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43 Aspirin Synthesis: A New, Inexpensive Twist on an Old Favorite
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Competitive Advantage:
Using Academic Competitions to Drive STEM and NGSS

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INTRODUCTION

Behind the daily challenges of teaching science concepts, laws and processes, are nagging, even haunting voices who whisper “When will we ever use this?” Thankfully the NGSS are the hearty response to structuring teaching in an integrated format to answer questions of this sort. The exploding world of STEM and STEAM are bridges taking the ancient world of the standalone concept teaching and rote memorization to a comprehensive approach providing an atmosphere more conducive to solving problems. Academic competitions are a model to successfully drive the incorporation of NGSS and STEM by harnessing inherent student drive.

PURPOSE

Academic competitions provide the context where students are challenged to use what they have learned. They can vary in design from simple recitation of learned facts to solving complex problems or designing intricate machines. The competitive element, when properly structured, can elicit from students more than they ever realized they could accomplish. Students quickly learn success requires valuing the process and always look for ways to improve. The engineering cycle of continuous improvement encourages a growth mindset as opposed to a fixed mindset. It encourages all learners to be successful because “winning” can be defined in a variety of ways from final product effectiveness to amount of growth from initial design to end result. The number of iterations of the improvement cycle can be emphasized to show how small incremental growth over a period of time can lead to great advances. Competitions at root level are a way of measuring how competitors stack up in comparison to each other or to some standard. Some might argue a detrimental effect on students who feel unprepared or lack confidence or ability. However, the opposite has been true, because competitions can actually drive the need for more learning or successful implementation of what is already known. While not all students will make the same gains or demonstrate the same quality of final product, properly-structured academic competitions can be an incubator where true learning grows as concepts are applied in context to solve problems. The end result is students who can take what has been learned and use it effectively, not in the abstract only, but in reality where deadlines, budgets, and cooperation with others matters. Points of emphasis for the value of competitions in academic settings.

• Complexity and comprehensiveness of STEM and NGSS
• Need for context and relation instead of stand-alone concepts
• Meaningful end-goals
• Process, process, process
• Not the answer for everything, but a valuable component
TYPES
The beauty inherent in academic competitions centers on flexibility, adaptability, and absence of the one perfect way to do them. They can range from a simple classroom activity developed to increase student interest, to sponsored state, national and even international events requiring months of preparation and complex final products. They can be individual or team oriented, simple or complex, using expensive or household materials. Importantly, some can be very expensive, but most are either free or relatively inexpensive. Many universities sponsor high school competitions to identify prospective students. Non-profit educational groups like Square One Education Network provide great programming and competitive opportunities for little to no cost. The primary common factors uniting any type of effective competition involve a result-driven objective and a process-oriented approach. Criteria to be mindful of when designing or entering competitions are:

• Number of students engaged (Ideally all students)
• Full on competition vs adding elements to existing labs or projects
• Individual vs. Teams
• Personality test and roles (Valuable for effective cooperation)
• Limiting factors (Parameters students who will find loopholes)
• Documentation (Lab notebook, Online Doc, design schematics)
• Assessment and Measuring Success (How do you win?)

Examples: Not an exhaustive list, but a starting point

Local: Competitive elements can be added to any activity

• Ping pong ball launcher with targets (Physics)
• Identify unknown substances (Chemistry)

Regional
• SAE Detroit Section Micro-Electric Car competition https://www.sae-detroit.org/students/collegiate/micro-electric-vehicle-competition/
• SAE Detroit Section Poster Competition https://www.sae-detroit.org/students/collegiate/2157-2/
• University of Toledo High School Engineering Competition http://www.utoledo.edu/engineering/

State
• Square One Education Network http://www.squareonenetwork.org/
  - Innovative Vehicle Design
  - Underwater robotics
  - V2X http://www.trafficandtransit.com/v2x
• Governor’s High School Cyber Challenge https://www.merit.edu/cyber-challenge/
• Michigan Mathematics Prize Competition http://www.nmu.edu/mathandcomputerscience/mi-mathematics-prize-competition
National: Many sponsored competitions start at a local level with the opportunity to advance to higher levels based on success.

- TRAC MDOT http://www.michigan.gov/mdot/0,4616,7-151-9623_38029_38059_41397---,00.html
- Ferris State University Spaghetti Bridge Competition https://ferris.edu/HTMLS/othersrv/sbridges/
- SeaPerch Underwater Robotics Challenge http://www.seaperch.org/index
- ACS Chemistry Olympiad https://www.acs.org/content/acs/en/education/students/highschool/olympiad.html
- AAPT PhysicsBowl https://www.aapt.org/Programs/PhysicsBowl/

Global: These promote the ability to not only compete on a larger stage, but to be internationally aware of education and trends on a much larger scale than normally accustomed to.

- Junior Breakthrough Challenge https://breakthroughjuniorchallenge.org/

OUTCOMES

These are fairly self-evident, though I have often been surprised at the lengths students will go to excel once imagination has been captivated. Even students identified as low-interest can be successfully motivated depending on how the competition is structured and scored. Not that winning shiny trophies is bad, but ultimately true success is gauged by successful application of learning and practices developed. Academic competitions produce students who can:

- Work cooperatively maximizing each member’s strengths
- Value process and improvement
- Identify need for conceptual knowledge to produce best product
- Observe and Document accurately
- Analyze data effectively to make decisions
- Think critically and communicate
- Solve problems

Ping Pong Launch Test 1: These students are testing their ping pong ball launcher created in an AP Physics classroom competition that is an application of projectile and rotational motion. They are aiming for two different sized buckets to score points. They analyzed data from testing to then redesign their launcher and improve its performance. The teams went through multiple iterations of the engineering cycle to achieve their final product.
Without having referred to STEM/STEAM or NGSS explicitly up to this point, revisit the ideas being presented here in light of what STEM and NGSS are intending to accomplish. How might competitions enable your students to achieve contextualized learning and successfully integrate current science trends? Do competitions encourage knowledge of core ideas, crosscutting concepts, and successful practices? Do competitions use Science concepts, the effective use of Technology, the ability to use Math to analyze data, and the Engineering process to continually improve the final product? How might the use of academic competitions compliment or revitalize current classroom culture and practice?
Whether it’s a biomedical breakthrough or an archaeological discovery, students and professors in Wayne State University’s College of Liberal Arts and Sciences work side by side to change our understanding of the world. WSU gives undergraduates the chance to learn across disciplines, combining the personal experience of a small college with the global advantages of a major research university.

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In our seventh-grade science class, we recently learned about energy waves. Students were asked the questions: Is there a relationship between frequency, wavelength, and speed? If so, what is it? If not, why?

I could teach about frequency, wavelength, and speed by having students memorize definitions, teaching them the math formulas, and having them do practice problems—then testing them on it. Instead, I had students use the vocabulary, design a model, and plan an investigation in order to discover the math formulas.

As a society and as science educators, we are in a transition from a focus on knowledge itself to a focus on putting that knowledge to use. That shift is behind Michigan’s move to a new paradigm for science teaching, the Next Generation Science Standards (NGSS), adopted last year.

The United States’ ability to innovate depends on science education. Citizens are required to use critical thinking and communication skills in a global economy driven by advancements in Science, Technology, Engineering, and Math (STEM).

The potential payoffs for students are big. The National Science Foundation reports there are currently 2-3 million unfilled positions due to the lack of qualified candidates in the areas of STEM.

The NGSS emphasizes the eight practices essential to scientists and engineers in their workplaces and intertwines these practices with the core ideas students are learning in science class. They include asking questions and defining problems; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing applications and designing solutions; engaging in argument from evidence; and obtaining, evaluating, and communicating information.

MICHIGAN SCIENCE TEACHERS TEST DRIVING “NEXT GEN” STANDARDS

When students are engaged in these practices, they learn how scientific knowledge is developed and how it is linked to engineering and other problem-solving fields of thinking.

In my energy waves lesson, the class designed an investigation for small groups to carry out. Then each small group developed a model of a wave using a slinky, meter stick, and stopwatch to measure frequency, wavelength, and speed. Students—not the teacher—determined how to measure the time it takes for the wave to travel down the length of the slinky and back.
All students collected data and recorded their observations. They analyzed the data and computed averages in search of a mathematical pattern or proportional relationship.

I was impressed with their organized data tables and graphs. If students found a mathematical relationship, they were asked to construct an equation or formula to compute quantities.

In their conclusion, students had to answer the investigation questions and write an argument for their claim supported by evidence from their data. Each small group had time to discuss and communicate their results to the entire class.

Many of the small groups discovered a cause-and-effect relationship between frequency, wavelength, and speed. Those who did not figure it out on their own did understand it after the reporting out and whole-class discussion.

That's an important point to make: This is not a magic solution for every student to get the “right” answer immediately. However, I believe my students understood more deeply what I was teaching, because they could apply abstract concepts back to what they saw with the slinky.

Engaging students in scientific practice also makes reading more relevant. As my seventh graders set out to investigate the properties of waves, they read “What are Waves?” to guide their thinking. As they did the work of exploring the interactions of frequency, wavelength, and speed—looking for patterns and relationships—we read an article titled “Wave Properties.”

