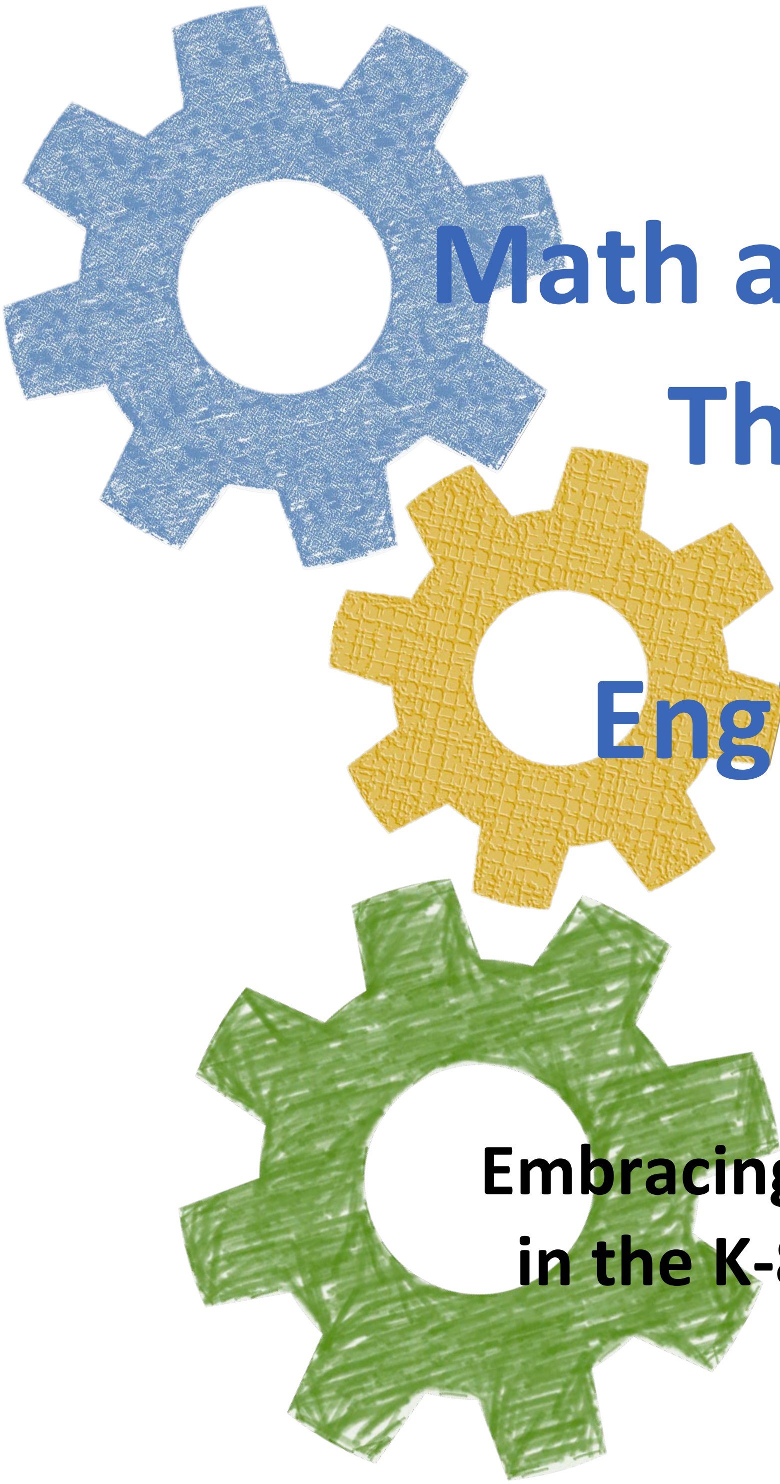
Math and Science Through Engineering



Embracing Engineering in the K-8 Classroom

Math and Science Through Engineering

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This publication, as well as any additional resources, can be found on the Maine Mathematics and Science Alliance's website www.mmsa.org/MSTE. Please contact us if you need further assistance accessing the materials.

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About Math and Science through Engineering

The Math and Science through Engineering (MSTE) project was a professional development collaboration between the Maine Mathematics and Science Alliance (MMSA), Maine Maritime Academy, and Husson University. MMSA staff members Lynn Farrin and Lisa Marchi co-led the project. MSTE supported K-8 teachers from Appleton Village School, Auburn School Department, Biddeford Middle School, Ridge View Community School (Dexter, AOS 94), Lake Region School District (MSAD 61), Mountain Valley and Dirigo Middle Schools (RSU 10), and Oxford Hills School District (SAD 17), as well as afterschool educators from Portland/South Portland Learning Works, Biddeford Learning Works, Sanford Kids Club, and Lebanon Kid Connection.

For school-day teachers, the goal of the project was to deepen K-8 teachers' understanding of engineering - a field unfamiliar to many and not part of preparation programs- and help them put into place instruction that capitalizes on the connections between engineering and the math and science they were already teaching. MSTE teachers participated in ongoing regional professional learning communities, online book studies, and a three-day summer institute on the campus of one of our higher education partners, Maine Maritime Academy and Husson University. The project developed a network of schools that shared strategies and effective instructional approaches for the integration of engineering into existing school curricula and developed examples of student work. Near the end of 2015, ten teachers representing five schools participated in a workshop focused on spearheading a Family Engineering event. Each participating school received a copy of the Family Engineering *Activity and Event Planning Guide*, as well as funding to cover expenses for hosting an event in their district. As a result, six schools and in one afterschool program held Family Engineering events.

For out-of-school providers, the goal was parallel to that for in-school educators: to increase their comfort with and capacity to engage students in engineering activities. This work focused primarily on using Boston Museum of Science's *Engineering Adventures* and *Engineering is Elementary* curricula, and other short engineering design challenges. Because their time was much more limited, we were unable to include stories from our out-of-school providers in this collection.

Participants received ongoing support from MMSA STEM Educational Specialists Lynn Farrin and Lisa Marchi, and were able to draw upon the expertise of our higher education partners, including Paul Wlodkowski and Barbara Fleck at Maine Maritime Academy, Irene Haskins at Husson University, and Yelena Meadows, formerly of Maine Maritime Academy.

During the third and final year of the project, school day teachers focused on developing a capstone project that incorporated and highlighted their learning from the first two years of the project. This publication captures their learnings. As you review their stories, you'll notice teachers tackled a wide variety of instructional dilemmas, focusing on different aspects of teaching and learning related to integrating engineering experiences with other disciplines. The authors will also tell you that their work here is not done; their efforts continue to be works in progress.

Acknowledgements

We would like to thank Jo Gates and Laurie Larsen for their assistance with proofreading, editing, layout and cover design for this monograph in addition to all the magical things you do behind the scenes on a day-to-day basis to support science and mathematics educators across Maine in perfecting their craft.

Rebuilding the Bridge

By Carolyn Dupee, Gifted/Talented Consulting Teacher, Auburn Schools

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My challenge on an everyday basis is that I service the Gifted/Talented population and high-achieving students in grades two through six in three schools in Auburn, Maine. Before becoming a Gifted/Talented Educator, I worked as a high school science teacher who specialized in teaching biology and Advanced Placement biology. My two big focus areas in teaching are literacy and math problem-solving, while I integrate both science and social studies into these learning experiences. All three schools are Title I schools, in an urban district of Maine, where I have some students who have a great amount of support at home, while other students lack that support.

By participating in Math and Science through Engineering (MSTE), I hoped for authentic and meaningful professional development where I could develop a collaborative network of teachers who believe in the importance of educating our students in science as much as I do. Although our group got smaller each year, I feel that I successfully achieved building that network of people. During the first year, I couldn't see a way to do all the things that I do on a weekly basis, and fit the scope of the project into my year. Multiple teachers work at our six elementary schools throughout the district. In an effort to be consistent, each grade had a specific curriculum driven by competitions and deadlines beyond my control. Because my instructional year runs from October to May with approximately 22 classes of instructional time, one hour each, initially I couldn't think of a way to easily incorporate my new learning into an entire unit of study within the limitations of my teaching job. Eventually, I found a way to work with others and developed a deeper collegial relationship with my fellow teachers with whom I work, and whom I seek guidance from when I get stuck on a problem.

My journey working with MSTE has deeply impacted the way I think about teaching and learning in meaningful ways:

1. ***Year 1***- I started collaborating with a team of teachers in one school to turn a schoolwide tradition, the Egg Drop, into a more engaging science and math based project. Students designed parachutes to hit a target based on a given scenario and environmental and geographic constraints

with the goal to get as close to the target as possible with the least amount of time while keeping the egg intact. In their design, students calculated the circumference of their parachute, the mass of their eggs, and the time it took to drop the egg. This allowed me to work with a bigger audience of students and set a precedent for future Egg Drops within the school. **Lesson Learned:** *I can collaborate with others to teach STEM.*

2. ***Year 2***- I integrated formative assessments into new second grade groups with a focus on engineering design integration with math and literacy integration with innovation and civilization. The formative assessments drove the depth of my classroom curriculum based on feedback from students as to what they did and did not understand. This allowed me to deliver enriching literacy instruction within my comfort zone as a teacher, while also allowing me to be creative and give students something beyond the scope of traditional classroom literacy instruction. **Lesson Learned:** *I can create STEM experiences on my own.*

3. ***Year 3***- I enriched the bridges unit of a fourth grade teacher at a school. This allowed me to truly enrich the regular classroom curriculum, while incorporating engineering and problem solving into my math enrichment group of hard-to-motivate students. **Lesson Learned:** *Although my classes are called enrichment classes, I rarely provide enrichment in the true sense of the word, I normally provide acceleration of thinking process in instruction.*

MSTE allowed me to enrich the STEM content and thinking process beyond the scope of an on-grade level unit while communicating regularly with the classroom teacher. Although some of the lessons were extended beyond the regular science curriculum, I designed many of the learning experiences to be experiences that the regular classroom teacher had not touched on in instruction at all. I also used formative assessments to determine what students needed as further math and science experiences in order to create a different type of bridge. Although this is best practice in gifted education, this was the first time I was able to make this happen for my students in science. Each year of MSTE I built on and mastered one new piece of learning, and in my third year put everything together into a cohesive unit. It was important for me to work within the expectations of my role, while incorporating new learning from MSTE to strengthen my teaching in both math and literacy integrated classes.

MSTE helped me to use my strengths of innovation and creativity in my teaching to create meaningful learning opportunities for my students. I now view science, technology, engineering, and math as needing the “A” for art in the acronym because I see the creativity piece as really having a link to the production of ideas and materials. MSTE gave me teaching tools and resources to streamline my teaching craft into manageable and valuable learning experiences, for both myself and my students. Before I design a unit, I ask myself if there are any pieces that I can integrate from STEAM. Students need the ability to construct models which I see as having an artistic component. This transpired in my third year learning through the bridge design unit.

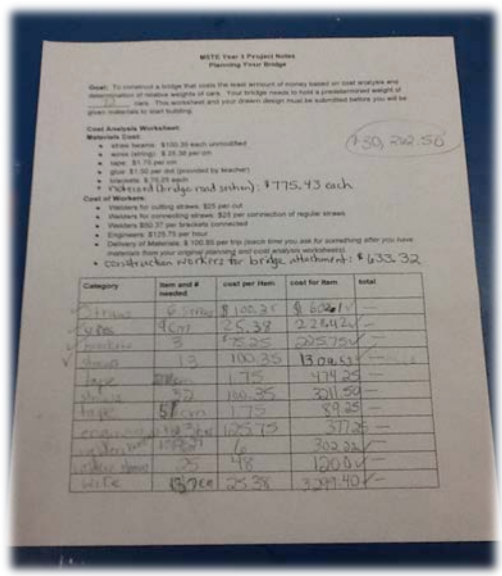
What Does Integration Look Like? A SnapShot into My Bridge Design Unit

During my final year with MSTE, I had a small group of fourth grade students at one elementary school. These students were above their peers academically, but not easy to motivate. In their regular science class, students had constructed bridges out of popsicle sticks and glue, constructing single-beam bridges with triangular trusses. They had already used one version of the engineering design process. The regular classroom teacher was frustrated because she remarked that every year her students always created this type of bridge without daring to push the limits and experiment with something different. I decided that I would integrate engineering into my math enrichment group while including acceleration of learning content and enrichment of the bridge building assignment.

I gave my students engineer’s notebooks where they took on the identity of an engineer. Each student made up his or her own name. Anything they learned in class went into the notebook: data, drawings, tables, sketches, and measurements. For example, when we were researching different types of bridges and I asked each student to act as an expert on a specific bridge, students wrote down research information from the internet into their notebooks to report out to the rest of the class. They used their notebooks to share their findings and to record new learnings so that they could refer back to it when they built their bridges.

I designed this lesson because I realized students only built single beam bridges because that was their experience from living in Maine. One of my goals was to motivate them to think beyond that single solution. I came up with three movie clips on the Golden Gate Bridge: one was mathematical in nature, one focused on the geographic and environmental struggles of the area, and one focused on the history of the bridge. This helped students understand the need for other types of bridges.

After they were hooked, I found additional resources for them related to different bridge designs. *"You mean we don't have to do the same type of bridge we did in science class?"* Students thought that although their materials were different—straws, connectors, and tape—that they had to make the same bridge they had already created in science class. Using formative assessment classroom techniques, such as the I Think-I Rethink from Page Keeley's *Science Formative Assessments Volume 2,* was crucial to uncover student thinking about bridges in general with respect to the geological, geographic, and environmental reasons for bridge design. This helped me understand the group's thinking about bridges, what they were afraid to ask, and the misconceptions they had about how and why different types of bridges are built. I asked each student to research a bridge that actually existed, but was extreme in some way; the more dramatic, the better with this group of students. Each student took ownership of his or her bridge and was excited to present what they had learned, such as the strengths and weaknesses associated with the bridge.



Bridge Budget Worksheet

Students were then given Strawbuilders Kit materials and presented with the following scenario: Today, we will be acting as a team of engineers making bridge models. We have been asked by the City of Auburn municipal government to create a bridge to cross the Androscoggin River. This bridge will be used to replace an older bridge that has rusted out over time. A surveyor has done an analysis of the area and has determined the following constraints for your bridge.

Students had to calculate a budget using the materials I had given them and costs I had included. Students were not allowed to do actual building of the bridge until they had calculated their first set of items needed, including the total cost for their bridge, using a calculator. They added items as they discovered they were missing pieces to their construction. The pictures show examples of my students' bridges. During bridge testing students added and calculated mass and for the final testing the students found the amount of mass the bridge held before it collapsed.

Golden Gate Bridge (Suspension Bridge)

What have my students learned about engineers and engineering?

"*Why aren't we learning math?"* About a month into the unit, my students were concerned because this enrichment class is entitled Math Problem-Solving, yet they felt like they hadn't done any math that whole month, because they didn't do a specific worksheet or packet each class. They were doing math, it was just integrated into every lesson. By the end of the unit, students came to realize that math can be useful and still be "math." My students began to think more and more like problem-solvers and identified with their engineer identity when they came to class.

Students learned much about engineering and engineers. Engineers are individuals who have to be able to problem solve and innovate in order to solve the problems of the world. Sometimes, this involves thinking through a problem, while other times this includes building models with math and science in order to show a potential solution. As adults, engineers have to imagine that models are real in order to find a solution without spending lots of money on the real materials. My students did not realize that when large companies build bridges that they have to pay all of their workers including bridge builders, designers, engineers, and welders to do their jobs. Engineers make a lot of money per hour to do their job. When trying to come up with a solution, engineers reflect on their thinking and think of more efficient and better ways to solve their problems. My students thought that in the case of our bridge design we probably should have used pilings made of cylinders to support our bridges (like the Golden Gate Bridge). They also noticed that the blue straws appeared to be thicker and stronger than the other straws, but none of our groups used them in the construction of our bridges in class. Although my students completed engineering design in their regular science classroom, these ideas only occurred in my small class setting. One of my students' grandfathers is an engineer, but he didn't really understand what his grandfather's job was until we completed the bridge design project.

