carlo simulations, and their effects on the overall landing systems were quantified. One product of these simulations was predicting the landing footprint. Refinement of the simulation allowed NASA to predict the landing location within a 99% confidence ellipse with a 10-kilometer radius.
Curiosity landed within 2.4 kilometers of the center of the landing ellipse, demonstrating the effectiveness of the engineering design process. The story of the Curiosity rover illustrates the fundamental practices of engineering and the vital components of these practices.

In *A Framework for K-12 Science Education*, science and engineering practices are recognized as one of the three fundamental dimensions of science, along with core disciplinary ideas and cross-cutting concepts (National Research Council, 2012). The framework states that effective science instruction requires the integration of all three dimensions, meaning that engineering practices should not be taught as stand-alone processes or ideas, but rather as integral to the core concepts (National Research Council, 2012). By the time students reach the 12th grade, they should understand and be able to apply engineering practices as they engage in engineering design – similar to how a professional engineer works and learns. Although engineering design can be accomplished through physical modeling and physical simulation, the complexity of modern systems makes physical simulation and testing cost prohibitive. On the other hand, the availability of high-powered computers now facilitates computer modeling and simulation at a relatively low cost. Such simulations enable engineers to evaluate a wide range of environmental conditions and system parameters, and to repeat them millions of times, all at a fraction of the cost and time of actual simulations. In short, computer modeling and simulation are an essential component of contemporary engineering design. The prominence of engineering practices in the new *Framework* implies that computer modeling and simulation should be taught in K-12 science courses. This article provides an introduction to computer modeling and simulation, describes a professional development program for teachers that offers training in these computational processes, and describes resources that are available for teachers.

**What is SBE&S?**
Simulation-based engineering and science (SBE&S) is the use of computer modeling and simulation to create solutions for real-world problems. This engineering process is an example of how to apply the eight essential practices found in the Framework (National Research Council, 2012):

1. Defining problems.
2. Developing and using models.
3. Planning and carrying out investigations.
4. Analyzing and interpreting data.
5. Using mathematics and computational thinking.
6. Designing solutions.
7. Engaging in argument from evidence.
8. Obtaining, evaluating, and communicating information (adapted from p. 49).

Engineering begins with a problem that needs to be solved. Engineers use modeling and simulation to test proposed solutions. A *model* is a simplified representation of a system under study. The creation of a model involves selecting key attributes, making simplifications and approximations, and defining relationships between the system variables. A *simulation* is a method to predict the behavior or state of the system at future points in time. Throughout the modeling and simulation process investigations are planned and conducted and the resulting data is analyzed and interpreted. Mathematics and computational thinking are needed to find relationships between the variables involved in the model and to create a computer-based simulation. The iterative design process engages engineers in the use of evidence to support which solutions are optimal. Thus, modeling and simulation embodies the eight practices identified in the *Framework* as essential to K-12 science and engineering curricula.
Modeling and simulation can be used for many different purposes. At NASA, typical applications include models and simulations of entry, descent, and landing (EDL), such as the landing of the Curiosity rover on Mars. This EDL was simulated millions of times to evaluate all flight systems and to predict where the rover would land. Existing knowledge about the conditions of the Mars atmosphere is not perfect; however, the average conditions are known, as well as the statistical lower and upper bounds. The Monte Carlo simulations used a random number generator to vary each input parameter, thereby simulating the many possible conditions that could exist during the landing. Besides atmospheric conditions, the simulations perturbed many other system parameters that might affect landing, with each simulation manipulating thousands of variables. In this way, the successful landing of Curiosity was rehearsed millions of times in the years leading up to the actual mission. Applications of modeling and simulation extend to many other disciplines as well.

Modeling and simulation approaches to problem-solving represent a significant shift from the typical kinds of problems solved in science courses. Most academic science problems are idealized situations that can be solved using pre-existing equations, or closed-form solutions. For example, most high school physics textbooks provide the equations of motion to predict the trajectory of a projectile. However, once the effects of air drag are included, the motion of a projectile can no longer be predicted accurately using closed-form equations. When high school physics students are calculating how fast a baseball has to be hit to make it over a fence, the effect of the air on the flight of the ball is neglected. However, this effect is not insignificantly small (as students are often led to believe). The closed-form solution is wrong! Through the use of computer modeling and simulation, students can include and account for the effects of air resistance without the use of calculus, using a spreadsheet. Modeling and simulation allow
students to find more realistic solutions for problems using the same techniques that are used by practicing engineers.