Students were more engaged in the reading since they were seeking answers to real questions, which makes it easier to embed Common Core State Standards for Literacy into science teaching.

As the NGSS begin to take the focus off rote memorization, reading, writing and critical thinking will become fundamental skills in a science class—just as they are in a world of 21st century problems that need solving.

That means we need to teach young people how to read and think critically by modeling the strategies we expert readers use to comprehend science text—skills that will be paramount in their lives as citizens and participants in the world.

Was my lesson plan perfect? No. As always, I’ve reflected on ways to make it better next time—for example, by assessing individual student understanding through some kind of visible (active) response to questions, differentiating my instruction for individuals who need re-teaching, and offering reading selections at varied readability levels.

Change is messy, and I am shifting my practice. Teachers beginning the transition to the NGSS should expect to have some trial-and-error, but that is appropriate. After all, trial-and-error is the scientific way.
Recently, I had the experience to observe and work alongside a truly inspired and ecologically-minded teacher. I am a retired science teacher, as well as a master naturalist and was asked to participate in a recent field trip farm experience at Clarkston Family Farms by founder, Chelsea O’Brien. My purpose in writing this brief article is to inspire other teachers to take advantage of this meaningful resource for your class of students; future environmentally conscious citizens.

FOUNDER AND MISSION STATEMENT
As educator, environmentalist and enthusiastic founder of Clarkston Family Farms, located in Clarkston, Michigan, Chelsea O’Brien was clear about her passion to get kids out in nature and making that natural connection through hands-on experiences. The farm’s mission statement serves as a curricular guide and supports the NGSS, next generation science standards. The mission statement: to educate and inspire the next generation about healthy food, sustainability, and the value of nature, while creating a positive community gathering place.

ABOUT THE PROGRAM
This extremely relevant outdoor educational experience is based on the 10/20/70 formula for learning. The ten percent is “Sit and Get”, observational learning, twenty percent “Turn and Talk”, sharing out what has been learned and experienced, and seventy percent” Move and Do”, hands-on inquiry-based learning in a natural setting.

In thinking about spring, which is right around the corner, the Clarkston Family Farm offers teachers the opportunity to allow students to experience nature first hand. Field trip themes include, Getting Your Thumbs Green, Wonderful Wetlands, Bees, Butterflies, Blooms.
Fantastic Forests, and What’s Down Under? Each ecological theme includes learning about an ecosystem bird, music and movement integration, a literature and writing connection, a Hands-On NGSS supporting activity along with a Make and Take and a Healthy Snack.

The Clarkston Family Farm field trip experience can also be designed to meet the curricular needs of the classroom teacher and program. Individual teacher requests and specific grade-related activities are welcome as lesson designs can be easily modified.

The two-hour sessions for up to 100 students are affordable, too, priced at only $4.00 per student. Grants are available, upon request. Clarkston Family Farm is located at 6800 Hubbard Rd. Clarkston, MI 48348. To view more information about available educational programs and events, visit the website at www.clarkstonfamilyfarm.com. I can not speak too highly about this program and the visionary work Chelsea O’Brien is doing for future generations. This will be an outdoor educational experience that your students will remember forever and mean it when they say “We Dig It!”
DISTANCE LEARNING

What is ECHO?
Visit the Michigan Science Center and engage in hands-on learning without leaving your classroom! Our new ECHO program allows groups to interact and engage with educators while participating in three dimensional, NGSS-aligned lessons.

Why ECHO?
Our videoconferencing programs allow you to interact and engage with an educator in real time with only the click of a link. No special hardware is required. All our lessons are NGSS aligned and truly take on the three dimensional learning approach. We embed science and engineering practices, disciplinary core ideas and cross-cutting concepts in every lesson.

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WHAT DOES THE FARM SCIENCE LAB PROVIDE?
• NGSS standard-based lessons for grades K-6, developed by a certified teacher
• Hands-on science experience
• An applied look at agriculture in our everyday lives
• Agriculture-related extension materials for each classroom
• Climate-controlled, handicap accessible trailer
• Up to five 50-minute classes per day
• 10 work stations (3 students per station)

WWW.FARMSCIENCELAB.ORG
For more information about how you can book a FARM Science Lab visit to your school, contact us at farmsciencelab@michfb.com or call 517-679-5969.
INTRODUCTION

Designing science instructional materials that are engaging for students takes time and creativity. Teaching in a manner that promotes scientific explanation is much more than providing and managing materials and activities for students to conduct investigations. Engaging students in kit-based science or lab investigations in and of itself is not inquiry. Scientific inquiry that goes beyond teaching the facts or what we know provides opportunities for students to share, discuss, debate, and argue the complex set of ideas information, beliefs, and questions that they bring to learn in the classroom. Designing, establishing, and managing science inquiry learning environments is difficult (Krajcik et al. 1994; Duschl and Gitomer, 1997; Black and Wiliam 1998). Consider the following excerpt from Roger Bybee:

In science, reasoning and argument are essential for clarifying strengths and weaknesses of a line of evidence and for identifying the best explanation for a natural phenomenon. Scientists must defend their explanations, formulate evidence based on a solid foundation of data, examine their understanding in light of the evidence and comments by others, and collaborate with peers in searching for the best explanation for the phenomena being investigated. (Bybee, 2011, p. 4)

Assessing student learning in an inquiry-based learning environment is not an easy task for the science teacher. This article attempts to lay out a process where students can plan, carry out, and reflect on their own science learning. The technique uses the backwards design process (Wiggins and McTighe, 2005) so that the teacher can design appropriate assessment for an inquiry science learning classroom environment.

Current research on intelligence and the brain suggests that we learn best when we are engaged in meaningful classroom learning experiences that help us discover and develop our strengths and talents (Silver, Strong and Perini, 2001). It is through these learning experiences that teachers not only motivate our quest to learn, but also foster the development of persistence and effort that is necessary for acquiring skills, knowledge, and attitudes in sufficient depth for us to be able to apply them in other settings. The prior knowledge that we bring with us to a new learning situation exerts a tremendous influence on how we interpret this new experience. In order to successfully learn new information, we must be able to construct meaning actively and relate it to our own lives in a meaningful way. Teachers should focus on the learner’s understanding of content and the ability to use the information rather than on the memorization of isolated bits of information. The new information that the student is engaged in learning focuses on “real life” or “authentic” tasks that require problem solving, creative thinking, and critical thinking. This approach requires teachers to structure
what is addressed instructionally and in the curriculum around key ideas rather than try to “cover content”.

When the teacher starts from where the learners are, helps them to take responsibility for their learning, and develops peer-and self-assessment to promote metacognition, the teacher becomes a supporter rather than a director of learning. This idea was taken further by Vygotsky (1962), who explained that because learning proceeds by an interaction between the teacher and the learner, the terms and conventions of the discourse are socially determined, and its effectiveness depends on the extent to which these terms and conventions are shared (Bransford, Brown, and Cocking, 1996; Boaler, 2000; Lemke, 1990; Wood Bruner, and Ross, 1976).

As educators it is of the utmost importance that we recognize and nurture all of the varied ways students learn. Through this recognition, we can increase our students’ learning and problem solving abilities if we increase their repertoires of problem solving tools by actively encouraging them to use all facets of intelligence (Parry and Gregory, 2006).

Similar arguments can be applied to other learning activities, notably the marking of written work, the use of peer-and self-assessment, the possibilities for the formative use of written tests, etc. As teachers change to make formative assessment a constant feature of their work, they will inevitably be changing their roles as teachers. They have to be more interactive with their students, and they have to give them more responsibility for their learning. This leads to a change in role, from directing students to empowering them (Black, et al, 2002; Black, 2003). One such tool that moves toward student empowerment is the backwards design model.

A BACKWARD DESIGN APPROACH
The backward design model (Wiggins & McTighe, 2005) centers on the idea that the design process should begin with your goals and by identifying the desired results of a project and then “work backwards” to develop instruction rather than the traditional approach which is to define what topics need to be covered. The model framework consists of three main stages: (1) identify desired outcomes and results for the assignment; (2) determine what constitutes acceptable evidence of competency in the outcomes and results (assessment); and (3) plan instructional strategies and learning experiences that bring students to these competency levels.

Stage 1: Identifying Desired Results. Wiggins and McTighe recommend that instructors first identify project outcomes to consider not only the course goals and objectives, but the learning that should endure over the long term. This is referred to as “enduring understanding.” Wiggins and McTighe suggest that “the enduring understanding” is not just “material worth covering,” but includes the following elements:

- Enduring value beyond the classroom;
- Values residing at the heart of the discipline;
- Required coverage of abstract or often misunderstood ideas; and
- Offering potential for engaging students.

Backward design uses a question format rather than measurable objectives. By answering key questions, students deepen their learning about content and experience an enduring understanding. The instructor sets the evidence that will be used to determine that the students have understood the content. These questions focus on the following:
• To what extent does the idea, topic, or process reside at the heart of the discipline?
• What questions point toward the big ideas and understandings?
• What arguable questions deepen inquiry and discussion?
• What questions provide a broader intellectual focus, hence purpose, to the work?

Once the key concepts-questions are identified, it is time to develop a few questions for the service-learning experience that apply the line of inquiry to a specific topic.