Leonard P. Zakim Bunker Hill Bridge
(Cable-Stayed Bridge)

Future Momentum for STEM

I have now created a community of learners motivated to learn and to challenge their thinking without having to negotiate with them to do so. They developed an appreciation for things that on the surface appear not to be math-related. My fifth graders saw the bridges and heard about the Egg Drop design challenge at one of my other schools, and insisted doing something similar. They did a shortened version of another engineering activity, Ship the Chip, that fit our timeframe. In this activity, students design packaging to keep a single potato chip intact while the chip sits in the back of my car for one week's time. All shipping packages produced fully intact chips, although one was stale upon delivery. Students were so engaged by this activity that they spent 20 minutes in the secretary's office explaining their design and its strengths and shortcomings when we borrowed her scissors for the project. As a result, I learned that the secretary's husband is an engineer who does the Egg Drop with his college students. My sixth graders at Washburn expect to do the Egg Drop next year. Clearly, the classroom climate has changed: my students now have high expectations for current and future design challenges.

MSTE has given me a network of people with whom I can connect when I need resources, materials, or someone to bounce an idea off of, and when I have questions or need feedback. I have mini-lessons and units of study that I have created that are authentic to the students and the schools in which I teach, based on best practice and research-based materials. As a result of working with this group, I have students interested in engineering and design. Students want to do hands-on work, and want to be challenged to problem-solve and create solutions to problems. My older students naturally have more of the thinking skills needed to complete challenges, and as I continue to develop certain skills with them each year, I am confident that they will be even more successful in this process. I have the confidence and the momentum to continue using the tools I've been given to be a better STEM educator.

STEM Integration for the Bridges Unit

Science	Technology
● Construction of the bridge. ● Finding the mass of a single car or truck and then determining how many their bridge would hold using a double beam balance.	● Researching bridge designs for extreme bridges including structure, materials, and spans. ● Finding pictures of bridge design related to their intended bridges.
Engineering	**Math**
● Constructing and comparing the number of books a cylinder, rectangular prism, and triangular prism made from oak tag will hold. ● Modeling the span of their bridges using graph paper. ● Construction of the bridge. ● Design challenge scenario based on a real challenge for the State of Maine.	● Measuring with a ruler in centimeters. ● Collection and organization of data into a table or graph. ● Conversion of metric units within the metric system. ● Conversion from standard units to metric units (pounds to grams). ● Any work involving a calculator including calculating price per unit for multiple units and total cost. ● Math problem solving strategies I typically teach: logical reasoning, making a table, drawing a diagram, making a graph, working backwards.

References

Keeley, P. 2014. *Science Formative Assessments, Volume 2: 50 More Strategies for Linking Assessment, Instruction and Learning*. Thousand Oaks, CA: Corwin Press.

Internet Resources

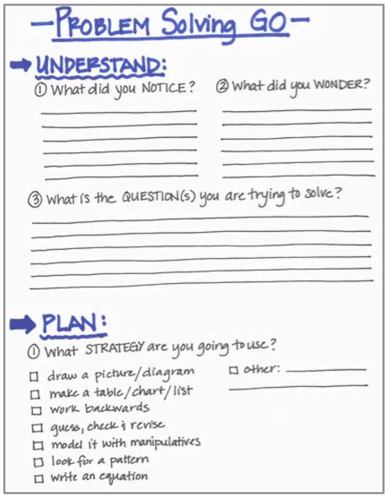
Ship the Chip
http://tryengineering.org/lesson-plans/ship-chip

Using Graphic Organizers to Support Problem Solving In Mathematics

By Michelle DeBlois, Gifted/Talented Consulting Teacher, Auburn Schools

I began my teaching career as a middle school science teacher in Livermore, Maine. After three years in the regular classroom, I became the Gifted and Talented Coordinator K-12 for RSU#36. Currently I teach gifted and talented classes in math and reading to grades 2, 3, 7, and 8 in the Auburn School Department. Our school district uses learning targets based on the *Common Core State Standards* (CCSS), along with those created by the Maine Cohort for Customized Learning (MCCL). Targets are tracked through a management system called EMPOWER. Problem solving strategies and process are not part of the content standards in EMPOWER; however they are accessed through Habits of Mind and Complex Reasoning targets.

I joined Math and Science through Engineering (MSTE) halfway through its second year after talking with a colleague involved with the project. I was looking for a way to help my mathematicians support their answers in class. MSTE provided an avenue to collaborate with others, gain a greater understand of STEM, and acquire resources for my teaching and my students. Although the focus of the professional development was on engineering, given my role in the district, it was most relevant for me to take a deeper dive into the science and engineering practice of arguing from evidence, a key focus in year 2 of MSTE. After the first session I attended, I went right to work and created a graphic organizer for elementary enrichment math students. At the time, I was providing direct service in math and reading to grades 2 and 3 students in two schools. I was teaching a Four-Step Method of Problem Solving based on the books by Creative Publications. Students were given a word problem and used a Problem Solving Standard Operating Procedure (SOP) to solve it. Although the SOP helped them with the process, students were not providing evidence and were making incorrect claims. They would simply write down the answer and rush through the problem, despite the SOP. I needed something more than this worksheet and SOP. I used what I learned about providing evidence from the book, *What's Your Evidence?* by Zembal-Saul, McNeill, and Hershberger, which was featured in our MSTE face-to-face meetings. The first graphic organizer that I developed for grade 2 and 3 included adding the "problem" and "evidence." Students provided one piece of evidence for their work; however, students still did not provide the correct answers to the problems and their evidence was not strong.



Page 1 of grade 7-8 graphic organizer

During the third year of MSTE, I decided to revamp my graphic organizer for grades 2 and 3 and include a claim and evidence. In addition, I picked up direct services for grades 7 and 8 in math and reading. I was excited to teach problem solving to the older students, and I decided to make a more complex version of my graphic organizer for them. I also participated in several other professional development opportunities that reinforced and supplemented what I was learning through MSTE. For the grade 7-8 graphic organizer, I utilized parts of the problem solving process used by CUETHINK, Math Forum, and Dan Meyers. All of these resources focused on creative brainstorming before the closed-ended part of problem solving (finding the solution). The problem solving process is broken down into five phases on the graphic organizer: understand, plan, solve, review, and reflect. These five phases work in conjunction with the engineering design process. For example, the Understanding phase of the graphic organizer relates to the Identify phase in engineering process, while the Plan phase focuses on the investigate, imagine, and plan parts of the engineering process.

Participating in MSTE has changed the way that I approach instruction in my classroom. I am more focused on the process of learning rather than just the product. It has challenged my students and I to look at providing evidence for our claims rather than just supplying an answer. I also now incorporate questions that foster critical and creative thinking and are based on real-world issues.

There were many positive outcomes, not just for me, but also for my students by my participation in MSTE. My students began to love learning again and became engaged in the learning process. My students used specific vocabulary to articulate their claims and started providing strong evidence for their claims. Students realized which strategies worked best in certain situations, which problem solving strategies generally worked well for them and which ones they needed work on. The problem solving process enabled students to recognize patterns, similarities and differences, and similar problems. It helped them to begin to know the boundaries of the problem so they have some idea where to begin. In addition, it helped them understand the story, quantities, and relationship in order to know what the problem was specifically asking and what the answer might look like. The Understand phase also created an even playing field for all students to access the problem, so students were less likely to give up or just sit there and wait for certain peers to find the answer.

Next year, there are certain aspects of the problem solving process that need more explicit teaching and practice. Students had a difficult time demonstrating their specific strategy enough to provide evidence for their claim and using another strategy to check their answer. In addition, providing the mathematical reasoning for the problem was one of the most difficult parts of the graphic organizer for students. Students generally provided the play-by-play on how they solved the problem instead of providing the rules, definitions, structures/patterns, properties/laws, theorems/postulates; the very reason one can obtain a solution through appropriate and sufficient mathematical principles. Mathematical reasoning appears to be one of the most difficult parts of the process for students because they don’t have the mathematical vocabulary and do not go deep to truly understand mathematical concepts. Another work in progress is the reflection piece for students. They had difficulty creating a Summary of Learning, which focused on their strengths and weaknesses as a mathematician and problem solver and listed specific behaviors, practices, and/or strategies to work on. Students had trouble creating goals and self-assessing themselves. This is probably due to the fact that teachers usually do this part of the process for students.

There are specific adjustments that I would make to the graphic organizers to improve student learning. First, for grades 2 and 3, I would change the clues to I Notice/I Wonder. For the grade 7 and 8 graphic organizers, I would add “Could Someone see how I got my answer (evidence)?” in the Review section. I would also add, “Did I include all of the information in the problem?” to the Review phase. I would make sure that students learn to look back at their I Notice and I Wonder and their estimate to check their work at the end of the problem. In addition, I would teach specifically how students can improve their noticings and wonderings through mini lessons and classroom discussions. Students need to learn to focus on which noticing and wonderings were important and mathematical in nature, which ones were not used, and which ones were missed. In their Reflection, I would add a piece on how their noticings and wonderings lead to the solution, and in their Summary of learning, make sure students' noticings and wonderings are getting more useful and increasing in number. Moving "What is your best guess or estimate?" to the Plan phase before they pick a strategy is another change I would make. Providing an estimate helps students to figure out what strategy might work best and doesn't rush to the solution. In the past, students would use the evidence box to support their estimate and not use the strategy to find and support their actual claim. The last change would be to focus more on the mathematical reasoning and introduce rebuttal to students (disagree with claim/solution) along with counterexample to rebuttal (counter evidence and counter reasoning). This raises the level of complexity in the framework sequence based on Zembal-Saul, McNeil, and Hershberger's work.

I am excited to take my work from MSTE and use it to collaborate with the other teachers in my schools. Many teachers use problems of the week and are struggling with the same issues. Next year, my colleagues are going to be using my graphic organizer and we are going to work together to refine the process. I look forward to the conversations and revisions to the problem solving process and the practice of constructing explanations in mathematics.

Internet Resources

CUETHINK
http://www.cuethink.com

Math Forum
http://mathforum.org/pow/teacher/samples.html

Dan Meyers
http://blog.mrmeyer.com

Math Class Needs a Makeover
https://www.ted.com/talks/dan_meyer_math_curriculum_makeover?language=en).

Resources

Find sample graphic organizers, SOP (standard operating procedure) and a list of references at www.mmsa.org/MSTE.

Engineering a Parachute Activity: Egg Drop as an Integrated Lesson

By Laurie Elliot, Grade 6 Teacher, Park Avenue School (Auburn)

When I first signed up for the MSTE project, I really had no expectations for my participation other than it seemed like something fun! I was a new teacher, having recently changed careers from being an accountant, and my science background was minimal. Having a science methods course and a couple of science classes needed for a business degree wasn't much experience with teaching science. I always liked science when I was a kid, but thought that what and how I was teaching in science class was rather boring. I figured maybe I could learn something to make science more engaging and fun for my students.

The first year of MSTE required that we come up with an engineering unit. My engineering project evolved from a school tradition for sixth graders. "The Egg Drop" consisted of an at-home family project where students packed a single, fresh chicken egg well enough that it would not break when dropped from a third-story window. The whole school showed up to watch and was delighted to see which designs keep the egg from breaking. The traditional egg drop rules include:

- Egg cannot be cooked.
- Packing may not be fused onto the egg.
- May use some type of suspension system.
- No parachutes.
- No jars of peanut butter.
- No remote controlled drones.

The tradition resulted in approximately 15 students bringing something from home. These students typically came from families actively involved in education where assistance and resources needed to complete the project were available. Unfortunately, most students were not able to participate. Our school population, which includes 30% English language learners, and high poverty with over 75% free and reduced lunch, probably was unable to get these resources at home.

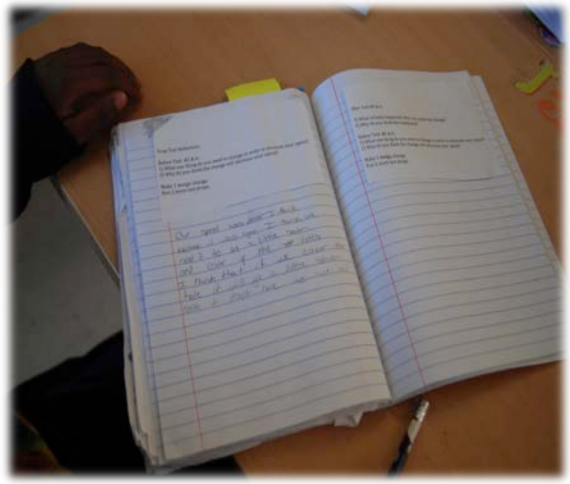
I decided to "interfere" with the school tradition and introduce an in-class engineering design unit. My thoughts were that everyone could now have a part in the Egg Drop tradition. In previous years, students always asked why they couldn't use parachutes. I really didn't have any good reason, other than I had inherited the tradition from the former sixth grade teacher and those were his rules. So, my response was "that's just the way it is."

Engineering parachutes

In response to their request to use parachutes, I came up with a way to marry engineering and tradition. The challenge was to design a parachute delivery system with a closed gondola that could carry an egg to the ground from the third floor, or a height of about 9.5 meters. Students must use the materials given to them in class, and designs must be completed during class time. Each team received a real life scenario to bring aid and supplies to a country devastated by a natural disaster such as an earthquake, mudslide, or hurricane. Each parachute delivery system was to hit a target while preventing the egg from cracking.

The engineering unit engaged and motivated all students to participate. There were many opportunities to differentiate and capitalize upon their various strengths. Through careful placement of students within groups of four, each was given a role as either the mathematician, the design engineer, the statistician, or the project manager. Group discussion and reflective writing along with practical life skills gave everyone multiple opportunities to participate. Students worked with dollars and cents as they used a requisition form for supplies and managed a $100.00 budget with play money. Using a stopwatch was something many students had never encountered. A 100-foot wind-up tape measure allowed students to practice measuring distances longer than a yardstick. This proved to be an unforeseen challenge; teaching kids how to wind up a tape measure in the proper direction. This came about when a student came to me with nearly 50 feet of tape still hanging out and yet they couldn't "push" it in anymore!

Over the past three years, MSTE has enabled me to look at engineering as a means to better problem solving. The engineering design loop impacts my teaching in ways that I cannot always consider beforehand. I now teach and use the design loop with students often for everyday problems. One time for instance, we had a problem with laptop use and storage in our classroom. With 20 laptops, we were struggling with keeping the laptops charged without the cords becoming tangled all the time. We needed a way store, charge, retrieve, and return laptops that was easy for all of us to manage. I took an Engineering Design Loop poster, and presented it to the class to see if we could use the same process to solve our problem. After a couple of attempted and failed solutions, we finally came up with a fix that required drilling holes in the side of a bookcase that remedied the tangled cords.



Student engineering notebook

Currently, our district is in the process of realigning the K-8 science curriculum to new standards. As it happened, three of us who participated in MSTE are also involved with the realignment committee. Because of our work in MSTE, the curriculum coordinator indicated that more engineering should be incorporated into more grades and that all of us who participated in the MSTE project might be called upon to help with this endeavor.

What started off as something fun to do has now transformed my teaching practice. I now plan times for students to do some of the TryEngineering lessons such as *Building a Better Candy Bag* or the *Tall Tower Challenge*. My commitment to incorporating engineering practices is more steadfast now than when I began. The life lessons gained from engineering practices encompass more than just math and science, they incorporate teamwork and life skills, which will lead to solving society’s challenges.

Title: Parachute Activity - Egg Drop

Overview

This unit requires 5 weeks or 10 lessons of 40 minutes.

1. Engage: Give scenario: Something like . . . .
You are a team of engineers who have been given the challenge to design a parachute out of everyday items. Your parachute will carry much needed supplies to people in a remote area affected by a natural disaster where you cannot get food or medicine in any other way.

2. Explore:

- Read about parachutes: Los Angeles Times article, *When Was the First Parachute Jump?*
- Investigate parachutes using TryEngineering's *Playing with Parachutes*, pp. 4-6 and online parachute simulations from *Design a Mars Parachute* and *Ranger Danger Dan*.
- Students individually plan out and draw their design.

3. **Explain**: After the assigning of Design Teams that capitalize on students' strengths and differences, each student explains their plan, materials, and reasoning for their individual parachute before the team decides upon a team concept. Students are then given a $100 budget and supply requisition form.

4. **Elaborate:** Students construct, experiment, and test the design for two drops. Students collect data: time and distance from target.

5. **Evaluate:**

Each student writes a reflection and responds to these questions:

- Did they hit the target (or come close)?
- If not, what would they need to do to come closer to the target?
- What did you need to do to slow the rate of descent for the parachute?
- Identify one thing that should be changed on your parachute and explain why.

The team then works together to make one change and drop two more times and collect data.

Teams should change the size of their chute, look at different diameters, and record results and how they differ.

References

The Engineering is Elementary Team. 2014. *To the Rescue: Engineering Aid Drop Packages*. Boston: National Center for Technological Literacy, Museum of Science.