Connections to the New Framework

Modeling and simulation are emphasized in *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. “Mathematical and computational representations of established relationships and principles are an integral part of design” (National Research Council, 2012, p. 51). The Framework also indicates that by grade 12 students should be able to use an existing computer simulation, or develop a simulation, using simple computer tools to understand and investigate aspects of a system (2012). Furthermore, students should develop skills with modeling tools (such as Excel or other software) so that they “come to value this core practice and develop a level of facility in constructing and applying appropriate models (2012, p. 59).” Clearly, computer modeling and simulation are poised to become an important part of science and engineering education. However, most practicing science teachers have not learned these skills.

The Simulation-Based Engineering and Science Teacher Professional Development Program at NASA was designed with the goal of training teachers how to teach using innovative engineering and design practices. This year, the third year of this program, 20 science and mathematics teachers participated in the two-week program at NASA Langley. The ten teams, of two teachers each, represented eight different Virginia high schools. The two-week program had four components: specialized SBE&S training, training on the use of aeronautics educational materials, tours, and mentoring.

In the SBE&S specialized training, NASA engineers worked directly with the teachers to introduce and demonstrate the modeling and simulation process. Several different simulation
programs were introduced including STELLA, Excel, and E-toys. Teachers learned how simulation could be used in solving problems such as: population growth, deciding the angle and velocity necessary to hit a home run, predicting the lengths of lines at the cash register in the cafeteria during lunch, and predicting the effects of changes in land use on the eutrophication of the Chesapeake Bay. Many simulation resources were presented and made available to the teachers. Sessions also provided opportunities to explore NASA educational resources. A NASA aeronautics education specialist conducted several sessions that demonstrated the integration of aerospace engineering into K-12 education. The teachers toured the different engineering facilities at Langley to get an insider view into the work that takes place there. Each pair of teachers was assigned a professional engineer as a mentor. The mentors helped the teachers to understand how they used modeling and simulation in their own work. Each pair of teachers created a lesson that would bring modeling and simulation back to their schools and classrooms. The mentors provided guidance and assistance to the teachers during this process. Each team of teachers left the program with a lesson that integrated real-world problem solving, modeling and simulation, and the content that they teach. Each team also created a short video about their lesson.

Over the past three years, 78 teachers have participated in the program, and some of the lesson plans that they created have been published in a new freely available online book, the CK-12 Modeling and Simulation Flexbook for High School Teachers (Raiszadeh, 2012). This book is a resource for teachers in grades eight through twelve and contains chapters that introduce and describe the modeling and simulation process as well as lesson plans that successfully integrate modeling and simulation. Videos that provide detailed descriptions of these and other lesson
plans created during this program are available on a Youtube channel at http://www.youtube.com/user/NASASimAero.

The *Flexbook* contains several lesson plans that illustrate how computer modeling and simulation can be integrated into science instruction. One of the plans is called “Exploring Trajectory Optimization Using Simulation”, and was designed for students in grade 8 or 9 who are in Physical Science or Physics. In this two-week long unit, students learn about the engineering design process through an example of trajectory optimization. An Excel-based simulation is used for the students to find an optimal trajectory for a robotic vacuum cleaner. Connections are made to the work done by NASA engineers through an interview with a senior research scientist at NASA Langley. All of the resources needed to teach this unit can be found in chapter 12 of the *CK-12 Modeling and Simulation Flexbook* (Raiszadeh, 2012).

The NASA Simulation-Based Engineering and Science Teacher Professional Development Program and the *CK-12 Modeling and Simulation Flexbook* (Raiszadeh, 2012) are valuable resources for teachers who want to learn how to integrate engineering design. Engineering practices have a more substantial role in the new *Framework* and this change will require significant changes to how science is taught. Collaboration between K-12 institutions and agencies such as NASA will be necessary to realize the goals specified in the *Framework*. The education office at NASA Langley is dedicated to supporting teachers and K-12 STEM education.

For additional information about the Simulation-Based Engineering and Science Teacher Professional Development Program program contact Dr. Thomas Pinelli of NASA Langley’s office of education (thomas.e.pinelli@nasa.gov).
References


The Magnificent Magnifying Lens

By J.S. Flannagan and H.L. Newton

Review by Anne Mannarino

What does a butterfly look like up close?
What colors are in the dirt, other than brown?
And how do you find out?

Use The Magnificent Magnifying Lens!

Jenny Sue learns all about how to use a magnifying lens, and she wants to tell you, too! This nifty tool can help you be a real scientist discovering parts of the world that are too small for your eye to see!

This is an excellent book for children in preschool and early elementary. The book is a narrative non-fiction and allows children to learn new “Fancy Words” through the story of Jenny Sue. There are vocabulary enrichment and extension lessons at the end of the book. If your child has ever wondered what it is like to be a scientist and has the passion to explore, then this book will open their eyes to exploring, asking questions, and sharing the love and knowledge of science with their friends. Teachers can use this book in the classroom to engage children in the use of scientific tools, careers in science, and a fun way to show explore the world around them.