**Stage 2: Determine Acceptable Evidence.** The second stage in the backward design process of the service-learning project is to define what forms of assessment will demonstrate that the student acquired the knowledge, understanding, and skill to answer the questions.

Wiggins and McTighe define three types of assessment:

• Performance Task— The performance task is at the heart of the learning. A performance task is meant to be a real-world challenge in the thoughtful and effective use of knowledge and skill— an authentic test of understanding, in context.
• Criteria Referenced Assessment (quizzes, test, prompts). These provide instructor and student with feedback on how well the facts and concepts are being understood. ISN’T THIS MEASUREABLE?
• Unprompted Assessment and Self-Assessment (observations, dialogues, etc.).

**Stage 3: Plan Learning Experiences and Instruction.** The third stage to planning is actual involvement in the learning experience and instruction itself. In this stage it is determined what sequence of teaching and learning experiences will equip students to develop and demonstrate the desired understanding. With clearly identified results and appropriate evidence of understanding in mind, it is now time to fully think through the most appropriate instructional activities. Several key questions must be considered at this stage of backwards design:

• What enabling knowledge (facts, concepts, principles) and skills (processes, procedures, strategies) will students need in order to perform effectively and achieve desired results?
• What activities will equip students with the needed knowledge and skills?
• What will need to be taught and coached, and how should it best be taught, in light of performance goals? What materials and resources are best suited to accomplish these goals?

Backwards design may be thought of as purposeful task analysis: Given a worthy task to be accomplished, how do we best get everyone equipped? What must learners master if they are to effectively perform? This is all quite logical when we come to understand it, but backward from the perspective of much habit and tradition in science education. A major change from common practice occurs when designers must begin to think about assessment before deciding what and how they will teach. Rather than creating assessments near the conclusion of a unit of study (or relying on the tests provided by textbook publishers, which may not completely or appropriately assess our standards or goals), backwards design calls for us to make our goals or standards specific and concrete, in terms of assessment evidence, as we begin to plan our unit.
DESIGNING ASSESSMENT RUBRICS

By their very nature, the products generated from student projects tend to be complex, filled with a variety of subjective outcomes. A rubric is an assessment tool used to measure students’ work. It is a scoring guide that seeks to evaluate a student’s performance based on the sum of a full range of criteria that can be interpreted and translated into a score or grade. A rubric is a working guide for students and teachers, usually handed out before the assignment begins in order to get students to think about the criteria on which their work will be judged. A rubric is one type of authentic assessment tool that is very useful when assessing complex and subjective outcomes. As an assessment tool, rubrics are designed to relate to real life activities as a formative, ongoing part of the assessment process. Used as a scoring guide, a rubric allows a students’ performance to be evaluated on a wider range of criteria rather than a single numerical score. Pickett and Dodge (2001) have identified a number of advantages to using rubrics which include: objective and consistent assessment; clear, specific outcome criteria; no surprises, students know how their work will be evaluated; increased student awareness about criteria to use in assessing peer performance; useful feedback related to instruction effectiveness; and benchmarks for measuring and documenting progress.

STUDENT-DESIGNED RUBRICS

Allowing your students to create their own rubrics to assess their project outcomes will increase learning focus and self-direction. Involving students in the creation of rubrics in all subjects, including science, allows for increased student involvement as called for by Wiggins and McTighe. Even young students can successfully create rubrics.

Try the following activity with your students to help them become familiar with the rubric design process. Divide the students into teams (use their project teams if possible). Provide a plate for each team containing four different brands of chocolate chip cookies and a blank rubric table containing a 5X6 square grid. Ask the students to brainstorm a list of chocolate chip cookie elements that they will judge. For example: taste, texture, color, flavor, and number of chocolate chips. Write these elements in the left-hand column of the table. Decide on a scoring range based on a numerical value from 1 to 4. One possibility is diagramed in the table below with the row for taste filled in:

<table>
<thead>
<tr>
<th>DELICIOUS = 5</th>
<th>GOOD = 4</th>
<th>NEEDS IMPROVEMENT=3</th>
<th>POOR = 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taste</td>
<td>Home-baked taste</td>
<td>Good store-bought taste</td>
<td>Tasteless</td>
</tr>
<tr>
<td>Texture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flavor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of chips</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Each team then decides the criteria to list from 1-5 for each cookie element. Be prepared for lively discussion and disagreement as each team discovers that not everyone agrees on the best tasting cookie brand! Your students may use different elements for their rubric, or may decide on different descriptor names for each score, that’s OK.

Once students have a basic understanding of what a rubric is and how it is used, they can then begin to construct an assessment rubric for their team project. Through the process of backwards design you and/or your students have already determined what outcomes will be part of the project assessment. Explain to the students that they will be responsible for determining how well they have learned, what the strengths and weaknesses of the project are, and where they need to try harder. By having students design and use their own rubrics they begin to view assessment as a positive tool for learning and personal growth rather than a reward and punishment system (Stix, 1997).

Use the same steps as the cookie rubric activity to assist your project teams in designing their class rubric for assessing their service-learning project. For example, if the final outcome of the project is a poster presentation ask the class what they might look for to grade their final project. Strive for a list of six to eight elements or qualities, allow discussion, and then ask each team to rank the elements from most important to least important. Settle on three to four elements. These are listed in the left column of the rubric table. Determine what would be considered ‘poor’, ‘fair’, ‘good’, and ‘excellent’ qualities for each element to fill in the rest of the rubric. To determine the proficiency ratings for each element, Stix (1997) recommends selecting neutral words. A science-based project, for example, can use words that thematically reflect the topic being studied. A project in astronomy might have proficiency ratings of comet, moon, planet, and sun; or in life sciences of larvae, pupa, cocoon, and butterfly. Including a numerical score is also helpful to differentiate between criteria that are almost proficient but not quite ready to move to the next level.

Once developed, a rubric can be adapted for assessing additional projects throughout the year. They allow students to know beforehand what they will be evaluated on, what makes a good project, and why (Pickett and Dodge, 2001). The rubric should be posted in the room as a reminder and working guide for students and teacher.

**REFLECTIVE ASSESSMENT**

The decision to use reflection as an assessment tool is one that requires prior planning and thought. The teacher must first decide on the method of reflection to be used. Students might be asked to record thoughts, observations, feelings, activities, and questions in a written journal that is maintained throughout the project period. Projects that require a team approach may use a team journal to ensure interaction within the group. Students can be assigned a paper to write based on their journal or engage in class discussions to encourage critical thinking about their project. Whatever method or methods are selected must be based on the project outcomes defined early in the planning process. In addition, the teacher must decide on two critical elements for using reflection as an assessment tool. The first is to determine if the reflective piece will be assigned a grade or simply be completed by the student. The second decision to be made involves the amount and type of structure or guidance to be provided for the reflection assignment.

For many students, the experience of learning tends to get lost in the process of ‘getting the job done’. Adding a reflective element allows students to examine their experience, make
connections between what they have done and the results, and translate that experience into knowledge (Eyler, Giles, & Schmiede, 1996). Through reflection, students make connections between theory and practical application. They look within themselves to discover what they have learned and how that process of learning may have resulted in changes. Unlike objective tests, reflective products tend to be subjective with students having an emotional and very personal connection to the outcome. A teacher may discover that students share their thoughts and feelings during reflection that leaves them vulnerable to criticism. However, by reflecting on what they have learned, students inform the teacher on how well learning objectives and outcomes have been met. The challenge then becomes how or even if to assess reflective products with grades.

The type of reflection method selected guides a portion of the answer as to whether or how to assess reflective assignments. An unstructured journal or class discussion where students are asked to reflect on their feelings, attitudes, or experiences may be best graded for completion in the form of credit or no credit. However, to objectively assess reflections requires the use of guided questions and structured reflection assignments.

Rama (2001) defines structured reflection as a process that is used to challenge and guide students in:

- examining critical issues related to their project;
- connecting the experience to coursework; and
- assisting students in finding personal relevance in their learning experience.

Reflection is most effective as a structured, guided, purposeful activity that occurs on a regular basis. To be assessed, the reflective components must be based on criteria that is well defined, linking the project objectives to the course objectives, and including both private and public reflection (Eyler, Giles, & Schmiede, 1996).

One of the most common methods of reflection used in classrooms occurs as a guided reflection paper. These can be thought of as a more formal example of journal entry where a students’ writing is guided by a series of questions. Students are asked to consider their learning experience within the context and framework of their science project. They may be asked to reflect on how they felt their group worked together, what the overall goal of their project was, to identify a concept or idea they learned that was new to them, how their group made decisions about the steps to follow for successful completion of their project, or to pick out the one most important thing they learned.

For younger children, students can be engaged in a guided discussion lead by the teacher. Students are asked to consider their learning experience within the context of their science project. The students may verbally respond to how they felt about the working in a group, how well they accomplished their learning goals and the goals of the project, or what they learned as a result of the project.

A series of objective questions can also be included that requires the student to conduct more research in the library or on the Internet. Students can identify the steps they took to complete their project, allowing the teacher to ensure that appropriate problem solving skills are being employed. Objective questions are more easily assessed for depth of research, correct number of references, or project management. For any reflective assignment it is
critical that the assessment criteria are shared with students beforehand.