The Engineering is Elementary Team. 2014. *Liftoff: Engineering Rockets and Rovers*. Boston: National Center for Technological Literacy, Museum of Science.

Maine Cohort for Customized Learning (MCCL) http://mainecustomizedlearning.org/

Internet Resources

Building a Better Candy Bag
http://tryengineering.org/lesson-plans/design-and-build-better-candy-bag

Design a Mars Parachute
http://www.pbs.org/wgbh/nova/space/design-mars-parachute.html

Northeastern University Center for STEM Education
https://stem.neu.edu/resources/activities/eggdrop/

Connection to *Maine Cohort for Customized Learning (MCCL)*

Math
MA.07.GME Geometry
Is skilled at finding area and circumference of circles.
Level 3: Solve real world mathematical problems involving area and circumference of circles.

Level 2: Knows the formula for area and circumference of a circle.
Knows the terms: circumference, radius, diameter, and pi.
Knows that 3.14 and 22/7 can approximate pi.

Science
SC.06.PSFM Force and Motion:
Level 3: Understands the relationship between force, mass, and acceleration.
Level 2: Knows Newton's Second Law. (Retrieval)

Complex Reasoning Process
CR.01.IVNT.01.01 Invention:
Is skilled at generating and defending ideas for improving a situation or responding to a need.

CR.01.DM.01.01 Decision Making
Is skilled at applying criteria to alternatives to make a decision.

CR.01.EI.01.01 Experimental Inquiry
Is skilled at generating logical potential explanations of phenomena or events that are being explored; figuring out a way to determine if the explanation holds up.

CR.01.PS.01.01 Problem Solving
Is skilled at identifying a problem situation by describing a goal and something that is stopping you from achieving that goal; generating multiple ideas that could help you to achieve the goal despite the fact that there are things that make it difficult.

Industrial Technology
IT.01.PRO.01.01 Production
Understands: Design Loop/Process from planning to production.

Playing with Parachutes
http://tryengineering.org/lessons/playingwithparachutes.pdf

Tall Tower Challenge
http://tryengineering.org/lesson-plans/tall-tower-challenge

Ranger Danger Dan
http://puzzling.caret.cam.ac.uk/game.php?game=9

When Was the First Parachute Jump?
http://www.latimes.com/science/sciencenow/la-sci-when-was-the-first-parachute-jump-andre-jacques-garnerin-20131022,0,3916977.story#axzz2mk6N8OFS

Resources
Find the Parachute Requisition Form and the Auburn School Department's Science Curriculum Scope and Sequence at www.mmsa.org/MSTE.

Wind Turbine Design Challenge

By Jim Rowe, Technology and Engineering Teacher, Auburn Middle School

I student taught in Auburn, Maine. I then took a position in Poland, Maine before returning to Auburn, where I have been teaching Technology and Engineering Education for the past 25 years.

Auburn is comprised of a mixture of rural and urban demographics. There are farms and lakefront homes on the outskirts and more densely packed houses, buildings, and apartments closer to the heart of the city. Six elementary schools are the feeder schools for the middle school. Auburn Middle School is a seventh and eighth grade middle school with approximately 275 students per grade level, divided into six teams—three eighth grade and three seventh grade.

I was trained in Industrial Arts Education, which is a very diverse field. The focus of the schooling was on graphic arts, including printing technologies, drafting, and design; one also had to be knowledgeable and skilled in machining and metalworking, wood and plastic materials processing, electricity and electronics, and mechanics and power systems.

Industrial Arts evolved into Technology Education, where the focus is not on specific processes and tool skill development with controlled and specific predictable outcomes, but rather on creative design challenges with open-ended and divergent solutions. With a nationwide focus on STEM education it is natural to connect and combine math, science, and engineering and utilize common formative and summative assessments to stimulate and assess student growth. This project has done just that. MSTE provided a pathway for me to work collaboratively with a diverse group of people, as there is growth potential inherent when working with so many individuals with a wide range of background knowledge and skills.

A common theme that has resonated through society for the past few centuries is energy transformation, production, and sustainability. Renewable and sustainable energy are essential to the increased energy demands of our world. Wind, solar, hydro, biomass, and geothermal are all potential sources that will fuel these demands.

As an engineering design challenge, a wind turbine design project is a context to teach the engineering design process as well as introduce seventh grade students to the growing industry of wind power and the field of energy conversion. The unit that I have developed takes 15-18 classes to complete and focuses on a five-step engineering design process model, which includes the following steps: Ask, Imagine, Plan, Create, and Improve.

The Auburn school system utilizes specific learning targets that its educational cohort has recognized as essential learning. The cohort is comprised of schools throughout the state that have agreed to follow a specific delivery system with learning goals or targets for each curriculum subject. The target that this challenge is tailored for is the Design Process.

The taxonomy bases outcomes on a level of 1.0 to 4.0. A 1.0 on the scale indicates that the student is a beginner and does not fully understand the concepts without help. A 2.0 is at the retrieval level wherein a student can identify and carry out procedures. A 3.0 indicates that students can analyze, make decisions, and apply learning based on data. A 4.0 is a higher level of investigation and invention than what is currently being taught in your lessons. This challenge is tailored for the Design Process target at the 3.0 taxonomy level of analysis.

At the 3.0 level, the student must use the design process to create a quality product. This is very general, to say the least, and I choose to elaborate further. *The K-12 Framework for Science Education* spells out the eight practices of science and engineering that are essential for all students to learn. These are listed below:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

The Wind Turbine Design Challenge utilizes all eight of these practices.

The unit begins with a pre-assessment followed by a classroom discussion, several videos, and a slideshow of general facts, followed by a reading booklet and worksheet about the history of windmills and wind turbines. Students learn the wind speed necessary to make a turbine feasible in a particular area, as well as the weather conditions that the structure must be designed to endure. They also learn what the terrain enhancement effect is, what a wind rose is, and how they both can be used to determine a suitable location for a wind farm. Maine has a high potential for wind technology development because of its geographic features, specifically its mountains and ocean coastline.

Students must learn the basic parts and terminology necessary to effectively construct a model wind turbine in the classroom. When they have completed this portion, they will understand that the kinetic energy of the wind pushes against the slanted surface of the blade, an inclined plane. The blade is slanted at an optimal angle to keep the hub rotating. The blades and hub together form the rotor, which spins a low speed drive shaft (a wheel and axle), turning a gearbox (or a pulley system if they choose), which rotates a high speed drive shaft, spinning the generator, which sends electricity through the wires, completing the process of transforming the kinetic energy of the wind into mechanical energy and electricity. Teaching this basic science information creates the scaffolding necessary to support the next phase of the project.

The next step is to set up a practice turbine like the one shown below. This is made from 1¼” PVC pipe and includes tees, elbows, and caps readily available at a hardware store. The wind generators and test hubs, also shown, were purchased from Kidwind, which has been recently renamed REcharge labs.

Turbine components

In my classroom I have eight of these test stations set up to accommodate 24 students in teams of 3. Typical class sizes can vary from 18 to 26 in number, so sometimes I end up with 2 on a team or 4 in some instances.

So how are we going to test various designs? What are the variables? Aha, asking questions! We brainstorm as a group and list as many variables as we can, including number of blades, length of blades, surface area of blades, blade material, blade angle… and then teams choose which variable(s) they are going to test.

Mulitmeter and leads

The team makes sample test blades using posterboard, cardstock, foamboard, mat board, or cardboard, then tapes the blades to ¼” wood dowels 4-5” in length and inserts the dowels into the test hubs. We do not glue them to the dowels; this is so that the dowels can be reused later on. The test hubs are pressed onto the shaft of the generator, the blades each set to the same angle, using a protractor, and then the entire turbine is placed precisely 2’ in front of a 20” window fan like the one shown on the below, set on high so that each team has the same wind speed, about 20 miles per hour. Once test leads from a multimeter are attached to the generator wires with alligator clips like those in the center photo below, the student is ready to test and record the data. As a class, we create a data chart and record each variable tested along with the results and then compare with all other classes.

Test hub set up

There is no mechanical advantage from gears or pulleys at this point, so the output is relatively low, but these tests allow for the analysis and interpretation of data.

Some teachers would call this the conclusion of the project, but MSTE has guided me to take the learning further by incorporating greater use of science and math concepts. Students now imagine a solution that uses mechanical advantage to increase the electrical output of their design in an attempt to exceed 10 volts dc. Each team must also incorporate an artistic theme into their design. A detailed drawing is required and must be approved as a plan before the actual creation begins. Students must also record and analyze their data to determine possible improvements.

A lesson on pulleys and gears is taught using LEGO machines, so that students may apply the concepts to their turbine designs. They learn that it is possible to multiply the speed of the rotor turning the low speed drive shaft by adding either a gear or pulley system to turn the high speed drive shaft on the generator. A combination gear/pulley, like the one shown, works very effectively on the generator.


Sample gears and motor

MSTE has greatly impacted the growth of my teaching as well as student learning. I plan more deliberately and intently by incorporating formative assessments into both daily lessons and discussions, and students are more excited, engaged, and therefore motivated to challenge themselves to go further. Because of their greater understanding of math and science concepts, students have shown that they are less apprehensive and are willing to take greater risks. The outcomes are less predictable and new discoveries are celebrated.

Students are encouraged to take risks by attempting to create designs other than the typical horizontal axis machines. There are many different vertical axis wind turbine designs currently produced as well as new concepts that combine features. The pictures show several student designs. The diagonal blade machine had difficulty maintaining speed but the students worked diligently to continuously improve and refine it. The emoji design is a horizontal axis machine that produced over 12 volts. The vertical axis purple octopus was a bit top heavy but still very creative as it wobbled round and round. The pink rainbow and unicorn vertical axis machine peaked at 10 volts and was the best performer for vertical devices.



Student designed wind turbines

Now that Auburn has made the commitment to turn in all iPads over the summer and revert back to 1-to-1 computing with MacBooks, teachers will be able to utilize more powerful tools in the classroom. To improve this design project in the future, students will create a shared electronic design journal—a Google Doc, for example—so that I am able to communicate with the students as they follow the design process. They will also communicate back to me, about which step of the design process they are working on that particular day, what they plan to accomplish during the class, and what they actually accomplished, as well as those “AHA!” moments when they discover how things work!

In Auburn we have a membership to a Share Center that collects materials from local businesses. This center also trades with other centers to increase the variety of materials available, from a plethora of papers, cardboard, dowels, and foam to a large assortment of wood scraps, fabric, and other useful supplies. Dollar stores come in very handy as well.

Materials Needed:

- Gears may be purchased from many online suppliers including Kelvin.com.
- ⅛” steel welding rods work very well for axles.
- Pulleys can be made by cutting three circles out of foamboard and sandwiching a smaller diameter piece between the two outer ones.
- Other materials needed to design a complete turbine model include: 2”x4”s to be cut into tower and base parts, cardboard tubes, pine boards, pieces of plywood, and whatever students can gather from home.

References

National Research Council. 2012. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington, D.C.: National Academies Press.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, by States*. Washington, DC: National Academies Press.

Internet Resources

Kid Wind Project
http://www.kidwind.org/#!blank/c1rzs

REcharge Labs
http://www.rechargelabs.org

Sun Edison
http://www.sunedison.com

Vestas
https://www.vestas.com/#

Kelvin
http://kelvin.com

The Biddeford Middle School Garden Project

By Lori Hickey, Barbara Burgess, Tammy Lavigne, and Ethan Davis,
Grade 6-7 Science Teachers, Biddeford Middle School

The Biddeford Middle School Garden Project is being run by four science teachers who teach topics ranging from physical science, earth science, life science, technology, and engineering. Grade six teachers are Lori Hickey and Barbara Burgess. Grade seven teachers are Tammy Lavigne and Ethan Davis. Biddeford Middle School (BMS) serves approximately 600 students in grades 6 through 8. The City of Biddeford has a densely populated downtown, but large portions of Biddeford are also considered rural. Biddeford is a former mill town in the process of revitalization. It has varied ecosystems including freshwater (the Saco River), the Atlantic Ocean, grasslands and forested sections.

Nearly 20% of the Biddeford student body has an identified disability. The BMS student population includes more than 50% who qualify for free and reduced lunch. Its English Language Learner (ELL) population has grown rapidly to nearly 4%.

Biddeford Middle School's garden has a long-standing history, starting around 2010. Lori Hickey and other home gardeners had been discussing the possibility of starting a garden at the middle school to give students experience with hands-on problem solving, introduce them to organic food production and sustainability, and introduce them to a very rewarding pastime. Ethan Davis solicited local area businesses for donations of supplies, started to build some garden structures, and registered it with the Maine School Garden Network. Lori created a website for the garden.

Initially, two raised beds were put in place and filled with compost that was delivered free from the town composting program. Paths were laid out using newspaper sheet mulch, along with wood chips, also donated and delivered by the Biddeford Department of Public Works. A few years later, an additional bed was installed using a traditional German technique called Hugelkultur, and a trellis was added. Since the garden was started, a wide variety of vegetables and herbs have been grown, and many students have participated in planting and harvesting food from the garden. In 2013 or 2014, however, compost from the city was delivered which was contaminated with invasive bindweed. Bindweed grows vigorously and climbs up and over the crops, competing with them for space and nutrients, crowding and choking them out.

Hugelkultur garden at BMS

We tried having students weed it out by hand during a summer program in 2014, and they also tried spraying a low toxicity homemade weed killer, but both were unsuccessful. The following year a mechanical sweeper was used to remove much of the infected topsoil, compost and woodchips. They estimated that approximately 90% of the bindweed had been eliminated. Subsequently, tarps were put down and it was intended that these were to be covered with woodchips to block the sun and smother the bindweed. Unfortunately, delay in delivery of the wood-chips prevented full implementation of the planned control effort and as of this writing, the bindweed is still present in the BMS garden.

As part of our Year 3 MSTE project, we took an engineering design approach to solving the garden problem. We purchased materials to eliminate the bindweed, and we are creating lessons for next year that will engage students in designing alternate structures for continuing the garden outside of its original footprint while the bindweed is brought under control.

Prior to becoming involved with MSTE, we had a range of experience with engineering. Ethan had some engineering coursework in college and had worked as a designer for a local wood products firm. As a teacher, after attending the Summer STEM Collaborative at Maine School of Science and Mathematics in Limestone, ME, he incorporated a number of engineering design challenges into his classroom. In the course of those activities, students were introduced to the engineering design process, followed by a hands-on portion in which the students had the opportunity to design, build, test and improve their creations. Lori and Barbara’s prior engineering projects came about after they participated in an Engineering Ambassadors, a joint project of the Maine Mathematics and Science Alliance, Institute of Electrical and Electronics Engineers EEE and Texas Instruments. With their students they, along side a visiting engineer, did lessons *Design a Better Candy Bag* and *Design a Dome* from TryEngineering. As a life science teacher, Tammy's prior exposure to engineering was limited before participating in the MSTE program.

All of us hoped to gain tips on teaching following an engineering design process, and to obtain additional lesson ideas that we might bring back to our classrooms. We also hoped for help with implementing engineering design as it relates to the *Next Generation Science Standards* and our curriculum. Through a book study based on *STEM Lesson Essentials*, we began to view STEM as an interdisciplinary approach to teaching and one that could use engineering to integrate math and science as well as social studies and language arts. We have also been collaborating with other teachers because of our MSTE participation. Incorporating more engineering design projects that align with our curriculum is one of our goals.

Although we have developed an approach to attack the bindweed problem, we will use the engineering design process with students to evaluate the effectiveness of our solution. If necessary, students will decide what should be done next to try to control the problem. Also, while the bindweed control measures are underway, students will design an alternative place to grow vegetables and flowers. The engineering design challenge will be to design a structure made from wood pallets that will allow plants to be grown outside of the original footprint of the garden. Since this project is a collaboration between the sixth and seventh grade teachers, students who participate as sixth graders will be able to revisit the effectiveness of their designs in the second year when they return as seventh graders. After the bindweed has been brought under control, the garden will be extensively used to address the sixth and seventh grade standards on ecology (NGSS LS2.A: Interdependent Relationships in Ecosystems), and matter and energy flow (NGSS MS-LS2.B: Cycles of Matter and Energy Transfer in Ecosystems and NGSS MS-LS1.C: Organization for Matter and Energy Flow in Organisms). At this point students will be involved in developing the layout and design of the new garden when it returns to its original location.