The following framework will assist the development of reflective questions that are pertinent and connected to a specific project.

<table>
<thead>
<tr>
<th>PROJECT PERIOD</th>
<th>ASSESSMENT PROCESS AND ACTIVITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Beginning</td>
<td>Ask students to reflect in their journals about what they already know, believe, or assume related to their project concepts. What do they expect to learn? Give them a question to explore during the project.</td>
</tr>
<tr>
<td>Behind the Scenes</td>
<td>Observe and listen to the students as they work in teams. What challenges are they encountering within their groups? What do they need more information about? What would help them move their project along? Make notes then have a class discussion and ask the students to identify their challenges, what questions they need answered, and what information they need. Have them write their questions in their journals and find the answers.</td>
</tr>
<tr>
<td>Project Completion</td>
<td>Although a guided reflection paper is the most commonly used method of assessment it is not the only one. Ask your students how they could demonstrate their knowledge or illustrate their experience. It might be through a skit, debate, song, or story. They may want to make a picture book of concepts for young children or put on a play for classmates. All of these can be valuable reflective experiences.</td>
</tr>
<tr>
<td>Providing project facilitation and feedback</td>
<td>Ongoing. If students are keeping project long journals review them on a regular basis. Provide nonjudgmental feedback, write responses, listen well, and ask questions. Appreciate the learning experience your students reveal.</td>
</tr>
</tbody>
</table>

Reflection helps students to improve their basic communications skills both orally and in written form. It assists students in self-examining their learning experience and leads to the development of better critical thinking skills. Students integrate their knowledge through the experience of reflection and begin to build a strong, basic understanding of underlying concepts and theories. By discussing and reflecting on their learning experiences students exchange critical ideas and insights about the information being shared. Deliberate and guided reflection leads to expanded learning and understanding. Reflection creates meaning.

The following questions are examples of actual guided reflection questions used during a class where students were conducting a science project concerning environmental issues.

- What have you learned from participating in taking action about your specific topic?
- What impact has participation in the action team project had on your life?
- In the future, if you became concerned about an environmental issue would you be likely to take action? If so, what kinds of actions would/could you take?
SCIENCE PROJECT ASSIGNMENT

The science project described below uses the backwards design process and poses a general outline for students to design a research project for a science topic. A student planning form, a description of the project, and a suggested rubric are provided. The project is described in general terms so that teachers can use the format in a flexible manner.

Attached is a Science Project Rubric that will be used to evaluate your science project. There are several parts to the Science Project Assignment that you must complete to get full credit for the project.

- Science Project Planning Form
- The Science Project itself
- Your reflection on the science project

The Science Project Planning Form needs to be completed **before** you begin your project and must be approved by your teacher before you begin. You must find a topic/problem that you wish to learn more about and make a plan of how you will find out more about the topic or problem. The purpose of this form is for you to plan the project ahead of time so you and your teacher will know what you are doing. Look at the Science Project Rubric to find out exactly what you need to plan to include in your project.

Your plan should include the following information: the project title, a brief description of the project, the statement of the problem, the procedure you plan to use to complete the project, the format of your project, how you will make your project interesting and unique, how you will present your project and a timeline for completion of your project.

You also want to make your project as original and attractive as possible using color and illustrations, and you must decide what format you will use to display or present your project. In addition the project must be completed on or before the deadline, and you must use proper grammar and spelling.

The project itself must contain all of the parts listed in the rubric to receive full credit.

Your reflections should include a brief description of your project and the reason you chose the topic/problem that you did. Describe how you thought the project went. What did you like about it? What was most difficult for you to do? What did you learn from the project? If you were to do this type of project again, what would you do differently?

CONCLUSION

Designing science projects with a large degree of student input is not an easy task. By using the backwards design process, teachers can consider the outcomes that they want students to achieve before choosing appropriate activities. Since all teachers are under pressure to teach to national, state, and district science standards, considering outcomes first has become a necessary practice.

Another goal for a lot of teachers is to have their students think about their own learning. Using student reflections at the end of a science unit can help teachers to accomplish this goal. Providing students with both rubrics and guided questions lets them successfully
complete the project, as well as think about their own learning. Instead of students simply trying to get the project done, using reflections throughout the project will help them integrate and apply knowledge.

Science Project Planning Form

<table>
<thead>
<tr>
<th>Name:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Project Title:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Brief description of the project:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Statement of the Problem:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Data: How will you gather data? Where will you look for information?</th>
</tr>
</thead>
</table>
What format will your project take? Written Report? Poster? Exhibit?

How will you make your project interesting and unique?

How will you present your project? Written? Orally? As an Exhibit? All three?

Time line for completion.
<table>
<thead>
<tr>
<th><strong>CONTENT</strong></th>
<th>Outstanding</th>
<th>Acceptable</th>
<th>Needs Developing</th>
<th>Not Acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title</strong></td>
<td>Accurate title given.</td>
<td>Title given.</td>
<td>Title is not clear.</td>
<td>No title.</td>
</tr>
<tr>
<td><strong>Introduction</strong></td>
<td>Presents a precise description of the project.</td>
<td>Gives information to help understand the project.</td>
<td>Gives very little information to help understand the project.</td>
<td>No introduction or information is not helpful in understanding the project.</td>
</tr>
<tr>
<td><strong>Statement of the Problem</strong></td>
<td>States the real issue and includes other interesting and pertinent facts.</td>
<td>States an issue somewhat related to the research.</td>
<td>States an issue but not related to the intended research.</td>
<td>Does not state an issue related to the intended research.</td>
</tr>
<tr>
<td><strong>Procedure</strong></td>
<td>Presents easy-to-follow steps that are logical and are detailed. Scientific process is explained.</td>
<td>Most steps are easy-to-follow but with lack of detail or are a little confusing. Scientific method is used.</td>
<td>Some steps are understandable but some are confusing. Difficult to pick out whether the scientific method was used.</td>
<td>No logical steps, or steps are missing or confusing. Scientific method was not used.</td>
</tr>
<tr>
<td><strong>Data/Results</strong></td>
<td>Data table and graph are neat, complete and fully accurate.</td>
<td>Data table and graph are accurate but not as neat or complete as they could be.</td>
<td>Data table and graph are complete but have minor errors or are hard to read.</td>
<td>No data table and/or graph or they are incomplete and/or messy.</td>
</tr>
<tr>
<td><strong>Conclusion</strong></td>
<td>Logical and is based on a full explanation of the findings.</td>
<td>Logical and addresses most of the findings.</td>
<td>Does not have a logical explanation for the findings.</td>
<td>No conclusion or explanation does not address the findings.</td>
</tr>
</tbody>
</table>

| **CREATIVITY** | | | | |
| **Originality** | Project design is unique, original, and shows a clear thought process. | Project design shows thought and attempts to present information in a fresh way. | Project design is fairly straightforward and done in a standard way. | Project design seems copied or approach is lacking freshness. |
| **Attractiveness** | Work processed or typed, clean, neat, format, with bound report with cover or poster or exhibit with color and illustrations | Legible writing, clean, presented with a report cover and/or poster. Little color or illustrations. | Material organized in a folder but not bound. Little color or illustrations. | Not legible writing. Unattractive folder or poster. No color or illustrations. |
## Format

<table>
<thead>
<tr>
<th>Outstanding</th>
<th>Acceptable</th>
<th>Needs Developing</th>
<th>Not Acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demonstration, poster, PowerPoint report, binder report or exhibit that grabs attention and explains the project completely.</td>
<td>Binder report, poster, PowerPoint report or exhibit that explains the project.</td>
<td>Material organized in a folder but not finished.</td>
<td>Material thrown together in an unorganized way.</td>
</tr>
</tbody>
</table>

## Presentation (if required)

<table>
<thead>
<tr>
<th>Outstanding</th>
<th>Acceptable</th>
<th>Needs Developing</th>
<th>Not Acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demonstrates complete understanding of the project and conveys excitement to the class.</td>
<td>Demonstrates understanding of the project and is comfortable getting the ideas across.</td>
<td>Does not display an understanding of the project.</td>
<td>Unsure of how the project is organized or of the content of the project.</td>
</tr>
</tbody>
</table>

## Time-Mechanics

<table>
<thead>
<tr>
<th>Deadline</th>
<th>Project completed and handed in ahead or on time. Effective use of time.</th>
<th>Project completed and handed in on time.</th>
<th>Project one day late.</th>
<th>Project more than one day late.</th>
</tr>
</thead>
</table>

## Grammar- Spelling

<table>
<thead>
<tr>
<th>Outstanding</th>
<th>Acceptable</th>
<th>Needs Developing</th>
<th>Not Acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>All grammar and spelling are correct.</td>
<td>Only one or two errors in spelling or grammar.</td>
<td>More than two errors in spelling and grammar.</td>
<td>Frequent spelling and grammar errors.</td>
</tr>
</tbody>
</table>

## References


PHENOMENAL SCIENCE

A free K-5 science curriculum crafted by teachers and aligned to the Michigan Science Standards

PHENOMENA-BASED
EVIDENCE-BASED
SCIENCE NOTEBOOKS
SCIENCE DISCOURSE
ELA INTEGRATION

MICHIGANVIRTUAL.ORG/PHENOMENAL-SCIENCE
An Analysis of Houghton Middle School Water Properties, Qualities and Environmental Science Project

By Sarah Geborkoff, Houghton Middle School

The project, supported by funds awarded from the 2016 Dan Wolz Clean Water Education grant, sponsored by the Michigan Water Environment Association (MWEA) and open to any MSTA member on an annual basis, targeted my 7th grade students at Houghton Middle School with the goal of engaging students in hands-on learning centered around the understanding of water. Research has shown that if concepts are integrated in multiple ways, learning will take place at a deeper and more meaningful level. The project united grade-level NGSS performance expectations in the areas of earth, life, and physical science into a broad experience that centered on an examination of our school water quality, its effect on our local environment, and sustainability.