MSTE has influenced our instruction beyond the garden, especially at the sixth grade level, due to our involvement with the Engineering Ambassadors program prior to MSTE. We have shifted our focus from just science to a blend of science, engineering, technology, and some math. For example, we have linked concepts of conduction, convection, and radiation, to designing solar ovens. Our newest engineering projects are more aligned with our curriculum, and we hope to continue to add more engineering design challenges in the future. Although the curriculum at BMS has recently been reconfigured, seventh grade science at BMS has been traditionally much more heavily weighted towards life science, an area of science for which application of the STEM approach is perhaps a bit more challenging. Involvement in MSTE has helped us think about how we could apply the STEM approach to our life science content.

Prior to the bindweed contamination, the garden played a significant role in the sixth grade curriculum, especially in our approach to the ecology/energy units. Students gained information on vermicomposting, soil testing, fertilizing, photosynthesis, and invasives. It allowed students the opportunity to participate in a community-based project. Students love hands-on projects and the garden fulfilled that need. Seventh grade is looking forward to providing similar experiences for their students as well. For all these reasons, we have decided to revive the garden rather than abandon it.

References

National Research Council. 2012. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington, D.C.: National Academies Press.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, by States*. Washington, DC: National Academies Press. www.nextgenscience.org/next-generation-science-standards.

Vasquez, J., M. Cormier, and C. Sneider. 2013. *STEM Lesson Essentials, Grades 3-8: Integrating Science, Technology, Engineering, and Mathematics.* Boston, MA: Heineman.

Internet Resources

Biddeford Middle School Garden Website:
https://sites.google.com/a/biddefordschooldepartment.org/bms-garden-project/

Design a Better Candy Bag and Design a Geodome
http://tryengineering.org/lesson-plans

Biddeford Middle School Grade 8 Science and Math Multidisciplinary Unit

By Ann Putney, Chelsea Brittain, Gert Webber and Linda Descoteaux, Grade 8 Science and Math Teachers, Biddeford Middle School

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The Biddeford School Department serves nearly 2,500 students and is anchored by Biddeford High School (BHS), a comprehensive four-year public high school serving nearly 750 students. BHS and the Biddeford Regional Center of Technology are located on an 18-acre campus in the city of Biddeford, Maine. Elementary and middle schools are located within a half-mile radius on Hill Street. Biddeford is nestled in the southern coast of Maine, 13 miles south of Portland and less than 90 miles north of Boston. The city's diverse economy is driven by industrial, professional, public administration, and service sectors, with strong connections to its industrial roots. It is currently undergoing a cultural and arts renaissance. Nearly 20% of the Biddeford student body has an identified disability. The BMS student population includes more than 50% who qualify for free lunch. Its ELL population is growing rapidly from 3.6% in 2015.

The two grade 8 science teachers and two grade 8 math teachers wanted to initiate an interdisciplinary working relationship for the long term, with the goal of making learning more relevant and engaging for our students. Our Year 3 MSTE project is a culminating activity that applies essential standards from science and math to engineering design of a satellite. Students will use an engineering design process to integrate knowledge acquired in math and science classes in order to deepen understanding of a real-life synergistic connection between the subjects. This follows a multidisciplinary model, as described in the book *STEM Lesson Essentials.* Students build a scale model of a CubeSat to accomplish an assigned mission, with specific constraints of mass, power, and budget. This activity is a way to integrate Earth and space science standards, including human impact on Earth systems, with mathematics standards in 3-D geometry, scale models, and scientific notation.

Three of us (Ann, Chelsea, and Gert) have been involved with MSTE since spring of 2015. We joined so that the Science, Math and Technical Education departments could collaborate and come to a common understanding of what STEM means to us. It was a perfect opportunity to look at science and math standards to see where they overlap, and it would make sense to build a multidisciplinary unit that included both subject matters, technology and engineering. The fourth member of our team (Linda) joined the project in the fall of 2015 when she began working at BMS as the math instructional coach. She was very interested in learning more about STEM and integrating math into other subject areas.

This teacher cohort looked at "Big Ideas" in each discipline that we could bring together for the unit. We settled on the science idea that the solar system consists of the sun and a collection of distant objects, including planets, their moons, and asteroids that are held in near-circular orbit around the sun by its gravitational pull on them. It made a lot of sense to use the solar system unit to integrate math, because students were studying scientific notation and volume of spheres. To use these skills in the context of our solar system was a logical choice. Through a culminating engineering project, students would learn how technology is used to monitor human impact on Earth systems by designing a scale model satellite to carry out an assigned mission. Our driving question for the unit is: **"**How has technology expanded our knowledge of the solar system?"

Lesson	Objective/Guiding Question	NGSS Practice	NGSS X-C Concept
Gravity ESS1-2	*How does gravity affect objects in the solar system and how they move?*	Modeling	Patterns, Systems and System Models
Lunar Phases ESS1-1	Develop and and use a model of the Earth-sun-moon system to describe cyclic patterns of lunar phases. *Why do we have different moon phases?*	Modeling	Patterns, Systems and System Models, Scale, Proportion and Quantity.
Seasons & Tides ESS 1-1	1) Use a model to explain how the movements and distances between Earth and Moon produce tides. 2) Explain how revolution, rotation, and precession of the Sun-Moon-Earth system produce changes in the solar angle of incidence that result in seasons.	Modeling Analyzing and Interpreting Data	Patterns, Systems and System Models,
Solar & Lunar Eclipses ESS1-1	Develop and use a model to explain the relative position of the Sun, Earth, and Moon during a solar and lunar eclipse and the shadows they produce.	Modeling	Patterns, Systems and System Models
Inner Planets	Analyze and interpret data to determine scale properties and characteristics of the four inner planets.	Analyzing and Interpreting Data	Scale, Proportion and Quantity
Outer Planets	Analyze and interpret data to determine scale properties and characteristics of the four outer planets.	Analyzing and Interpreting Data, Using Mathematics and Computational Thinking.	Scale, Proportion and Quantity
Asteroids, Meteors and Comets	Compare and contrast the physical properties and locations of asteroids, meteors and comets.	Modeling, Constructing Explanations.	Patterns, Systems and System Models

Unit Overview

In science, students explored how gravity affects objects in the solar system and how they move. They found that the distance between them affects the force of gravity between them. Using the Earth-moon model students explored the position of the Earth, sun, and moon during the lunar cycle to answer the following questions: How do these movements and their distance produce tides?

How do revolution, rotation, and precession of the system produce changes in the way sunlight reaches the Earth to cause seasons? The focus broadened to the solar system: What can we learn about objects and where they are in the solar system through data analysis?

Connection to *Next Generation Science Standards*

MS-ESS3-2 Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

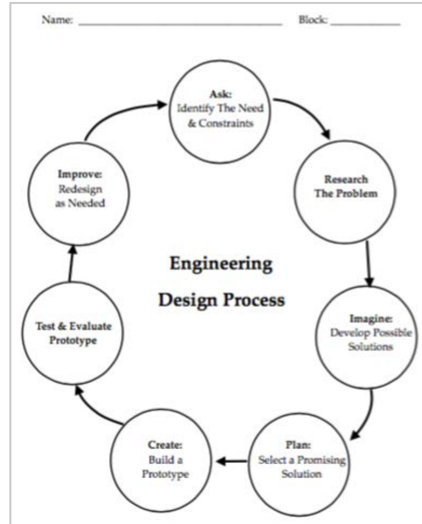
MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they met the criteria and constraints of the problem.

MS-ETS1-4 Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

This unit concluded with an engineering design challenge during which students designed a CubeSat, a relatively inexpensive satellite for space research that is built from 10×10×11.35 cm cubic units. This challenge was based on *CubeSats: Big Science in Small Packages* from the Teaching Channel and Boeing. According to the unit plan, "After being provided with criteria and constraints, student teams engage in an authentic design process to create CubeSat models that are then tested for various capabilities through an iterative cycle of testing and optimization. This engineering project provides students a deep dive into the application of science, math, and engineering concepts, as they work to meet all mission requirements. The unit ends with students writing and presenting a mock proposal to NASA to build a CubeSat with a specific payload." This is a fifth grade unit, but time constraints at the end of the year truncated our plans to increase the level of sophistication for eighth grade. The kids were able to design, construct, fail test, and revise their models, following the newly adopted BMS Engineering Design Process Model.

Linda and Gert decided what the students would need to complete the math portion of the solar system project, which would culminate in building a scale model of the solar system. Students began with a geometry unit addressing the *Common Core* Math standard that expected them to calculate the volume of round 3-dimensional shapes (8.G.9), including the volume of spheres. This skill would be used to find the volume of the planets. From there they moved into a unit on exponents and scientific notation, addressing the *Common Core* Math standard 8.EE.A.4.

During the final weeks of school, students were introduced to a scale model solar system project for math class. At the same time, they were working on the solar system unit in science. Our goal with this unit was to incorporate those skills we had worked on in class (volume of spheres and scientific notation) to make learning more relevant for our students. The expectations were that students would calculate the volume of all the planets and use their knowledge of scientific notation to find distances in our solar system. Students were given a chart and worked in teams to complete it. This chart was meant for them to get a better "feel" for the distances/sizes in the solar system. The most interesting finding for the students was that the planets were not even visible on our corkboard representation of the solar system once they found the scaled sizes. Their next task was to research a planet and create an informational card that would be included in a class scale model of the solar system. It was interesting to see how students made connections to science during the project. Many used what they had learned in science to create these cards, even though it was not a requirement. We had given them a website to use for them to find information on their planets. We had asked for a few facts, as well as the distances. Students said they already had information they had learned in science and quickly opened documents on their iPads or asked to get their science folders to complete their cards. Each group of students then used string to demonstrate the scaled distances from the sun (which was represented by a pushpin) to each planet on corkboards in the back of our classrooms. It was a whole class effort to create the representation. Students were shocked to see how the solar system looks when the planets and their distances were scaled down to fit on a class bulletin board. Since the planets were not even "visible," the end of the string marked where the planet should have been. This is where they attached the cards that represented "their" planet.



It was interesting to see where students made automatic connections between the science and math content without being prompted. For example, they pulled out their science research to add to their informational cards, and when we first started the unit, many students asked why we were learning about the planets in math. We quickly pointed out that they would need math to calculate distances and the volume of the planets; it was not just a science unit. This understanding created more connections to deepen their learning. It makes sense to recreate a similar unit next year, with some adjustments, but including building the CubeSat in science and making the scale model of the solar system in math. Students were very much engaged with the notion of the CubeSats as little units that could do a simple job alone or in concert with others. The fact that CubeSats are used in real-world research made the students feel that the design exercise was relevant to them.

Working together to create a single-theme unit from our usually distinct content areas has been a pleasure, with direct benefit to our students. Students clearly made direct practical application of skills learned in math class to the design and building of their satellite models. We'll build on our new more cooperative style as we repeat and broaden the unit. We plan to do this earlier in the year and include both English language arts and social studies standards as well. We would follow a similar timeline for teaching the math and science content. The satellite challenge will be further developed using Landsat imagery lessons that will connect to the NGSS Earth and space science standards regarding the impact that humans have on the Earth. In addition, we have in-house resources available that will help us refine the various satellite missions that are described in the lesson plan. Next year we would make more connections by including a writing component in English language arts where they reflect on the engineering process, and perhaps by having students do some research on space travel in their social studies classes. In math it may be interesting to calculate the time it may take their CubeSat to reach the planet each group had researched, if launched from Earth. We would also like to have students use their knowledge from science class to develop their informational cards for the planet used in the math solar system model, rather than look up random facts on the internet.

MSTE has been invaluable to us as we came to a focus on a multidisciplinary topic and developed our project. First, the opportunity to collaborate with our entire ten-person Professional Learning Community for the two years of this project has not been possible for us in the past. The able facilitation from Maine Mathematics and Science Alliance has helped us to discover synergy between our content areas that we were previously unaware of, and our work at the Maine Maritime Academy and with Husson University provided common engineering-specific professional development, which would otherwise have been unavailable to us as a group. As we began to focus on a project, four of the ten of us came together. Three of us are grade 8 instructors in science and math and the fourth is the BMS math specialist. With the asynchronous book study of *STEM Lesson Essentials* behind us, we were well equipped to choose a style for the unit and to begin our work. The fact that the budget allowed us to purchase materials and put them directly to work in the unit was very helpful. We are grateful, as well, for the compensation of our time spent in this work outside of contract hours.

References

National Governors Association Center for Best Practices and Council of Chief State School Officers (NGAC and CCSSO). 2010. *Common Core State Standards*. Washington, DC: NGAS and CCSSO.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, by States*. Washington, DC: National Academies Press. www.nextgenscience.org/next-generation-science-standards.

Vasquez, J., M. Cormier, and C. Sneider. 2013. *STEM Lesson Essentials, Grades 3-8: Integrating Science, Technology, Engineering, and Mathematics.* Boston, MA: Heineman.

Internet Resources

CubeSat
http://www.cubesat.org/

CubeSats: Big Science in Small Packages
https://www.teachingchannel.org/cubesat-engineering-unit-boeing

Landsat Science
http://landsat.gsfc.nasa.gov/?page_id=11

Resources

Find the complete Unit Overview, BMS's Engineering Design Process Model, the *NGSS* Performance Indicators for the satellite engineering challenge, instructions for scale model solar system project, and distances in our solar system student chart at www.mmsa.org/MSTE.

Engineering with LEGO Robots

By Raymond Sampson, Technology Education Teacher,
Biddeford Middle School

I've been teaching Technology Education at Biddeford Middle School for 29 years. I've attended training on LEGO robotics through NASA Explorer Schools and have been utilizing these kits since 2005. Being a technology teacher, I was my own island that was not included in the planning of curriculum of the science department until the MSTE initiative and the focus on incorporating engineering. Because robotics is an elective, not all students will have this class in any given year. MSTE's approach has allowed me to emphasize how math, science, technology, and engineering all fit together to accomplish the goals of the NGSS.

LEGO robots have been around since 1998 and are currently on their third generation of robotic kits. Maine Robotics holds an annual Spring Track Meet with ten different events that attracts over 100 teams from around the state. One of the events is known as the "Table Clearer." In this event, the robot must autonomously remove eight soda cans from the 3' x 4' tabletop. My MSTE project involved designing a learning activity using the "Table Clearer" that I will use at the seventh grade level next year.

I have been doing a similar activity that involves a 2' diameter circle and five cans placed at very specific locations, which I plan on continuing at the sixth grade level. Students design a robot that is limited in size and must use at least one sensor to control its movements as it pushes the cans out of the circle. Adding the element of a tabletop that the robot can actually fall off increases the difficulty for the seventh grade robotics class. I also want to encourage seventh grade students to be as innovative as possible by giving them access to more sensors and building components.

Like in all of the design challenges that I do, the students engage in engineering design using a process outlined in the *Next Generation Science Standards*. I learned this process from the work I've done with MSTE. This has led to better student understanding of design, and clearly their motivation has increased because they can see the results of effectively using a process to create a better solution. Without the support of the MSTE project, I probably would have continued being my own stand-alone program without tying the NGSS standards with mine, which were from the *Maine Learning Results*. The other advantage of using the NGSS standards is that students have been using the same terminology in their science classes so they recognize the vocabulary, practices, and design process. When students see the standard in multiple places, they have opportunities to meet that standard in a variety of ways. The increased coordination between science and technology educators is a direct result of the MSTE project.

Because of how engaging the LEGO robotics program has been, next year the fifth grade science teachers will be using NXT robot kits, and the district has bought 24 additional EV3 kits to be used with the sixth graders. The district is very committed to expanding STEM throughout the curriculum and has even started a STEM Academy at the middle school. I will be a member of that academy along with a science/math teacher and an English language arts teacher. MSTE had an influence on my decision to step off from my island and join an academic team that is focusing on STEM. The STEM Academy teachers have had time to plan this summer and will get together again before school starts to continue laying out our curriculum.

Title: LEGO Engineering: Table Clearing Robot

Overview

This activity will take approximately five to six 45-minute class periods and was designed for seventh grade students.

> **Connection to *Next Generation Science Standards***
>
> MS-ETS1-4 Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Students will design a robot to complete the table clearing mission. The design must include at least one sensor to control the robot and keep it from falling off the table. Sensors that are included in the EV3 kit are: ultrasonic sensor, gyro sensor, light/color sensor, and touch sensor. Students will have already completed tutorials on each of the sensors so that they know how they work, and how to include them in the program that controls the robot. The completed robot must fit within a 12” square and cannot expand once it’s started. The components used to build the robot are from the Core EV3 kit and an Expansion kit that includes additional technic LEGO pieces.

Upon completing this project, students will be able to:

- Work as part of a small group to accomplish tasks.
- Utilize sensors to control their robot.
- Use the design process to make modifications to their design.
- Write a computer program to maneuver their robot.
- Build an original robot using their EV3 kits.

At the time of this writing the unit is still being planned for the upcoming school year so I still have some work to do on the specifics of the activities. The project will be introduced toward the end of the robotics class, after students have already used each of the sensors in the EV3 kits and understand the advantages/disadvantages of each. I expect the students to come up with a variety of solutions to the given problem. They will have to develop possible models and programs to accomplish the task. They will have several chances to test their model and make modifications as they see fit.

References

Maine Department of Education. 2007. *Maine Learning Results: Parameters for Essential Instruction*. Augusta, ME: Maine Department of Education.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, by States*. Washington, DC: National Academies Press. www.nextgenscience.org/next-generation-science-standards.

CO_2 Cars and Newton's Laws of Motion

By Douglas Bertrand, Technology Education Teacher, Biddeford Middle School

I teach sixth, seventh, and eighth grade technology education at Biddeford Middle School. The city of Biddeford is a unique community of both urban and rural. It consists of very affluent beachfront property, inner city urban areas, and rural farm zones. Biddeford is very committed to education. During my 29 years in the district, the city has built two new middle schools and a new elementary school and has completed a total renovation of its high school. The district has maintained all the programs we have seen other districts eliminate during budget cuts including all of its unified arts classes such as woodworking, foods, sewing, 2-D art, 3-D art, robotics, band, chorus, physical education, and foreign language (French and Spanish).

I participated in MSTE in hopes of gaining insight on how I might include science and math into my curriculum. I used a CO_2 cars assignment as my MSTE project. CO_2 cars are model dragsters powered by a CO_2 cylinder. I have been using the CO_2 project to teach my students about technology and engineering for much of my career. Newton's third law of motion has always been a side note as students began designing their cars. Aerodynamics and mass needed to be considered as students' ideas become concepts on paper. With their design concepts they would use drafting equipment to draw their design to size while following a list of size specifications.

In an effort to include more science in this project, I had students research Newton's second and third laws of motion. This helped them develop a better understanding of the science behind the car's performance. I brought in more math by having students use the mathematical formula that summarizes Newton's second law to calculate the car's acceleration. Students also weighed their cars and tested the aerodynamics in a wind tunnel. They collected data along the way. Using their data they determined the weight to aerodynamics ratio and made predictions as to the winning order of the cars. Students then raced their cars and recorded the race times. Using the car's time and the track distance students calculated their car's actual speed. They compared the data to see if the cars placed in the same order as predicted. If the cars did not place in the predicted order, we discuss what factors might be the cause, such as friction.

My students have become much more knowledgeable about the physics behind the cars and this has made them more excited for competitive side of the project. Students also have been able to help teach those who struggle.

One way I plan to maintain the momentum gained through my participation in MSTE is through my involvement in our new STEM Academy. Next school year my schedule includes classes of both seventh and eighth grade STEM Academy students.

CO2 cars designed by my students.

Resources

Find the CO2 car specifications, student data chart and background materials for aerodynamics, Newton's Laws, and friction at www.mmsa.org/MSTE.

Earth Systems Unit: Bodies of Water, Landforms, and Erosion

By Vicki Norris and Holly Patenaude, Grade 2, Songo Locks Elementary School

Holly teaches grade 2 at Songo Locks Elementary School in Naples, Maine. She got involved with MSTE by joining the Professional Learning Community (PLC) meetings with Vicki this year. She saw the opportunity to team teach with a colleague during her move to second grade from first grade. This year she was able to work directly with Vicki on MSTE, as well as join in on other professional development that focused upon instruction in science. Her goal was to collaborate with a colleague and develop units of study that were engaging and meaningful for students. In this endeavor, she hoped to gain some more knowledge of what STEM has to offer students, and develop a better understanding of STEM in order to help promote its usefulness in the classroom.

Vicki currently teaches grade 2 at Songo Locks School in Naples, Maine. In 2013, Vicki was asked to join a group of teachers within MSAD #61 for a Science, Technology, Engineering, and Math (STEM) Professional Learning Community (PLC). The PLC began looking at the *Next Generation Science Standards* (NGSS). From there, she was invited to join the MSTE Professional Learning Community. When she joined, Vicki was seeking professional development in engineering, since it was threaded throughout the NGSS. Vicki had not, up to that point, had any engineering lessons for her second graders and was looking for support in this area.

Both Holly and Vicki currently co-teach grade 2 as part of the STREAM Team (Science, Technology, Reading, Engineering, Arts, and Math) at Songo Locks School, a rural school in Naples. Songo Locks School is a Title 1 funded school with over 400 K-5 students.

MSTE has allowed us to grow as educators. Collaborating with colleagues helped us create a learning environment that engages all learners and includes all students, regardless of their abilities. It has created the opportunity to effectively and efficiently integrate learning from all content areas, and to engage students in problem-based interactive learning. We are constantly thinking about how to integrate the curriculum more. Science and social studies are often pushed by the wayside in favor of a focus on reading and math. Student learning is enriched when teachers are encouraged to integrate all aspects of learning into their practice, and students are exposed to a much more robust curriculum when teachers are able to have them explore and investigate the world around them. We have the opportunity to be creative in our approach to teaching and learning by finding engaging ways to help students meet *Common Core State Standards* and NGSS. We can use the standards as the springboard to deeper learning and connections.

The unit that we developed was based on the *Next Generation Science Standards* for Grade 2: Earth Systems - Processes that Shape the Earth. Vicki began this unit last year as part of her work with MSTE. This year, we chose to collaborate and develop the unit further. Through MSTE we had time and resources to develop a unit that is full of exploration and hands-on learning opportunities to engage a variety of learners in both classrooms. We took several components examined through the MSTE PLCs and incorporated them into integrated units. These components include: identifying what engineers do, identifying the design cycle, using engineering designs to collect data and quantify it, applying a claim-evidence-reasoning (CER) framework for scientific explanation, and supporting families in hosting an engineering component of our STEM night at Songo Locks School.

The unit began by exploring different bodies of water and landforms using a variety of nonfiction resources and flipped classroom strategies. We incorporated map skills for social studies by having students create a 3D map. A geologist/vulcanologist community member visited our classroom to explore volcanoes with us. Students graphed how fast they ran in 10 meters. Then they compared that to the data shared with them about how fast a volcanic flow is. The goal was to explore and see if they could outrun a volcanic flow. Through a simulation, students were also able to “feel” what it is like when the Earth’s plates move and cause an earthquake. Students stood on a table resting on balloons. The table was moved, simulating the movement of plates during an earthquake. This experience inspired us to seek out more professional learning opportunities outside of the classroom to help enrich the lessons even more through personal experiences.

At each step of the lesson development, the end goal was always an engineering project. Last year, Vicki's classroom developed a structure that would withstand the elements, using "The Three Little Pigs" as inspiration. This year the building activity continued to be influenced by "The Three Little Pigs" as a YouTube video was used to "hook" students for engagement in the engineering project. Students were asked to figure out how to keep the three houses from washing away. They were shown the beginning of a video, and then students were asked to solve the problem of houses being washed away by quick changes in the water flow in a river. Students planned their structures, then built and tested them as a group. Looking back, students could have spent more time on building, and maybe less time could have been spent developing the background knowledge, or this could have been integrated into the building process. Students could have engineered more complex structures, and had more trials for their structures. During the testing phase, many students didn't pour the water correctly to create a river, but instead just dumped the water in one place and created "ponds" or standing water that was absorbed by the sand. Through this process we discovered what materials should be planned on for future trials, including a larger sand table for trials and/or a specific placement of the river.

In the units that we have developed through MSTE, students are learning to think "outside the box." They are using the engineering design cycle and becoming problem solvers. Through these experiences, they learn how to work in groups, how to gather information, and how to use that information to help them solve real world problems. They gain a better understanding of what is happening in the world around them, they are engaged in the lessons through engineering opportunities, they are motivated to solve the problems they are presented, and they are able to apply what they learn to other situations and make connections to their own experiences. They become much more resilient, making mistakes and learning from them. Many can move beyond failure and stay focused on the task at hand. This spills into many academic areas. Our students LOVE engineering!

MSTE has given us the opportunity to team with other teachers in our district, as well as other teachers in Maine. This has allowed for the development of units that can be used to promote the integration of STEM and the *Next Generation Science Standards* with the everyday curriculum by integrating math, science, engineering, writing, and literacy through project-based learning opportunities. We will continue to use what was gained from the MSTE experience and build upon the lessons that have been developed to effectively integrate science, engineering, and social studies into daily learning. The units we developed during this process are the framework. They will evolve and each lesson will be refined to meet the needs of the students and the curriculum. The students will continue to teach us what their needs are and how we can help them. Collaboration will keep us moving forward. As we continue to work together, we will be able to develop these projects and make them into something that can be shared within the district and beyond our state to assist others in effectively integrating all content areas.

Title: Earth Systems Unit: Bodies of Water, Landforms, Erosion

Scope and Sequence Overview

Introduction to Earth Systems (1 session)

An introduction to the unit for students, explaining what they will learn and be able to do. The introduction addresses the burning questions and key take-aways.

Burning Questions:

1. Where can water be found?
2. Can the Earth change suddenly?
3. Can Earth only change very slowly?
4. Why do some changes to land take so long? How will we answer this question?
5. How are wind and water alike?
6. What are some problem solving strategies or technologies that help us deal with changes in our landforms? How can we prevent erosion?

Key Unit Take-aways:

1. Water is found in the ocean, rivers, lakes and ponds.

2. Water exists as solid ice and in liquid form.

3. Bodies of water have a beginning and an end.

4. Water contributes to the development of landforms.

5. Landform events can happen very quickly and others occur very slowly, over a time period much longer than anyone can observe.

6. Maps show where things are located.

7. One can map the shapes and kinds of land and water in an area.

8. There are technologies that people design to help solve the problem of erosion.

Forms of Water on Earth (4-5 sessions)
Students will learn and explore the different bodies of water on the Earth. The focus will be on oceans, rivers, ponds, and lakes.

Forms of Land on Earth (4-5 Sessions)
Students will learn and explore the different landforms on the Earth. The focus will be on mountains, islands, plains, plateaus and hills.

Mapping Our World (3 sessions)
Students will create a 2-D map using landforms and bodies of water to plan a 3-D model. Students will create a 3-D map of 3 landforms and 2 bodies of water using white dough.

Connection to *Next Generation Science Standards*

2-ESS1-1 Use information from several sources to provide evidence that Earth events can occur quickly or slowly.

2-ESS2-1 Compare multiple solutions designed to slow or prevent wind or water from changing the shape of the land.

2-ESS2-3 Obtain information to identify where water is found on Earth and that it can be solid or liquid.

Connection to *Maine Learning Results*

D. Geography Students draw on concepts and processes from geography to understand issues involving people, places, and environments in the community, Maine, the United States, and world.

Connection to *Common Core State Standards*

Reading Informational Text, Grade 2
a. Key Ideas and Details
b. Craft and Structure
c. Integration of Knowledge and Ideas
d. Range of Reading and Level of Text Complexity

Writing, Grade 2
Research to Build and Present Knowledge
Speaking and Listening,
a. comprehension and collaboration
b. presentation of knowledge and ideas

Mathematics, Measurement Data, Represent and Interpret Data

Effects of Wind and Water: Erosion
Quick and Slow Changes to Land: Students explore ways in which the land can change quickly and slowly, including volcanoes, hurricanes, tsunamis, erosion, weathering.

Project Based Learning / Engineering: Students create a barrier to protect the Three Little Pigs' houses from being washed away.

References

Maine Department of Education. 2007. *Maine Learning Results: Parameters for Essential Instruction*. Augusta, ME: Maine Department of Education.

National Governors Association Center for Best Practices and Council of Chief State School Officers (NGAC and CCSSO). 2010. *Common Core State Standards*. Washington, DC: NGAS and CCSSO.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, by States*. Washington, DC: National Academies Press. www.nextgenscience.org/next-generation-science-standards.

Resources

Find a detailed scope and sequence for the Earth Systems Unit: Bodies of Water, Landforms, Erosion at www.mmsa.org/MSTE.

Serious First and Second Grade Scientists and Engineers

By Randa Viitala, Grade 1 and 2 Teacher, Sebago Elementary School

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Sebago Elementary School, a rural community school that sits on the shore of Sebago Lake in Cumberland County, is a very close-knit school, where everyone knows everyone. The school community is made up of about 85 students in grades K-5. If you've taught there long enough, you taught the parents of some of your students.

Three years ago, our school revamped the way we teach. With the exception of Kindergarten, we are not traditional teachers. There is a lot of kid swapping. We teach to our strengths or passions. I have the privilege of teaching math, science, and social studies to first and second graders. My partner teaches all of the language arts to our students. Grades 3-5 have also divided up the curriculum. This allows us the time to focus on fewer subjects.

The year before our MSTE project began Ted Bridge-Koenigsberg and I sat down to make sense of the *Next Generation Science Standards*. We wanted to come up with investigations that could be easily completed. We began by searching for investigations that would meet Kindergarten standards. When the flyer appeared about participating in this project Ted and I immediately signed up. Another colleague also signed up. The following year, a colleague new to our building joined the team. I am really proud that the smallest school in our district has the most teachers participating in this project.

I have gained so much from MSTE. An important piece I gained is the beginning of an understanding of the process of engineering. I knew nothing of the engineering process. I can't quote all of the steps without looking, but I now know there is a process. Whenever I heard the word *engineering,* it was daunting, I immediately thought, "This is something I am not qualified to do. How am I ever going to teach it?" Throughout this project I have been exposed to a variety of ideas and methods for teaching engineering to kids. The understanding I have gained from MSTE is the "how" of how I can combine science with engineering. I was concurrently involved in a University of Maine professional development project that integrated productive talk, higher-order thinking skills, and writing in science with an existing curriculum called STEMScopes. I have learned many methods that have shown me that I can teach engineering to my first and second graders. I don't have to have all of the answers, just a lot of questions to make my students think and question their own actions.

MSTE has provided me with professional friendships, some old and some new, and personal experiences. The old friendships with the three teachers actively involved in my school have deepened through cooperative work. I have also had a chance to work with other teachers from my district. I never would have formed these new friendships had I not attended the summer work in Castine. It was great to meet and talk to teachers from neighboring districts to see how they have decided to tackle the new science standards. I have especially enjoyed meeting a second grade teacher and hearing how she plans to integrate the standards with engineering. I have been able to share some engineering tasks with her, occasionally exchanging emails. It is amazing to see the path our kids take. Teaching both first and second grade, I get very excited by the progress I see my students making. But, when I hear the middle school teachers talk about the things their students are doing in the name of STEM, I'm awed by their sophistication.

MSTE has resulted in several shifts in my instruction. The first was to add engineering. During year 2 of MSTE I dabbled with STEMScopes. Most of the year I spent reading through the materials afraid to try the activities. I wasn't sure if I had the time to do them justice. In the spring of that year, I decided to jump in with both feet and really try the activities. Additionally, I was able to integrate science content with engineering, have shifted my role from delivering all the information to guiding students through explorations, and have started working with students on supporting claims with evidence.

My first topic of the year was on Properties and States of Matter. I combined a variety of activities with literature and class discussion techniques. I asked the students to first discuss what they thought I meant by the term *matter.* This led to several hands-on activities where students came up with a number of ways to describe the objects they were exploring. They found they could describe an object by its color, shape, size, or texture. Students were then placed in groups to apply their learning about properties of matter to the creation of a monster that fit specific criteria and constraints. The students were to create a monster that could be added to a toy store collection that, if selected, would then be produced for sale. Each monster needed to be flexible and have both smooth and rough parts. One of the constraints was that they could only spend twenty dollars on materials. Another was that each monster be at least 20 cm tall. In a later engineering project tied to the matter unit, groups created a shoe sole that had a purpose. In addition to shape and size we looked at how different properties are suited for different purposes. For example, the purpose could be to mop a floor or help you walk across the ice. The students were placed in teams. Each team had to decide on the purpose of the shoe sole before the designing could begin. Once each child designed their own shoe sole, they met as a team and collaboratively designed one shoe sole that would be created using only the materials provided.