Service learning plays an important part in the development of productive citizens, and before this project was initiated, there was no continuous, long-term service project incorporated into any curriculum within our school. As the result of this project, our students complete volunteer work at both the Huron Creek, a local urban stream ecosystem, and they also assist in tending the garden at our school multiple times throughout the year.

The project has given me the opportunity to teach my students about the qualities of water and how it impacts every aspect of their life. Because our students live in the Upper Peninsula, an area with rich mining heritage, they also learn about the effects of mining on our use of land and water and the effects that mining has had on local water quality. This learning inevitably leads to discussion of careers related to environmental science and engineering as students engage in field trips, activities, guest presentations, and service work. The project thrives on the collaboration of many local educators, scientists, and organizations within the community.

Michigan’s Water Resources: Why Should Students Care?

Houghton is in the Keweenaw Peninsula of upper Michigan, an area rich with natural resources. Lake Superior, the largest, coldest, cleanest, and deepest of the Great Lakes, surrounds our community on three sides. My students swim in its icy waters, fish, and enjoy the beauty of the Lake Superior shoreline year-round. It is critical that they appreciate how amazing it is to have this resource in their backyard. If the appreciation is not there, the concern over its protection and management will not be there as this generation reaches adulthood. One of my most important goals, aside from teaching students about the importance of water as a resource and relating it to all areas of our studies in science, is to help my 7th grade students mature and develop into citizens that are truly aware of the
importance of our freshwater supply as well as our other natural resources and who will be actively involved with protecting and managing them far into the future.

The idea of integrating the themes of water quality and environmental sustainability is a perfect way to bring that goal in focus. The hands-on work of engaging students involves activities that include stream monitoring, chemical water analysis, and remediation to stress the importance of maintaining clean water in a community where it has the potential to be degraded by mining activities. The opportunity to help students identify and monitor real-world problems that impact our own community gives them the incentive to continue to become part of an active citizenry that will make a positive impact on our community and the world.

IMPLEMENTATION OF THE PROJECT

In the fall, Mike Schira, a forester from the Michigan State University Extension Service in our county, provided an interactive presentation on freshwater stream quality as it relates to the Huron Creek, part of our local watershed. He hosted a field trip to the creek and supervised testing of the water chemistry. Students sampled for the presence of nitrates, ammonia, phosphates, carbon dioxide and dissolved oxygen. They participated in a biodiversity survey, examining insect larvae and counting the numbers of each species to appreciate the extent of biodiversity that was present in the water. Students used our data to assess the health of the stream. Later in the season, students participated in the Great Lakes Shoreline Clean-up and had the opportunity to analyze the trash that was collected.

As weather turned colder, we brought our studies inside. Activities included a field trip to the Portage Lake Water and Sewage Authority to learn how wastewater is treated to remove material that could be dangerous to either humans or the surroundings. We visited the city water plant to learn how they prepare water to be distributed to homes and businesses in our community. We examined the importance of correctly placing groundwater wells in areas to ensure that clean water flows efficiently. In class, we performed activities that included learning about plant and animal cell structure and we used microscopes to identify freshwater protists.

Spring at last arrived and we continued our study of water by examining the concepts of pH, acidity and alkalinity and how water, as the universal solvent, is critical to maintaining chemical stability that is necessary for life. During a field trip, we toured the ecosystem surrounding the environment of the Huron Creek and participated in an invasive species removal project. Students helped with the organization of a starter plant fundraiser and began greenhouse work that allowed them to learn about planting and flower bed and garden care that extended into the summer months, in concert with a local 4H Youth group.

PROJECT PARTNERS AND THEIR ROLES

Keweenaw Invasive Species Management Area (KISMA) – Dr. Sigrid Resh leads the 7th grade students to Huron Creek each spring to identify and remove invasive plant species from our adopted site. In addition, as part of our ‘Day of Science’ at MTU, Dr. Resh leads student groups in sowing native seeds along the Portage Canal waterfront.

MSUE – Forester Mike Schira comes into the 7th grade classroom to talk about the history behind Huron Creek in terms of the impact of copper mining, urban sprawl, and other human activity as well as the characteristics of a healthy freshwater stream and watershed.
Lucky Charms 4H Club – Currently, 46 Houghton elementary and middle school students participate in this school-based 4H youth club, which helps to maintain the school gardens and greenhouse during summer recess. This club is the only youth service club of its kind in the area that is directly linked to a local school and works together with community stakeholders to sustain a year-round service project. Produce is used by the district lunch program and eaten by our students!

2017 7th grade ‘Day of Science’ at MTU - Materials science session, removing invasive plants (spotted knapweed) at Huron Creek, and using proscopes to view mushroom spores
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Renewable and Nonrenewable Resources: An Integrated Unit for Fourth Grade

By Abbey Kaufman, Lauren Lynn, Marissa Ricketts and Kristin Wolber, preservice teachers, Central Michigan University, and James T. McDonald, Professor of Science Education, Central Michigan University, Department of Teacher Education and Professional Development

BACKGROUND
Four future elementary teachers worked closely in their interdisciplinary courses to design an integrated unit for a fourth grade classroom of students. The teachers were given one social studies and one science standard to build the unit around. The team of teachers then collaborated and designed four lessons that would eventually be taught in a series of four sessions with the students. This unit worked to seamlessly integrate social studies, English language arts, and science standards for a Michigan classroom. Each future teacher took one lesson and chose a foundation subject to build their lesson upon. The first lesson was heavily based on social studies and set the stage for the future lessons as it covered the key vocabulary words and content such as nonrenewable and renewable resources. Following that, students were taught a lesson largely based on mathematics to better understand what the human footprint is. The third lesson took the form of an interactive science experiment so students could see the impact of pollution on a lake, while the fourth lesson concluded with an emphasis on language arts to engage students in the creation of inventions to prevent pollution in the future and conserve the earth’s resources. Contrary to the future educators’ initial thoughts, integrating the various subject areas into one lesson came much more easily than expected! Overall, they felt that their lessons were more engaging than a single-subject lesson and observed their students making connections on their own from previously taught lessons and different content areas.

STANDARDS

State Social Studies Standard

<table>
<thead>
<tr>
<th>Standard Number</th>
<th>Detailed description of each standard you are discussing.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.G5.0.1</td>
<td>Assess the positive and negative effects of human activities on the physical environment in the United States.</td>
</tr>
</tbody>
</table>

Next Generation Science Standard

<table>
<thead>
<tr>
<th>Standard Number</th>
<th>Detailed description of each standard you are discussing.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESS3.A</td>
<td>Energy and fuels that humans use are derived from natural sources and their use affects the environment in multiple ways. Some resources are renewable over time, others are not.</td>
</tr>
</tbody>
</table>
**Common Core Standards**

<table>
<thead>
<tr>
<th>Standard Number</th>
<th>Detailed description of each standard you are discussing for Math and Literacy/Reading/Language Arts.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCSS.MATH.CONTENT.4.OA.C.5</td>
<td>Generate and analyze patterns.</td>
</tr>
<tr>
<td>CCSS.ELA-LITERACY.W.4.2.E</td>
<td>Provide a concluding statement or section related to the information or explanation presented.</td>
</tr>
<tr>
<td>CCSS.ELA-LITERACY.SL.4.1</td>
<td>Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 4 topics and texts, building on others’ ideas and expressing their own clearly.</td>
</tr>
</tbody>
</table>

**LESSON 1**

The first lesson in the integrated unit series was Renewable vs. Nonrenewable Resources. This lesson worked to seamlessly integrate social studies, English language arts, and science standards for fourth grade students. The English language arts focused heavily on discussion, the social studies focused on the type of resources produced in the physical world, and the science component was the vocabulary content of renewable and nonrenewable natural resources derived from the earth. The lesson started off with the teachers giving each student a cupcake. The students were then told that this was the very last batch of cupcakes on earth. Next, they were asked, “Now, that you know this is the very last batch, how would you treat this “valuable” cupcake?” Most of the students answered in ways such as, “I would never eat it, so I could sell it” or I’d break it into a million pieces so that it would last a long time.” The main point that I hoped the students would realize was once it’s gone, its never coming back so we have to use it efficiently.

From there the teachers moved into a teaching strategy called Concept Attainment. The concept attainment activity helps students uncover vocabulary words by using a compare and contrast method with pictures. The point of this activity was to provide students photo examples side by side so that could decipher the vocabulary word attached to each column. In the first column we had a picture of- oxygen, wood, water, puppies- and in the second we had- natural gas, coal, oil, and dinosaurs. The images were shown in 4 rounds, comparing two images, one from each column, to one another. The last example, dinosaurs and puppies is a less concrete comparison that often helps the students come to the conclusion, extinct or nonrenewable vs. replenishing or renewable. One major goal that my team and I strived for was representing the materials in many different methods so that each learning style in the classroom was engaged. With that being said, from the discussion we transitioned into a video titled, Renewable and Nonrenewable Resources, which summed up the topics we had already discussed. From the video, the lesson transitioned into creating two Frayer Model vocabulary charts. The Frayer Model vocabulary charts had four sections: definition, facts, examples, and non-examples. This allows the students to explore and think critically about the term. The two terms that the students explored was nonrenewable and renewable which was matched with a PowerPoint. The charts
sections included: definition, facts/characteristics, examples, and non-examples. They thought it was “so cool” that the examples and non-examples were the opposite on the other sheet. To begin summing up the lesson, the class was invited to join in a team assessment game. The four co-teachers spaced out around the room and each group member was assigned a number for a question or became the scribe. The teachers prepared five questions that the group member would take back to their table, discuss with the group, and then decide on an answer together. The questions included:

<table>
<thead>
<tr>
<th>Number</th>
<th>Questions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>What is an example of a nonrenewable resource?</td>
</tr>
<tr>
<td>2.</td>
<td>Name a renewable resource.</td>
</tr>
<tr>
<td>3.</td>
<td>Humans are an example of ___.</td>
</tr>
<tr>
<td>4.</td>
<td>Gasoline for our cars is an example of _______.</td>
</tr>
<tr>
<td>5.</td>
<td>When we produce more than we consume, it is a renewable resource. True or False</td>
</tr>
</tbody>
</table>

The team with the most correct answers won a free pencil or homework pass. It was great to watch them self-correct and explain the topic to one another. To end the lesson, it’s important to understand where the students are at, and help them make a real-life connection with their learning. The lesson ended with a ticket of the day that asked, “where do we see natural resources in our everyday lives?” Each student had the chance to add their sticky note to the Ticket of the Day board that the teachers can then quickly and anonymously analyze where the class is as a whole. Through collaboration, discussion, differentiation, prior knowledge, and integration, the lesson was setup to prepare the students with similar background information for the following three lessons of the integrated unit.

**LESSON 2**

During the second day of the integrated unit the content area we tried to focus on most was mathematics but it also incorporate science, social studies, and writing. The overall theme of the lesson was the human footprint, the impact that humans have on the Earth. To start the lesson the students were given a problem of the day. This problem used math to determine how many trees would be lost over all in a span of 8 years by the act of humans cutting down and replanting trees based on a statistic. The problem the students addressed was, “Every year humans cut down trees to make different products for us to use and to create land for us to build on. Approximately 15 billion trees are cut down each year by humans. At the same time humans are planting 5 billion trees each year. If these numbers stays the same, what will the total loss of trees be over the next 8 years altogether?” This was meant to get the students engaged in the lesson and start thinking about the way humans affect the planet.

After reviewing the answer to the problem of the day and how the students completed the math portion, one of the teachers had a discussion on what a human footprint is and how it is influenced by human demands for renewable and nonrenewable resources, tying it back to the previous lesson. The teacher had the students come up with countries and different areas on Earth where they thought there might be a large human footprint and small human footprint and why that might be.
After allowing the student's time to discuss this, another instructor pulled up an interactive map (mapmaker.nationalgeographic.org) that showed where there are large human footprints and small human footprints in order to see if the student's ideas and thoughts were correct. She led a discussion on different ways we leave footprints on the Earth and why it is different in some areas. As well as, what they thought could happen if we keep moving forward with a negative human footprint.

We then lead into a small discussion on pollution and how it is just one negative human footprint. We focused mostly on plastic pollution. We showed the students a video of the life cycle of three plastic water bottles. The video starts out with the three different water bottles and it explains how and where they were made. It then goes on to explain what happens to each bottle after it is used and discarded. Bottle ones ends up in a landfill, bottle two ends up in the Great Pacific Garbage Patch, and bottle three is recycled. For each bottles journey the video explains how its destination impacts the Earth.

Video Link: "What Really Happens to the Plastic You Throw Away" (https://www.youtube.com/watch?v=_6xlNyWPpB8)

After watching the video, the teachers lead their own group of five or six students in a science experiment of plastic waste. The groups were determined before lesson one and were the same for each lesson. This allowed us to get to know students better in the short time that we had. Each teacher had collected all of the plastic that they normally would have thrown away over a week's time. Each teacher went through the plastic with their color team and counted how many items they had. They then completed worksheets, calculating how much plastic their instructor would approximately be throwing away over a month and year. They then used the students homework from the previous lesson (to tally how many pieces of plastic they threw away) to see much plastic their group as a whole would have approximately thrown away in a week, month and year. After each group finished, one instructor brought the class back and they added up each groups total to see how much plastic the class would approximately waste in a week, month, and year. The worksheets themselves were simple. They had prompts of what they should calculate next and left room for students to do the math behind the answer. It would have been more ideal for each student to actually collect their plastic for a week like the teachers did, however time did not permit this for us. We had the conversation of whether this is a lot of plastic or not and we helped them come to the realization that this is just one classroom, to imagine how much plastic the 7 billion people in the world throw away collectively. We then led a discussion on the three R’s: Reduce, Reuse, and Recycle. As a class we came up with ideas to help reduce our plastic waste and waste overall.

In order to assess the students understanding of lesson, we finished by playing the same game we did in the first lesson. However, the questions used were related to the things taught that day. We also used a ticket out the door to see what the students took away. They were asked to write on sticky note what they thought would happen if we threw all the plastic we had talked about during the lesson into Lake Michigan. They put their sticky note on a poster board so we could take it with us and look over their answers. Lastly, the students were given the homework of asking their family members what they would do if they went to Lake Michigan and it was full of trash and plastic. This helped to get them engaged in the next lesson on pollution.
LESSON 3

The third lesson of the integrated unit met more of the stereotypical science class expectations by including an experiment, but also greatly contributed to other standards that the core content areas included. The lesson began with a CNN news story about the effects that an oil spill in 2010 had on the gulf region had on animals, especially birds, and the surrounding habitats. Within the video, the scientists and news anchor discussed how difficult it was to remove the oil from the area and animals impacted by the spill. After watching the video, students were asked to write their reactions, responses, what they learned and wonder on a corresponding worksheet and were assured they would have the opportunity to discuss their reactions later on in the activity. To help students further understand the impacts of pollution on the environment, they were given a “problem of the day” to get them thinking mathematically while connecting the situation to their lesson for the day. The question the students addressed was “In 2011, scientists estimated that 6,000 sea turtles died from an oil spill that leaked into the Gulf of Mexico. Scientists also estimated that five times the amount of turtles was the number of birds affected between the 102 species of birds around the Gulf area. How many birds of each species died because of the oil spill?” This led them to determine how many birds perished from the oil spill in the gulf based on the ratio of birds impacted to sea turtles and improve their number sense and help them become more engaged in the day’s lesson as they came to better understand the widespread negative effects of pollution. Students first worked independently, then were provided time within their color teams to collaborate before a couple students presented their findings to the class.

After this, students were introduced to the experiment portion of the lesson. Contrary to many experiments that students complete, this lesson allowed students to determine the variables and materials they used, in addition to creating a unique experiment and outcome for each group. Being provided a plastic food-storage container of warm water (their “lake”), a box of pollutants (sprinkles, rice cereal, Cheetos, flour, pepper, etc) and a box of clean up tools (paper clip, dryer sheet, straw, tape, wax paper, soap, etc), students decided what pollution their lake would be subject to, then what method would be used in an attempt to clean up the pollutant. Since our color teams had six people each, there were six designated scientist roles: the secretary was expected to record the groups observations, the polluter was the person who selected what pollutant would be introduced to their lake and they had 30 seconds to add as much or as little pollutant as they wanted, the clean-up crew was the student who was responsible for choosing a tool from the provided tool box and attempt to remove the pollutants from the lake to the best of their ability in 30 seconds, the timer was in charge of watching the clock and calling out stop every 30 seconds, the assistant was expected to jump in when help was needed and clean up any spills immediately, and the observer was asked to draw a before and after picture of the lake on a notecard during the round. The students rotated through the roles so each time a pollutant was added and removed, every student was engaged and had a new, corresponding task to complete. This activity led students to conclude that pollutants are hard to clean up even if responded to immediately and that their impact on habitats could be almost immediate. As the experiment continued, the students’ lakes became more and more dirty and harder to clean up. The notes and pictures that students create while fulfilling their assigned roles, in addition to their hands on experiences, throughout the
experiment will lead them into group discussion and the creation of a poster to display their findings to their classmates.

Following the experiment, students were engaged in a strategy called community circle which provided opportunities for discussions, thoughts, questions, and findings about the impact that pollution had on our environment to be addressed between groups of classmates. By breaking the classroom into four circles of students, we were able to intentionally group students so that one to two representatives from each color team was together to share about their unique experiences and learn from other experiences that different color teams had. Their discussions could include things they came to know from any of the previous lessons, the video, the experiment, and more. After discussing their findings in their community circles, they then presented a few big ideas their community circle discussed to the whole class. The lesson ended with a ticket out the door activity that challenged students to think about building an anti-pollution machine. On a sticky note, students were asked to jot down ideas, an item, or a drawing of a tool that would be incorporated on their anti-pollution machine to remove pollutants from water.