Second grade monsters

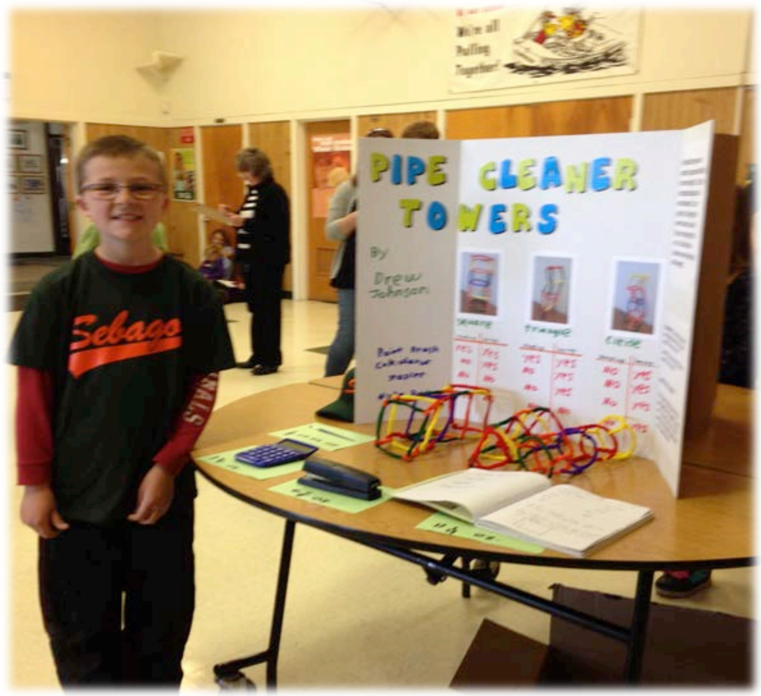
During a unit on slow and fast changes to land, the students learned about the changes that have happened to our planet. We learned that things like earthquakes and volcanoes can change the surface of Earth quickly whereas rain and wind take far longer to make changes to our planet. We saw evidence of slow changes in pictures of the Grand Canyon. We looked at pictures and read books and discussed how we thought the changes presented happened. Did they happen quickly or over a long period of time? One engineering task was to create a building that was between 40 and 50 cm tall that could withstand a 10 second earthquake (me shaking a desk). Each of these projects had the teams designing, testing, redesigning, and testing again.

I loved being able to walk around the room and listen in on my students' conversations and then ask thought-provoking questions for them to think about. I hoped they would talk to their team, and maybe use these new thoughts as part of their engineering challenge. Being able to walk around this way allows me to guide them through their discovery rather than standing in front of the class presenting information. When it came time for the students to present their findings to the class, a whole new challenge was brought to the forefront. I need to think about what I want them to present, and maybe provide an outline and give them more time to practice their team presentation. Finding time to do this is always a problem.

Another change to my instruction has been the introduction of claims and evidence as a way to respond to questions that have been asked at the end of an investigation. One of the most challenging parts of this whole experience was teaching my students how to write a claim supported by evidence. This was something that everyone struggled with. As a teacher I asked, “How am I going to teach this?” Students were asking, “What am I supposed to write?” I read through a couple of books on the topic and found that I needed to have my students practice orally first. They would come to me and say, about a partner playing a math game, “He’s cheating.” I would reply, “That’s your claim. What’s your evidence?” It seemed to help. I need to have my students do this for all content areas, and they need to practice even when we aren’t doing a unit on science. I found that when I went back to a science topic after completing one on social studies, they had forgotten how to write a claim supported by evidence.

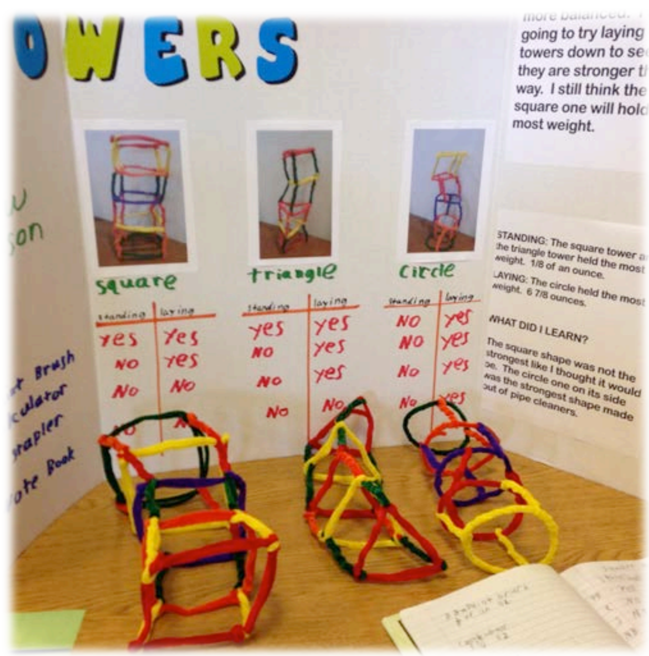
This fall, my colleagues attended a workshop on running a Family Engineering Night. We had so much fun we wanted to plan one of our very own. We decided to hold one, hoping it would help students come up with ideas for the upcoming science/STEM fair. We met as a team, chose the opening activities, and selected the group engineering challenge. We were each in charge of an aspect of the event. My job was to prepare the materials for the opening activities and the engineering challenge. I also created excitement throughout the building by posting signs. The signs simply said “Coming Soon: Family Engineering Night.” These signs did exactly what I wanted them to do. Several kids kept asking me, “What’s Family Engineering Night?” I replied that they should just keep reading the hall. My next set of signs took the engineering process and made them into questions that would lead the students to want to come to the event. The night was fast approaching, excitement was building, and I couldn’t wait. Then it came—an ice storm. We were forced to postpone our night. We were all so disappointed. I began promoting our new date.

Family Engineering Night was finally here! By the time our doors opened we had gone from an anticipated 20 participants to an actual 80! Not bad for a school with a student body of 85. We had preschool children through eighth graders. Parents, guardians, and grandparents accompanied the children. The room was abuzz with excitement. We decided to add a component to our night that was not a part of the Family Engineering Night training. We wanted to extend the experience by giving each family or child a “make it and take it” engineering project. I received an email from a mother 30 minutes after our night ended. Her son had completed the pipe cleaner challenge and wanted me to see his tower. The challenge was to make the tallest freestanding tower using only 15 pipe cleaners. We received a lot of positive feedback from the families. They were appreciative and couldn’t believe how much they learned about engineering and its process.



This student took the Pipe Cleaner Challenge and turned it into a STEM Fair Project.

This child took the pipe cleaner challenge one step further. It became the basis for his science/STEM fair project. He created towers made out of different shapes. He tested them and recorded the time they were able to stand on their own.



I noticed that there were several science/STEM fair projects that had their start as part of Family Engineering Night. I couldn’t have been more pleased. If the projects weren’t related to Family Engineering Night, they showed more of an engineering process. Many projects weren’t your typical science fair projects. We had taken one more step in the right direction.

I think MSTE has had a huge impact on our school. The kids now have an opportunity to experience engineering projects from first to fifth grade. I feel that our small school has supported Ted and me in our attempt to incorporate engineering into the science program. The kids are excited. At the beginning of the year, the third and fourth graders would ask me what I was wearing. I told them I was wearing a lab coat and safety glasses because we were serious scientists. Anytime after that when they saw me they would comment that we (first and second graders) were serious scientists and they wanted to know what we were learning. My own students can't wait for science. Whenever I say, "Scientists, please show me you're ready" the room fills with excitement as they get out their lab coats. They always want to know if they can wear their safety glasses and I always say, "Sure." The lesson may not require them, but if it helps us get in the frame of mind of a serious scientist, then I'm all for it.

As our school year winds down, I am already thinking about next year. I can't wait to get started. I've already replaced most of my materials. I have a huge collection of toilet paper rolls, cereal box panels, and egg cartons to be used for the engineering challenges that await my students. I'm thinking about pacing. I should have pushed us along a little bit faster, as I've been feeling very rushed at the end of this year. I want to add some engineering activities to my stations, independent work areas where small groups of children work together, since most are math-related. I need to rethink storage for our science and engineering supplies. I've already begun preparing for future Family Engineering Nights. My goal is to prepare all of the opening activities and divide them up into three boxes to represent three different years. Once we have used each activity at least once, we can rotate through them in successive years.

I believe that as long as Ted and I are excited about STEM then there will be momentum for this work. My first graders are already wondering about the science and engineering they will be participating in next year. I also wonder if my current second graders will want to continue to wear their lab coats and safety glasses next year when they are with Ted.

References

Jackson, M., D. Heil, J. Chadde, and N. Hutzler. 2011. *Family Engineering: An Activity and Event Planning Guide*. Portland, OR: Foundation for Family Science and Engineering.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, by States*. Washington, DC: National Academies Press. www.nextgenscience.org/next-generation-science-standards.

Internet Resources

STEMScopes

http://www.acceleratelearning.com/

Makerspaces...How Can You Fit Them into the Curriculum?

By Carolynne Skarbinski, Grades 3-5 Teacher, Sebego Elementary School

I began my career as a teacher in rural Sebago, Maine. Sebago Elementary School is one of three elementary schools in the Lake Region School District (MSAD #61). My teaching career began with teaching reading, writing, science, math, and social studies to grade 5. Later on, I taught reading, writing, and math to grade 5 and reading to grades 3 and 4. I still teach this way today.

Why a makerspace? What is a makerspace? Why is it important? As a new teacher, it is difficult enough trying to figure out what being a teacher means and what the requirements and duties of a teacher are in the district you teach in. While spinning all these plates, I wanted to make sure that I am being effective in what I am teaching. I joined MSTE in the fall of 2014 so I could do just that. The group already had a year under their belt with engineering as I was just testing the waters. On top of this our school was in the process of adopting the *Next Generation Science Standards* so I was creating lessons, units, and assessments as I was going along. MSTE was eye opening. We discussed how engineering, math, and science are all interconnected and how they work together. We worked hands-on with engineering and discussed our learning and experiences.

This year (2016) I am no longer teaching science but I still wanted to integrate engineering and science into my classroom. I have many students who enjoy watching how-to videos on YouTube to teach themselves things. I have one in particular who does this regularly and shares with me what it looks like by showing me how to do it. They also explain the significance of it. This is why I chose to introduce a makerspace as my year 3 MSTE project. A makerspace is a place where creating, thinking, testing, building, and perseverance takes place and where students share new ideas and ways to do things. It is an area specifically set aside for creative thinking (brain exercise) and doing, complete with the tools and materials needed. This could include items such as popsicle sticks and CDs or 3-D printers and laptops/iPads. I took all this into consideration as I was picking out a table space to use. I found a portable space that includes drawers and shelves to hold materials. Since I planned on it being in my classroom, I wanted to make sure it worked with the chaos of my classroom. Makerspaces can be used in large groups, small groups, or individually. As the year continued, I read a book, *Worlds of Making: Best Practices for Establishing a Makerspace for Your School*, on to help me grasp the concept more fully and learn how to implement a makerspace.

As a class, we started learning about measurement conversions. I came up with the idea of engineering paper airplanes. Everyone was given the same materials (printer paper) to create his/her plane. After these were created, we tossed them and measured in inches how far they flew, then converted the inches to centimeters, meters, feet, and yards. We also discussed why some planes went further while others did not. We discussed what we could do differently next time to improve the distance the planes flew. Another day, I let the students use printer paper, staples, and tape to modify their planes. They realized that weight and stability had a direct impact on the flight path of their planes. This time they went further and straighter. I decided to integrate engineering this way because the end of the school year became busier and busier and time was running low. I wanted to introduce our makerspace, and introducing in a class setting made all the students aware and got them thinking about engineering, science, and math at the same time. They were all testing out their ideas, working through their mistakes and failures, and sharing what they experienced. It was also very hands-on, which they loved! I feel that the inclusion of the makerspace will motivate students and engage them in learning without realizing it. It will also allow them to work out and see their ideas come to life. I loved seeing them laugh and giggle while doing math and helping each other try doing the activity in a different way. It was a great form of collaboration.

MSTE has been the driving force behind my classroom's makerspace. Like I have said, I joined this program later than my colleagues, but I feel that it allowed me to learn and integrate engineering, math, and science learning in my own way, which for me happens to be through a makerspace. MSTE also funded and supported our Family Engineering Night, where we invited students and their families, as well as the community, to come and enjoy solving problems together. This allowed us to show our community what we have been working on through MSTE. Our staff has been very supportive and welcoming of our ideas and suggestions about STEM. One of the families stuck around after school to help me put together my makerspace portable table. I hope to keep this momentum going through the continued use of my makerspace. After I have it well established in the classroom, it can then become a rainy day recess activity and then possibly an afterschool activity that reinforces math and science.

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Internet Resources

Making in the Classroom
https://www.youtube.com/watch?v=kxWf7gk8szA

Bringing Your Makerspace to Life through STEM
https://www.youtube.com/watch?v=zFAg7f-uLig

Creating a Making Space in your Classroom
https://www.youtube.com/watch?v=zFAg7f-uLig

Makerspace Intro
https://www.youtube.com/watch?v=UNlZLUaMakw

What is a Maker Space?
https://www.youtube.com/watch?v=NLEJLOB6fDw&feature=youtu.be

How a Stuffed Polar Bear Led to Engineering in Social Studies

By Anita Quinlan, Grade 3-5 Teacher, Sebego Elementary School

I teach fourth grade mathematics and 3-5 social studies in a small, rural setting. We are part of a larger district and our students will join with three other towns for middle and high school. At my school, three other colleagues have participated in the MSTE project over the last three years. This has allowed us to offer STEM experiences to our students as a team.

My reasons for participating in the MSTE project are layered. I was excited to work as a team with a group of colleagues. In a small school, it is easier to make significant changes with a few people. I wanted to see what we could do with four teachers from multiple grades all focusing on the same initiative at the same time. I also wanted to explore some new ideas and thinking, as well as perhaps try a different approach to instruction. I had heard a lot about STEM and wanted to know more. Since participating in MSTE I have presented lessons from a wider viewpoint. I work to incorporate real life thinking into my subject matter whenever possible, and to present learning from the perspective of how to solve a problem.

Engineering can be folded into math and social studies content much more than I had ever realized. In social studies we examine the economic development of the colonies, and now I can look at this through the lens of inventions and technology. I have been able to incorporate engineering into mathematics lessons even with simple experiences like measurement. When we are reading, we take the opportunity to discuss any ideas around engineering and possible future careers.

My year 3 MSTE project prompted me to *strive* to include engineering as an ongoing component in the classroom. One way this happened was through a social studies discussion. I happen to have a huge stuffed polar bear in the closet left from an energy conservation project. This caused a commotion among my students every time I opened the closet door. The students wanted to play with it. We were learning about early Native Americans before Europeans arrived. We looked at different regions of North America. From there the discussion turned

The stuffed polar bear that inspired an engineering challenge

to possible early engineering techniques for building shelters. This is one conversation that would never have occurred prior to my participation in MSTE. We would have named the shelter and moved on. I had never really thought about the role of engineering in this context. This initial conversation led to another about particular shelters for different regions of North America. As usual, the igloo of the Arctic caught the fancy of many of the students. This discussion evolved into how they could use the polar bear and incorporate learning into the event. Eventually they thought of building an igloo from milk jugs. The class wanted to build an igloo and reasoned that this would allow them to have the opportunity to play with the polar bear in the igloo. At this point I had no idea how to go about this, although I had heard about such a structure being built.

We began collecting milk jugs and thinking about how to build the igloo. Collecting milk jugs took several weeks, and when we had five super-size bags full we looked at how to begin. I looked online and found some directions, but no real engineering information written for kids. The article was more about how two adult teachers built an igloo for a reading area. My hopes were that the kids would be taking the lead in figuring out how to design and build the structure. I also tried to keep the claims-evidence-reasoning process in mind as we attempted to figure out a building process out. Students had several ideas about what to do and how to begin. We started building the igloo by thinking about bridges and arches, piggybacking on a topic that they had already explored. We discussed how big the igloo would need to be, where we could put it, and how to make it possible to get inside. There was also the engineering challenge of figuring out how to connect the jugs in a manner that would hold them in place.

The first question was how big to make the igloo because we had to start with a base. As we began working, we realized that we would not have time to collect enough jugs if we made it the size originally planned. They immediately recalculated how small it could be and fit everyone inside by sitting on the floor and squeezing together. Then they decreased the circumference of the base according to how much space they had decided was necessary to go around them. I really thought this was ingenious. We addressed problems when they occurred. One morning they came in to a collapsed igloo and they were sure someone had come in and broken it (probably based on their experiences with snow forts on the playground). I told them I had found it this way and that no one had been in the classroom except me. From this experience we looked at why it might have caved in. Students learned to provide braces to support free-standing “sides” using chairs on the inside and outside of partially completed walls, solving the problem of keeping the structure standing until it could be completed.