LESSON 4

In the last lesson of the Integrated Unit the focus was to assess the students’ knowledge, as well as give them a chance to apply their learning. While we wanted to keep the lesson fun and engaging, we also needed to gather information as to whether the students learned anything from the previous lessons. To assess the students, we created an activity where the students get to assess their own learning based on their own understanding. Students were greeted by the teachers, then put into their previously decided color groups. In the color groups is where the short informal assessment would take place. In the form of an interactive activity each student will demonstrate their knowledge on a part of the previous lessons. A facilitator/teacher put up a word or an idea that had been taught previously in the lesson and the groups collaborated with each other to write down all the words, ideas and pictures that they can think of that correlate with the word or idea from the lessons. To further describe, each table had two vocab words. The students rotated through the four tables. At each table they were expected to write a personal connection to each word. Every four minutes the groups would switch. The movement allowed for students to use their bodies and not get restless or bored in the assessment process. Each word or idea was chosen by the teachers/facilitators, based on the learning outcomes that were believed to be reached. The students seem to enjoy not only moving about the classroom, but also challenging themselves to write or draw everything they knew about the words/phrases that were in the color groups.

After each color group, had returned to their respective groups, it was time for the students in the color group to grade, the thoughts, and ideas that the other students wrote and drew when they were moving about the classroom. The students and the facilitator for that group took time to write down appropriate words, and ideas that they would be looking for from the responses from other students based on the words they were assessing. They created a rubric in a sense that would guide them in their ability to assess the other students learning. This gave the students that opportunity to be part of the assessment process and made learning a collaborative function. Students were talking and debating on whether they should accept certain responses, and it was in the debates that
collaborative learning happened. When challenged, students could show how much they know, and other students would agree or negate the other student’s responses. After 10 minutes of assessing the responses, the color groups were to give the class a grade based on the responses that were given. Each group shared that grade with the class. Not only were those grades fun for the students to give but it allotted the teachers/facilitators the opportunity to see where there was need for re-teaching.

After the word assessment was finished and all the facilitators see what the students know, it was time for the invention part of the lesson. The facilitator explained that “real scientists” do not just research and learn new things, they apply that knowledge and make things better. The leader explained that each group is going to get a renewable or nonrenewable resource and is going to create an invention that will help conserve the resource. Example: if a group got crude oil, they may create a car that runs off corn or water because, those are renewable resources and having that will help save or conserve the oil. Each group got a card with a nonrenewable resource that has a scenario on the back that they must create an invention for. The leader of the color group gave these expectations: name for the invention, a picture/drawing of the invention, what the invention does and how it conserves a nonrenewable resource, if this invention stemmed from something they have ever seen in the world, and how they would encourage others to use their invention, and what kind of footprint would their invention leave. The student’s were free to design their own invention based off of those 4 questions. There was no set grading rubric because this was the last time we would see the students. Each person in the group had speaking part. Each group will be given two sheets. One for a rough draft and one for the final. Each group will have 25 minutes to come up with an invention and how they will present the information about their invention. Each group will come up to present their invention. And each group that is the audience must come up with 2 questions to ask the group that is presenting. After each group presented there was a short discussion about moving forward with resources, and how we can educate others. The students got a chance to see themselves as scientists and put learning into action. This activity allowed for debate and for a chance for students to collaborate. It gave the teachers/facilitators a chance to see the students use the previous lesson material to create a great invention.

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Aspirin Synthesis: A New, Inexpensive Twist on an Old Favorite

By May Daher and Mark Benvenuto, University of Detroit Mercy, Detroit, Michigan

ABSTRACT:

An interesting activity for students, whether they are enrolled in basic chemistry or AP class, is synthesizing aspirin and assessing the efficiency of their reaction through the melting point or chemical analysis. The basis for this idea is the use of a physical property of a chemical compound, the melting point, to determine the efficiency and the purity of a reaction's product. As well, this can be a chemical test, complexation with iron (III) chloride, to determine the same chemically.

In a novel twist, a set of standards was made that allows students to estimate the degree to which the reaction ran to completion. Such a set of standards is easy and inexpensive to produce, and adds a new dimension to the experiment.

We hope that other students can enjoy and benefit from the experiment!!

INTRODUCTION:

The physical properties of an organic compound, such as melting point, can provide useful information about the sample’s identity and purity. By definition, the melting point (MP) is the temperature at which the solid and the liquid phases are in equilibrium. In other terms, MP is the temperature at which a solid melts and becomes a liquid. Determination of the MP is quite difficult with a small amount of sample. Thus, in practice, most melting points are determined as capillary melting points using a Meltemp apparatus. A capillary melting point is defined as the temperature range over which a small amount of solid in a thin capillary tube first visibly softens (the first drop of a liquid) and then completely liquefies.

Melting of a solid requires that the intermolecular forces that maintain the solid lattice together to be overcome. Therefore, the MP depends on the structure of a molecule. Thus, different compounds tend to have different melting points. A pure solid will generally melt sharply (narrow melting point range 0.5-2.0°C) as the forces of attraction among the particles are the same. However, a mixture of very small amounts of miscible impurities will produce a decrease of the melting point and an increase in the melting point range. The presence of a foreign particle in a crystal lattice interrupts the uniform structure and weakens the forces that hold the solid structure. Thus, a solid’s melting point is useful not only as an aid in identification but also as an indication of purity.
The reaction of salicylic acid and acetic anhydride to form aspirin and acetic acid has become a classic over the past several decades, as shown in Figure 1. The completion of this reaction is very often monitored by its melt point, or rather by how small its zone of melting is.

The completion of this reaction can however also be monitored by the addition of iron (III) chloride (aka. ferric chloride), because the iron ion forms a complex with salicylic acid in solution, but does not do so with aspirin. This is because the addition of the acetate blocks what was previously an –OH position, and thus blocks the ability of the iron ion to form a bond at this site.

The iron (III) chloride test is a low-cost chemical alternative to the use of a melting point apparatus. But we have also found it to be a good means by which students can be taught how to produce a simple set of standards, discussed below.

**FIGURE 1: REACTION TO FORM ASPIRIN**

![Reaction Diagram](image)

**MATERIALS**

- 100 ml beaker
- Watchglass
- Microwave
- MEL-TEMP apparatus
- Ferric (III) chloride
- Filter paper and funnel
- Salicylic acid
- Acetic anhydride
- Phosphoric acid
- Toluene

All reactants can be purchased through most scientific supply houses, including Flinn Scientific.
PROCEDURE, ASPIRIN SYNTHESIS

1. To a clean, dry 100 mL beaker, add 0.01 mol of salicylic acid, 0.03 mol of acetic anhydride and one drop of 85 % phosphoric acid.

2. Cover the reaction mixture with a watchglass. Place the covered beaker in a microwave oven and heat at a 30% power level for 5.0 min. (This step can be substituted with a more traditional heating on a source such as a hot plate, or in a warm water bath, accompanied by mild shaking for approximately 30 minutes).

3. Remove the beaker from the microwave oven with metal tongs and allow the reaction mixture to cool to room temperature.

4. Once at room temperature, place the beaker in an ice bath (0 °C) to aid crystal formation.

5. Filter the solid using a Büchner funnel or fluted funnel and collect on the filter paper. Be sure to wet the paper with ice-chilled (0 °C) toluene first, and rinse the crystals with the same solvent.

6. Recrystallize your product from toluene and dry the recrystallized material.

ANALYSIS

The analysis of the aspirin product can be determined in two different manners: via melting point apparatus, of via the addition of iron (III) chloride. Both methods lend themselves to the production of a series of standards, which can be used to determine how far the reaction has proceeded to completion.

a) Melting point:

Using the MEL-TEMP apparatus, perform the melting point measurement on the crude and the pure product.

To further analyze the effect of impurities on the MP, we determine the MP of different mixtures of the starting materials (salicylic acid (SA) and the product (aspirin or acetyl salicylic acid (AS)) that prepared as followed:

Mixture (A): (10:90= S.A.: A.S.): 0.01 mol (0.001 mol S.A.: 0.009 mol A.S.)
0.001 mol=m/138; m= 0.138g
0.009 mol=m/180; m= 1.62g

Mixture (B): (25:75= S.A.: A.S.): 0.01 mol (0.0025 mol S.A.: 0.0075 mol A.S.)
0.0025 mol=m/138; m= 0.345g
0.0075mol=m/180; m= 1.35g

Mixture (C): (50:50= S.A.: A.S.): 0.01 mol (0.005 mol S.A.: 0.005 mol A.S.)
0.005 mol=m/138; m= 0.69g
0.005 mol=m/180; m= 0.9g
Mixture (D):  \((75:25= \text{S.A.}: \text{A.S.}): 0.01 \text{ mol} \ (0.0075 \text{ mol S.A.}: \ 0.0025 \text{ mol A.S.})\)
\[
0.0075 \text{ mol} = m/138; \ m= 0.45g
\]
\[
0.0025 \text{ mol} = m/180; \ m= 1.035g
\]

Table 1 shows the melting points of several mixtures, including results obtained by the instructor (as points of comparison). This is not meant to be considered exhaustive, as several other aspirin-salicylic acid mixtures can be produced, and their melting points determined.

b) Ferric chloride test: Dissolve 5 mg of each of the mixtures (A, B, C and D) in approximately 0.2 ml of dichloromethane, add 3-5 drops of a 1% ferric chloride solution (prepared in a mixture of water and methanol) and stir. The formation of a purple coloration indicates the presence of phenols (salicylic acid).