An ongoing challenge was how to join the milk jugs together. The class suggested some ideas, and I consulted with a colleague who suggested gorilla tape—sort of a duct tape on steroids. We were fairly successful joining the jugs together using the tape. This worked while we made about six layers of jugs that essentially were the walls. The greatest challenge became the roof and entrance. We tried building the roof on the floor and lifting it in place but we were unable to lift it without it falling apart. The kids tried reinforcing it with a yardstick used as a truss. This also did not work. Then they tried putting cardboard on the roof and taping milk jugs to it only to find that the cardboard would not stay in place. Eventually we ran tape over the top of the milk jugs and reinforced the roof this way. It really did not achieve what we had hoped, but the partial roof did stay in place long enough for a photo.

At this point we were out of milk jugs and time, and some were clamoring for the polar bear. I accepted the fact that they were very happy with what they had built. I realized that they considered it completed because students started bringing stuffed animals to school the next day and putting them in the igloo. So we decided it was officially done, everyone cheered, and the big polar bear came out of storage. Some were so amused as they looked at me and said, “I can’t believe we did all that work to hold a stuffed animal!”

It is interesting to note that within the class there were those who were the builders, those who were the thinkers, those who were concerned about how it looked, and those who just wanted to get inside. It allowed me the opportunity to see individual students in a different light. The roles some took were somewhat unexpected. The biggest and most heartwarming surprise was to see a special education student, who rarely says anything, take the lead. He was the one who actually got me going by saying something along the lines of “Let’s stop talking about this and get started." This showed me that kids were very comfortable diving in, trying one way, and when it didn't work, adjusting their thinking and redesigning on the fly.

Almost all of the students were actively engaged in problem solving and building. The goal was to get the polar bear, but the means to do so kept the motivation high. Understandings around size, shape, measurement, and how the design had to be altered as the igloo became taller were aspects that had to be considered. Sometimes I just listened to them problem solve and sometimes I offered suggestions. These collaborative small group discussions, which focused on the design problem, allowed students to debate the pros and cons of various solutions and approaches and to share and work through their building ideas. Their practical analysis of the best way to do something was to see if something worked, and if it did not, to try something else. The analysis of what worked was based upon what didn't work. Listening to students share their thinking gave me insight into what they knew, and listening to their discussions allowed me to watch them think.

I have always felt that I do not have a strong science or engineering background. My college science courses were methods courses and I think there were only two or three. Any professional development since then has been mostly in the area of life science. Therefore I do not feel confident teaching something without a prescribed curriculum and we do not really have one in our district. MSTE gave me a new confidence. This igloo project would have been too daunting before the class. How the igloo idea itself evolved, how we actually did it, the fact that it wasn't perfect (and that was OK) all "stemmed" from MSTE. MSTE influenced the development of this project because it gave me the background knowledge to know that this wasn't just a fun idea, but a serious engineering project that was worthwhile. Year 3 validated this project in my mind. From here I hope to try something else that dovetails with social studies. It really gave me a new perspective on how to develop the essential understandings in social studies and how to work toward the answers.

Engineering in the School Gardens

By Ted Bridge-Koenigsberg, Grade 3-5 Teacher, Sebago Elementary School

Sebago Elementary School is a small rural school for grades K-5. We are part of MSAD #61, Lake Region School District, in western Cumberland County. Currently we have eighty-five students. During the time I have been involved with the MSTE project, my focus has been science in grades three, four, and five. I also teach language arts and math to third grade students. Randa Viitala and I work closely together so the transition from second to third and beyond is seamless. In addition to our wonderful building we have access to a nature trail and gardens on our school grounds. It is a fantastic place to be a student and a teacher.

Prior to be becoming involved with MSTE, I worked hard to internalize the *Next Generation Science Standards* and *A Framework for K-12 Science Education*. My focus has always been the science practices because I see science as dynamic, not a static collection of information. As I was working through the standards I struggled to understand the engineering practices. They were new to me. The first year of the project, when we delved into the nature of science and engineering, I came away with an understanding that continues to grow. I've been around engineers but really had never thought about how they work and solve problems. That first year we used the *Engineering Is Elementary* unit "To Get to the Other Side: Designing Bridges" and made bridges with students in grades 1-4. It was a great introduction for me and the students in our school. They speak highly of the experience. One of the most significant take-aways has been the statement I use with students on a daily basis, "scientists explain how the world works, engineers solve problems." Every student I work with has a clear understanding of this relationship and how two types of professionals work in tandem.

This newfound understanding of the difference between science and engineering also helped me as a parent. During the time I was participating in the MSTE project our older son was a student in the College of Forest Resources at the University of Maine. I was able to help him through some of his struggles with the applied science of forestry. I was able to help him see how engineering and pure science are interconnected.

In 2004 a very energetic parent started a school garden at Sebago Elementary. She designed and implemented the typical raised bed system that is so popular in school gardens now. Everyone in the school became involved and the project took off. The garden was labor intensive beyond anyone's expectations. The beds regularly needed to be filled with compost and soil and the demand for water was amazing. It required an army of volunteers and students spending recess watering and weeding. The initial plan was to grow huge amounts of food and either use it in the cafeteria or make donations to the local food pantry. The parent group had an extensive fundraising structure and network of people to do much of the work. They even planted spring bulbs that could be sold to raise more money as needed. For a number of years they would request donations of everything from seeds to seedlings to tools to cash. The garden was attractive and productive but required vast inputs to just maintain it. It wasn't sustainable in terms of human energy or garden energy.

Students making observations in garden plots

The students loved to help and do jobs, and the benefit of being outside, learning skills, is amazing. Teachers were asked what they wanted in their bed and it was done for them. The parent group's passion overshadowed student and teacher needs. We did what was asked of us but the system wasn't ours. We didn't want to upset the system or do something incorrectly. This was a group of highly talented gardeners. A number of years ago I voiced concerns that the way the garden functioned didn't fit the curriculum. The parents assumed we would be able to simply use this tremendous resource to teach a wide array of content. They were perplexed and frustrated, and the project made no progress. For lots of reasons not every teacher was comfortable with this system and few used the garden as the parent group envisioned. To make matters worse we couldn't get the produce to the food pantry regularly and we wasted food. Essentially, they had innocently created a tiny version of conventional agriculture with huge production levels that exhausted the soil and disconnected people. I have been interested in school gardens since college and was convinced there was a way to make the garden sustainable in all senses of the word.

During the first year of MSTE, when we explored engineering, I learned it could be much more than tinkering to solve problems. I began to see the garden as an engineering system with a series of problems. As I started looking at it this way I saw we had a system that was layered with problems. For example the soil in the beds had to be brought in every year or two so plants would grow. I presumed this is what happens in all raised bed gardens; they are dependent on outside soil. The beds dry out very quickly, requiring a irrigation system or army of volunteers to water every other day. Solutions to these problems didn't come from large-scale models of conventional agriculture. Instead I used simple observations of natural systems and tried to mimic them in raised beds tended by elementary students.

The system is predicated on what helps the soil, is easy to care for, and that children can be actively involved with. We have been working on developing projects and investigations that are easily undertaken by teachers who aren't gardeners or who are very pressed for time. Investigations also need to be manageable and meaningful for kids. The fall and spring are particularly busy times for elementary classroom teachers. For example, covering some of the beds with leaves collected from the school yard during the fall has built layers of organic matter in the soil. In other beds we have grown winter rye that also keeps the soil covered in the winter. It has been turned under, made into straw mulch, or more recently crushed by children's feet to make a mat for no-till seeding. Another issue has been fertility, how to get a balance of nutrients to the soil life so they could in turn promote the plants we wanted for food, fiber, and flowers. Four years ago we starting setting beds aside to grow red clover so we would have a source of nitrogen for subsequent crops. One of the distinct advantages to growing cover crops with children is that they are easy to plant, easy to maintain, and unless they are being harvested for food grade grain they are easy to process. The system is by no means perfect; we do have a crude irrigation system and we have bought some lime to maintain neutral pH as well as small amounts of seed, but our expenses have been minimal. Also our time has been cut considerably. Students can easily do the garden work and actually work as scientists instead of farm labor. It is a work in progress in the truest sense of the word.

Students experiment with crushing winter rye

In the Matrix of Lessons/Investigations, are six investigations—some science, some engineering—that I have designed to try in the garden. They were written from the NGSS and real needs that came from our garden system. Each one meets criteria on grade level progress reports so teachers have an investigation that isn't an add-on. A word of caution: gardening is really working with nature, and even when well planned and implemented real things happen. Dry growing conditions or insects, for example, are real issues that don't have parallels in a classroom. Keeping the focus on working with nature rather than trying to change nature will even out the revisions. These investigations are by no means fail safe but they should work well in most situations. The matrix of outlines the standards, practices, content, materials, and additional resources so teachers with access to gardens can use these.

Matrix of Lessons/Investigations for teachers with access to school gardens				
NGSS Standard	**Science and Engineering Practices**	**Cross Cutting Concepts**	**Garden Investigation**	**Resources**
K-PS3-1 Make observations to determine the effect of sunlight on the Earth's surface.	Planning and carrying out investigations.	Cause and effect: The sunlight heats the soil.	Using soil thermometer and moisture probes to collect data from garden beds; chart and graph the data.	Soil-A-Bration Section from *Grow Lab*
1-LS3-3 Inheritance and variation of traits; make observations to construct an evidence-based account that young plants are like but not exactly like, their parents.	Constructing explanations and designing solutions.	Patterns: Patterns in the natural world can be observed, used to describe phenomena and used as evidence.	Growing dry beans inside bags with moist paper towels and outside in predetermined beds in the school garden. Collecting beans to save from each year. Also designing a winnowing tool to remove the dry beans from the dry pods.	

2-LS2-1 Plan and conduct an investigation to determine if plants need sunlight and water to grow. Plants depend on animals and the wind to pollinate and disperse seeds.	ETS1.B Developing possible solutions. Develop a simple model that mimics the function of an animal pollinating plants.	Cause and effect: Events have causes that generate observable patterns. The shape and stability of structures of natural and designed objects are related to their functions.	Designing a hand pollinator as well as developing mazes for plants to grow through. Comparing different companion plants that shade as well as support growth. Also comparing mulches.	*Engineering is Elementary* The Best of Bugs: Designing a Hand Pollinators.
3-LS4-3 Construct an argument with evidence that in a particular habitat some organisms can survive, some survive less well, and some cannot survive at all.	Analyzing and interpreting data. Simple data sets to reveal patterns that suggest relationships. Describe, measure, estimate and or graph quantities.	Cause and effect: Relationships are identified and used to explain change. A system can be described in terms of its components and their interactions.	Raising earthworms in the classroom. Developing tools to measure the number of earthworms in each bed. Determine what needs worms have and how to enhance the garden to promote worms.	*Healthy Food from Healthy Soil*
4ESS3-2 Generate and compare multiple solutions to reduce the impacts of human impact on the natural world and vice versa. Living things affect the physical characteristics of their environment (and specific location).	Constructing explanations and designing solutions.	Cause and effect: Relationships are routinely identified and used, and tested to explain change. Influence of science and engineering on society and the natural world. Engineers develop tools and technologies to decrease known risks.	Plants impact on the garden soil. Does this change over time? How can this change be measured? Can soil be created by certain practices? What does clover do for a plot? What does living mulch or crushed mulch do for the garden? Students can collect data on a plot to get a baseline. Winter rye can be crushed instead of tilled and beans can be planted by poking holes. Students can design tools to crush rye and compare with human crushed rye.	
5ESS2.C Roles of water in the Earth's surface processes. Percentages and distribution of freshwater on Earth.	Using math and computational thinking.	Systems and System Models: The garden can be described in terms of its components and their interactions.	Water resources in the garden. How much water do the plants grown need? How better manage the water in the garden. How much water transpires out of the garden plots? Mulching and rotations to use less water. Determine how much water flows into each bed and in between plants. Compare soil surface and at root levels. Compare with more natural systems.	

I am convinced school gardens have a huge potential to teach a wide array of content, just as the founders of the garden project here at Sebago Elementary believed. I try to see this content through the eyes of sustainable science teaching and garden engineering.

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Connecting Science, Engineering, and Writing with Lucy Calkins' *Units of Study* Curriculum

By Sarah Otterson, Grade 2 Teacher, Hebron Station School

I participated in the Math and Science Through Engineering program from 2013 to 2016. I have taught second grade for 26 years in the town of Hebron, Maine. Twelve of those years were at Hebron Elementary School, a K-3 school. Then a new K-6 school was built four miles down the road in 2002. The new school, Hebron Station School, currently has a population of 130 K-6 students. Hebron is located in Oxford County in western Maine, and it is part of Oxford Hills School District. Hebron Station School is a small rural school. My colleagues and I have worked to make Hebron Station School an active, authentic learning place through classroom science and engineering lessons, and through getting students outdoors with the development of gardens, schoolyard habitats, an outdoor classroom, and nature trails. I would like to thank Lynn Farrin for reviewing the *Lab Reports and Science Books*, commenting about the science in the unit, and providing another set of eyes.

During the 2015-16 school year, Oxford Hills started implementing Calkins' *Units of Study for Writing* curriculum in grades K-8. *Units of Study* was designed by the Teachers College Reading and Writing Project (TCRWP), part of Columbia University, and is directed by Lucy Calkins, the lead author. The curriculum is aligned with the *Common Core State Standards for English Language Arts* (CCSS-ELA). Of the several *Writing Units of Study* available, I was particularly interested in sources listed for the Grade 2, Unit 2 Information: *Lab Reports and Science Books.*

I was very excited to teach the *Lab Reports and Science Books* unit**.** I had been hoping for a long time for my school district to find a writing curriculum that integrated science and engineering. My Year 3 MSTE project involved looking closely at several lessons in the unit to see how TCRWP did in developing writing in science. I also wanted to see if there were engineering teaching points that could be added to the unit. Of particular interest to our district's K-5 teachers were instructional techniques that would support students in building science vocabulary, in learning how to write claims supported with evidence and in understanding the processes of engineering through first hand experience. We were looking to the *Lab Reports and Science Books* unit for suggestions and felt the materials would be an important link toward connecting and weaving CCSS and NGSS together.

In preparation for teaching this unit, I looked at TCRWP's references, and other established writing in science programs with which I am familiar, to get a sense of the research behind such approaches. Two items I found are particularly relevant to my situation.

First: According to his work in *Seeds of Science/Roots of Reading* and a study of the research foundations of the *Common Core* in 2013, P. David Pearson states, "[Common Core] Standards are definitely a move in the right direction—toward (a) deeper learning, (b) greater accountability to careful reading and the *use of evidence to support claims and reasoning* in both reading and writing..." (my emphasis). Both *Common Core* and NGSS recommend emphasis on claims, evidence, and reasoning, so teachers placing an emphasis on these practices in their science teaching, as well as in reading and writing teaching (*science* reading and writing included here), makes sense.

Second: The *Units of Study* writing team is working to include argumentation in all of its student publications. "We have also brought argumentation into the content areas *encouraging students to debate issues in science and to analyze informational texts*… In all of our argumentation work, there is a focus on debate and dialog as a way of rehearsing and developing the ability to engage in written argument" (my emphasis). Argumentation, using oral debate and dialog, is highly recommended in both sets of standards. Students need to be given opportunities to talk together about important issues in both the humanities and the sciences.

Even though the groundbreaking 2012 document *A Framework for K-12 Science Education* is not referenced in the *Units of Study* curriculum, the quote above shows that the *Framework's* Practice 7, Engaging in Argument from Evidence, has overlap with the Capacities of the Literate Individual described in the CCSS-ELA, which guided the development of the *Units of Study* curriculum.

The second grade band of the NGSS identifies learning standards related to Plants, Animals, and Ecosystems; Earth Changes-erosion; Matter and Its

Interactions; and Engineering Design (for my students, engineering design is part of the ecosystem unit). The content identified in the *Lab Reports and Science Books* unit is force and motion, which is not a grade 2 NGSS standard but rather a standard identified for kindergarten. The children in my class love science. They had lessons with ramps and balls previously, but nevertheless, they eagerly dove into this opportunity for more science. They agreed that the lessons in *Lab Reports and Science Books* were "way different!" It's interesting to note that *Lab Reports and Science Books* paired grade 2 CCSS-ELA standards with kindergarten science content. It worked for the second graders to use higher level thinking and process skills (like measurement) with the science content, but second grade teachers may find it a challenge to fit NGSS units into their curriculum, because *Lab Reports* is a six week unit.