**RESULTS**

In this activity, we divided the class into pairs: One experimenter prepared the aspirin, and the other was the analyzer who performed the melting point analysis and/or the iron (III) chloride test. Groups 1 – 4 also prepared at least one standard in what became the set of standards by which the completion of the reaction could be judged. This arrangement works well, but certainly does not have to be a requirement to make this a rewarding experience. Additionally, this preparation of standards appears to be a new dimension to this very established experiment.

a) Melting point:

**TABLE 1: MELTING POINT RESULTS**

<table>
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<tbody>
<tr>
<td>#1</td>
<td>120-130</td>
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</tr>
<tr>
<td>#2</td>
<td></td>
<td>116-126.3</td>
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<tr>
<td>#3</td>
<td></td>
<td></td>
<td>114-120</td>
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<tr>
<td>#4</td>
<td></td>
<td></td>
<td></td>
<td>110-142</td>
</tr>
<tr>
<td>Instructor</td>
<td>128-134</td>
<td>114-132</td>
<td>111-127</td>
<td>112-136.6</td>
</tr>
<tr>
<td>Instructor</td>
<td>128-132</td>
<td>113-128</td>
<td>114-120</td>
<td>113-140</td>
</tr>
<tr>
<td>Average</td>
<td>125±5 - 132±2</td>
<td>114±2 - 129±3</td>
<td>113±2 - 122±4</td>
<td>112±2 - 140±3</td>
</tr>
<tr>
<td>Range</td>
<td>7</td>
<td>15</td>
<td>9</td>
<td>27</td>
</tr>
</tbody>
</table>

**MP of pure AS** | **136-138**
b) Iron (III) chloride test (aka. Ferric chloride test):

The ferric (III) test or the phenol test is generally used to test the presence of phenol in an indefinite compound based on the following reaction:

\[ 3ArOH + FeCl_3 \rightarrow Fe(OAr)_3 \text{ (Purple complex)} \]

In our case, the presence of purple color is an indication of the presence of salicylic acid in our solution as it reveals a phenol in its structure.

This test was performed on a pure aspirin sample (100% AS), a pure salicylic acid sample (100% SA) and the four different mixtures A, B, C and D. The result (Figure 2) reveals a change in the AS color as increasing the amount of unreacted SA is present in the solution.

**FIGURE 2. FERRIC CHLORIDE TEST REVEALS THE PRESENCE OF THE PURPLE COMPLEX AS INCREASING THE PERCENTAGE OF THE SA IN THE MIXTURE.**

Thus, even for classrooms that are not equipped with melt point apparatuses, one can construct a simple yet effective means of determining if the reaction has occurred. The change from yellow – pure aspirin – to a dark, purple-brown – unreacted salicylic acid – is dramatic and easy to see, while the color changes for the various mixtures is somewhat more subtle.

As an educational exercise, the instructor does not have to be the individual who produces the set of standard solutions. Students or student groups can construct a set of solutions, as seen in Figure 2, in lieu of the set being presented to them. Having the students construct a set provides them with the following opportunities:

The chance to discuss and examine how various factors can be controlled, such as the concentrations of solutions and the similarity of the depth and breadth of the sample solutions.

Practice in making solutions, and in computing solution concentration in percentage.
An early experience in creating their own set of standards, importantly adding a new dimension to the experiment.

This simple, straightforward exercise in constructing a set of standards can be a first example for students of how this is done, and can lead to a discussion of standards and how standards are used in a variety of situations, often beyond the chemistry laboratory.

**CONCLUSIONS**

This study presents a safe, fast and simple technique that allows students to find valuable information about the identity and the purity of an organic compound. Using an affordable analytical apparatus, such as MEL-TEMP, we were able to investigate the efficiency of the aspirin synthesis and the effect of the impurities on its melting point.

Should no melt point apparatus be available, this experiment gives the teacher or the students the ability to construct a simple set of visual markers that show whether or not aspirin has been formed or whether the starting material is still present in some degree.

Importantly, this experiment can serve as an excellent first experience in understanding how a set of standards is made, and what they mean.
Active Formative Assessment
By Jim McDonald

When you sit down to plan a unit of instruction what resources are you using to map out what you are going to teach? Standards, check. District pacing guide for your grade level, check. The Performance Expectations from NGSS, check. The teacher manual for the science book you are using, check. But do you know what your current group of students know about the science concept that you are going to teach? Maybe not.

Formative assessment should be one of the tools that you consider when planning instruction. Why formative assessment?

• An assessment activity can help learning if it provides information to be used as feedback by teachers, and by their pupils in assessing themselves and each other, to modify the teaching and learning activities in which they are engaged. Such assessment becomes formative assessment when the evidence is actually used to adapt teaching to meet learning needs (Black & Wiliam, 1998, p.2)
• Formative assessment is the process used by teachers and students to recognize and respond to student learning in order to enhance that learning, during the learning (Bell & Cowie, 2001, p 536).
• Formative assessment is a process that takes place continuously during the course of teaching and learning to provide teachers and students with feedback to close the gap between current learning and desired goals (Heritage, 2007, p. 10).

When you teach one of your goals is to have students understand the science concepts after the unit of instruction. But before you can know what to teach and how to teach you have to know what your students know. So, your unit of accountability are all of those individual students and what they know at the beginning of instruction.

Since your students are the focus of teaching shouldn’t they be involved in the assessment process?

Students get very frustrated and annoyed with assessment when it is passive and when it does not seem to have a purpose. Active formative assessment is involving students in thinking about what they already know and how they can improve their understanding. In the age of 3-dimensional learning and NGSS we are looking for deep understanding from students and how the parts of science are connected.

What does active formative look like?

Active formative assessment takes place in a classroom environment where students feel safe sharing their ideas, listening and learning from the ideas of their peers, and from a teacher who uses the tools of assessment to improve learning. That is the teacher involves students in the assessment process by telling them what the assessment is for and how it will be used. The teacher tells their students that they will use the assessment to guide their teaching and that the students will receive feedback on the formative assessments on how they can grow as a science learner.
Active formative assessment is also promoting a classroom atmosphere where ideas can be shared. Models of this include the Claims-Evidence-Reasoning framework by Carla Zembal-Saul, the Talk Moves strategies from TERC Inquiry Project. Students need to know that they are not the only ones with a certain science idea. When students hear the ideas of others, it helps them improve their own science knowledge.

**What are some tools that you can use that will help with active formative assessment?**

- **Thought Swap:** To begin, have students pair off, and if there is enough room, have the students form two lines facing one another. Have a A line and a B line. Pose a question and have the A line answer the question first in 30 seconds, then have the B line share to the A partner. Have the line move down one and meet a new partner. Have the new partners share their answers to the same question. Repeat process until the question has been answered 3 times. Add a second question if needed. Debrief the answers with the entire class. This lets students hear the ideas of others quickly, in a personal manner and in the debrief.

- **Formative Assessment Probes:** Created by Page Keeley in her *Uncovering Students’ Ideas* series, these are one-page assessments that allow students to share their current science understanding with the teacher and other students. The probes are aligned with science standards and include teacher background knowledge, common misconceptions, how to administer the probe, and how to make sense of student answers.

- **Concept Cartoons:** Concept Cartoons are designed to introduce science concepts in everyday settings. Each character has a different opinion about science being discussed. All of the possible answers are plausible and highlight common learner misconceptions. Learners are invited to join in with the discussion happening in the Concept Cartoon. This can be in the form of a vote, group discussion or class debate. Each Concept Cartoon includes ideas for finding out about the science concept in question.

- **Pre/Post Unit Questionnaires:** Give students a two-page pre-unit questionnaire that includes making choices from pictures that show different aspects of the science concept and multiple-choice questions. Mix up the questions and give it to the students again as a post-unit questionnaire. This show student growth and provides data points for teacher evaluations. When shared with the students, it allows them to know how they have progressed in their science understanding.

With the teacher establishing the proper classroom environment and active students participating in their own learning and assessment, science understanding can be a dynamic process. Students will benefit from getting a handle on what they know as opposed to not knowing where they stand. Teachers benefit from finding out what this particular group of students know and how they can adjust their science teaching and even where to begin.

*Jim McDonald is a Professor of Science Education at Central Michigan, current President of the Council for Elementary Science International, and the MSTA Regional representative from Region 8.*
REFERENCES


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**CHECKLIST**
- Author’s name, current position, mailing address, phone numbers are included with article.
- Written clearly and concisely with an introduction and conclusion.
- Stresses classroom applicability.
- References are complete.
- Photos show students following appropriate rules of safety.