In the *Lab Reports and Science Books* unit, the second graders completed two sets of investigations, and wrote about those investigations. In Lesson 1: "Learning to Write about Science," the first focus question was, "Will the little car go farther off the ramp on carpet or on bare floor?" As a whole group, the second graders observed, wrote procedures, recorded data, analyzed the data, and came up with conclusions. During the lesson, the teacher says to students, "The next thing a scientist needs to do after arriving at a question is to think and write what the answer *might* be. ...On the next page in your lab report booklet, will you **hypothesize** whether this little car will go farther on the carpeted floor or farther on the bare floor?" (p. 5, my emphasis). The teacher should use the word **predict** instead of the word "hypothesize." A hypothesis is an explanation written on the basis of limited evidence. The evidence is usually prior knowledge or observation, and often it is the starting point for further investigation. Young children usually do not have the background to write a tentative explanation, but they can make a prediction that describes the outcome of the investigation, for example, "the little car will go further on bare floor, because there aren't any bumps like there are on the carpet" (Keeley, 2014). Later in any science investigation, when writing their conclusions, children can use their prediction to make claims about their findings.

In Lesson 2, students looked at the procedure for an investigation in a mentor text, and revised the procedure section of their first lab report written as part of Lesson 1. They adopted some of the strategies the mentor text authors used to show the procedure, such as numbering the steps, telling how to do the investigation, drawing pictures with labels, including a "You will need" section, which included detailed measurements, and a clock to tell how much time the investigation would take. My students were very impressed with the clock! I compared the philosophies and methodologies regarding procedure writing of two educational leaders in teaching writing, Lucy Calkins and Betsy Rupp Fulwiler, author of *Writing in Science.* Calkins teaches revision in every part of children's writing. In *Lab Reports and Science Books*, the children start revising with the less challenging procedural work and move to more challenging revision work when they think about how to write a stronger conclusion. In contrast, Fulwiler says that children should not be spending time writing procedures at all, at least independently. Procedure writing can be learned by having the class work together as a whole group. The teacher transcribes and photocopies what was written, and this is taped into scientist notebooks. She believes that children should concentrate their writing energy around the higher order thinking skills that are essential to analyze data, make claims, and support claims with evidence.

In the subsequent lessons, second graders worked with partners to come up with a new force and motion question to investigate. They had a chance to try another investigation more independently, and wrote their lab reports independently. At several points in the six lessons of the first "bend," *Writing as Scientists Do* ("bend" is Calkins' word for different parts of a unit), my students had opportunities to learn more about and revise the ways they recorded data, to revise and strengthen conclusions, and to integrate science vocabulary in their work.

To illustrate science writing from *Units of Study*, *Writing in Science*, and from my classroom here are three typical conclusions written by students about force and motion investigations using ramps, balls, and little cars:

1. From *Lab Reports and Science Books*, p. 50, Juliana, a second grade student, writes a conclusion about her investigation of different surfaces and their effects on the distance a little car travels.

   "The car slowed down because of the surface where it traveled. The carpet is thick and bumpy. There is more friction. The car has to go up and down all the little bumps on the pieces of carpet. The car went really far on the tile floor, because it is so smooth it is almost slippery. The tires on the car don't have anything to make them slow down. That is why they go really far."

2. From *Writing in Science,* p. 185. Symphony, a first grader, writes about her investigation of a 2-block-high ramp vs a 1-block-high ramp, and how far another block will slide down each ramp.

"I notice the block moved more on the 2-block ramp then the 1 block. My evidence is that the block moved 9 cm from the 2-block ramp and the block moved 4 cm from the 1 block ramp. I think the ball went fast on the 2-block ramp because it had 2-blocks and it is steeper."

3. From my school, Jenni, a second grader, investigating different surfaces and their effects on how far a little car traveled.

"I was right [about her prediction that the car would go farther on bare floor], because on the carpet the data table shows that it went 90 cm, 56 cm, and 94 cm. On bare floor it shows 155 cm, 177 cm and 197 cm. So my little car went farther on bare floor."

Juliana wrote her conclusion after the six lessons in the first bend. At this point she hadn't learned about using quantitative evidence in her conclusion, but she is starting to put together an explanation about how different surfaces affect the distance a car travels. The next lesson, 7, in Bend 2 "Writing to Teach Others about Our Discoveries" teaches second graders how to organize quantitative evidence using data tables and to use this evidence in their conclusions.

Symphony and Jenni are already using quantitative evidence in their conclusions. By quantitative data, I mean that Symphony and Jenni are measuring, recording, and analyzing data by comparing the measurements of each trial. They both use this information in their conclusion. Jenni also mentions the science vocabulary word "data table" in her conclusion. She knows to organize her work in a table, so that it is easier for her to see the relation between surfaces and how each affects distance.

Early in the second bend, children engineer catapults, test them with ping pong and cotton balls, record and analyze data, and write conclusions. Unfortunately, the authors do not mention engineering. The purpose of these activities would have been clearer if the students had been taught to find a solution to an engineering problem and then improve it. For example, they could have been charged with building a catapult to fling a cotton ball and a ping pong ball, and then tasked with improving the catapult to fling the objects further. Instead, the writers couched this as a scientific investigation designed to gather data to explain a phenomenon. I could and should have embedded the Boston Museum of Science's *Engineering is Elementary* Engineering Design Process here: Ask -> Imagine -> Plan -> Create -> Improve. Hindsight is 20/20.

Overall, I was impressed with *Lab Reports and Science Books.* I appreciated the encouraging tone throughout the lessons, "of course you (students) can do this." I also appreciated the high expectations of the qualities of student writing, which are listed in *Information Writing Checklists* in each grade level. My students routinely demonstrated several items listed for third grade, which served as motivation for them to do quality work. There were moments in our science discussions when students came up with ideas that were truly transcendental. For example, in answer to the question, "Why would our data be different from group to group?" the class came up with nine different reasons, including force of push and height of ramp. One student even asked, "Did you use a different car?" I had!

I surmise that the TCRWP authors developed a "writing in science" unit to fill a gap in their curriculum, and to address some extra standards in the *Common Core*. I am glad they did! The authors are not scientists, and even though they have some effective writing strategies there are missed opportunities in maintaining the integrity of science. I hope that any second grade teacher, or any teacher that uses the *Lab Report and Science Books* unit will be careful to adapt the curriculum using words like *prediction* instead of *hypothesis* and *belief* instead of *theory* to avoid creating misconceptions. Instead of dictating a narrow lab report format, a more open, broader format for science writing should be taught. Using a strategy such as scientist/engineer notebooks to capture observations, science explanations, and engaging in arguments also does not perpetuate that sense that there is only one prescribed way to "do" science.

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Online Resources

Engineering is Elementary, Engineering Design Process
http://www.eie.org/overview/engineering-design-process

Hebron Station School Grades 5 and 6 Tower Engineering Challenges

By Lydia Eusden, Grade 5 and 6 Teacher, Hebron Station School

"National research has shown that by grades 5 to 7, students lose interest in individual STEM (science, technology, engineering, and math) content areas," states Scott Settar from Virginia's Fairfax County Public Schools (NSTA Reports, 2016). As a three-year MSTE member, I could not agree more. I have observed effects of student hands-on learning experiences that are not only engaging but also invoke a sense of purpose to solve a problem. This teaching strategy is an effective way to hold student attention solidly.

In the past, I have always completed a Read Aloud of the picture book *The Man Who Walked Between the Towers,* written by Mordicai Gerstein, on September 11 at school to help my students understand the tragic Twin Towers 2011 event in New York City. It is difficult for children to conceptualize adult sadness when the event happened before they were even born. After taking part in the three-year MSTE project, I now approach this day differently by weaving in student engineering challenges focused on tower structures. Furthermore, this year I took students to a higher level of thinking, exploring scientific and mathematical concepts instead of merely talking about a sad day in history for adults around the world.

The Oxford Hills School District adopted a shift in curriculum teaching for grades 5 and 6 teachers three years ago. The administrators' purpose was to accommodate the new CCSS and NGSS for student learning. I suddenly became a fifth and sixth grade STEM teacher instead of a general fifth grade classroom teacher. My personal interests in art gave me the courage to add "A" to my job as well and integrate STEAM into my teaching pedagogy. Hebron Station School can be described as a small rural K-6 school where most students receive free breakfast and lunch. The geographical location of the town does not lend itself to public venues for further academic enrichment. Although the school district is one of the largest in the state of Maine, it is also identified as one of the poorest and unhealthiest of student populations.

Three years ago, I joined the MSTE group for guidance and support because I was unsure how I would teach 38 fifth and sixth grade students STEAM. My schedule provides 90-150 minutes of academic teaching time per day. I realized that I had to integrate my curriculums because of limited student contact hours. Also, less than one half of my supplies would be paid for by the school district. I was hoping for insight from colleagues and MSTE professionals to improve my curriculum delivery to Hebron Station School students.

My involvement with MSTE has created four major changes in my instructional strategies. First, I feel secure in knowing I have student engagement because each of them now understands that the role of engineering is to solve a problem or fill a human need. I make it clear to my students that these engaging activities are not simply for fun but for solving real problems. Second, all four STEM subjects that my school district requires me to teach can be creatively woven together with student hands-on learning. The activities usually involve movement, sensory motor skills, collaboration with a partner or small group, and important communication of learning by doing. Third, special needs students can easily participate in STEAM learning because they can progress at their own ability and level of thinking within the regular classroom. Typically, in the past during a regular STEM class, my special needs students were out of the room working on other curriculum with a separate teacher in a small group setting. Now, for engineering challenges, the hands-on learning style encourages these identified students to take on the assigned task without assistance from the Special Education staff and meets their IEP requirements. A shift in my instructional strategy for these students is to have them with me in a 1:1 conference to understand the challenge first. Then they can move on to sketch a plan and proceed to the building stage. Additionally, I accept a short simple written sentence or an oral explanation of what they have just learned at the end of each challenge. This provides them with a strong sense of accomplishment and genuine feeling that they are no different from their peers. Lastly, as a teacher, I can stand back and observe all student learning more easily because I am a coach rather than telling them what to do. I can lend support when needed but allow them to learn by doing first on their own, which is very empowering to elementary students. These are all shifts in my teaching strategies since joining MSTE.

One recent integrated unit that both my fifth and sixth grade students participated in had the overarching concept of towers. All students read nonfiction informational books about tower purposes, construction, and needs. Discussions included job requirements of architects, building inspectors, structural engineers, inventors, and even people who operate excavators. I showed several images of historical towers such as the Eiffel Tower, and modern towers such as Burj Khalifa in Dubai. Open classroom student discussions moved on to other known towers around the world, construction constraints, and artistic designs. My first assigned student tower challenge was called T-Rex Plays Golf. It purposely had limited materials for students. This challenge introduced the concepts of stability and gravity to my students and was chosen as an "opener" at the beginning of the year. The concept of a T-Rex dinosaur playing golf is amusing and I knew that students would enjoy the whimsy of the task. The second assigned student challenge was called Tennis Ball Aloft Tower Challenge. Again, students were confined to limited materials but this time, they could use some of these for mere artistic purposes instead of only structural supports. The artistic component allowed students to use their inventive and expressive talents. From these two challenge experiences, students employed newfound knowledge about columns, frames, beams, and architectural beauty to a third challenge titled Oreo Cookie Tower Challenge. Students were limited to using only Oreo cookies for a building material, but they could use as many cookies as they wanted. It was exciting to observe students who took the cookie gingerly apart to use creme frosting for concrete to build their towers. Some students connected back to their nonfiction reading about concrete as a major building material for modern skyscrapers, which was compelling for me to see. This year-long unit finished with a fourth assigned challenge titled Free Choice Tower Challenge with objectives and constraints written by myself. The assignment was for a freestanding tower that supported a favorite stuffed animal positioned at a required height of 20 inches for a minimum 10 minute duration. The tower was of each student's own architectural design and could use only five different types building materials. All students were required to present their tower to the class in order to practice their oral presentation skills, as a real engineer would need to do for a job. Their presentations needed to describe the plan for their chosen design, why they imagined it, a list of their five materials, the exact height of their platform, an explanation of any design changes from their original sketch, and what they learned in their building processes. Many students received help from a family member, so the project became an informative experience for parents to understand what their child was learning at school. Not all students had family

Example of an Oreo cookie tower

help but those that did stated it was fun to do a project with someone from home.

These very different tower challenges were grouped in this way for four specific reasons. First, the T- Rex Plays Golf Challenge was based upon a playful idea suitable for 10-11 year old children. It involved only newspaper and masking tape. The Tennis Ball Tower Challenge was chosen to make sure students observed a more complicated materials constraints list. This second challenge was selected because the task was still fairly simple, to keep a freely positioned ball aloft. Students were forced to slowly and carefully plan their designs accordingly because of their limited supplies. The objective with the Oreo Tower Challenge was to allow students to be creative with just one material type, a cookie. The fourth culminating tower challenge was unique because it offered a wide open choice of materials for students. I encouraged students to look for recycled or found materials. The selection of this challenge series progressed in order of complexity so students could build on their previous knowledge, reflect on their previous understanding, and make observations and collaborations with classmates.

Students working on a tower challenge

Before participating in MSTE, I believe I was only covering a superficial layer of thinking for my students. Science and mathematics instruction were previously separated into individual teaching blocks. For this year-long tower unit, all STEAM subject areas were woven together. This was a shift in my teaching pedagogy. Grouping these four challenges over the course of the year provided stepping stones for students to build their knowledge about engineering but through a small focus of towers. It also provided the opportunity for students to understand the Engineering Design Process involving imagination, planning, creating, asking questions, improving, and retesting a design. The four challenges had materials constraints that fostered analytical thinking and extension planning. Students were involved artistically because they were required to create labeled scientific drawings of their challenge plans. Also, all challenges involved student writing. Students wrote claims incorporating new understandings, and supported these statements with evidence as seen by them during the different challenges. This mimics real world scientists, mathematicians, and engineers, who need to back up their designs with data gathered from tests before they can sell a product or obtain credit for a new theory. Engineering offers hands-on learning opportunities related to mathematical thinking, including measurement. These four challenges each required student understanding of measurement by having them use rulers and yardsticks to accurately read and record numbers. I believe I took students to a higher level of thinking involving all STEAM foci. With MSTE guidance, I was able to nudge my students to be more advanced critical thinkers.

Our MSTE meetings provided me with resources for planning and provided opportunities to share ideas and points of view with my colleagues. Furthermore, the classes helped me find solutions to struggles and frustrations on my part as a teacher because of our collaborations during professional development meetings and online chats. I am more confident as a teacher because I have learned how to structure my introductions to new units in a more organized and informed way that results in a better curriculum flow.

The impact of my MSTE work has also been noticed at multiple levels at Hebron Station School. Younger students take note of the creativity in the STEM classroom and seem eager to become a grade 5 or 6 student. They see students solving challenges in the hallways or notice projects being transported on the bus needing a separate seat space. That brings a huge sense of pride and accomplishment for my STEM students. In addition, STEM colleagues in the district have openly shared their experiences and resources, which has provided a wealth of knowledge and firm foundation for me as a relatively new STEM teacher. Finally, Hebron Station School has hosted two Family Engineering Nights, which have been strongly supported by parents and extended family members. We have had two nationally recognized presenters as keynote speakers. It is inspiring to have all ages of people learning new concepts at these engaging and fun events in our beautiful school.

My intent is to continue to integrate STEAM into as many units for my fifth and sixth grade students as I can. For two years, I have collaborated with the school art teacher on different projects and will continue to do so. Time, funds, and materials sometimes limit creative ideas. I have grade 5 and 6 math curriculums from a purchased program, chosen by the school district, for me to teach.

However, it will be even more meaningful if I can integrate the scripted teacher text with hands-on learning from engineering challenges. Next year, I have enrolled in a Complex Systems - Vital Signs professional development course through the Gulf of Maine Research Institute in Portland, Maine for continued integration of STEM curriculums. As for my own reflection on being a student the past three years with MSTE, I have learned so much about engineering. That in itself has completely excited me. I can genuinely state my teaching is current and enriched with fresh new concepts and a vision for future students.

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Internet Resources

Oreo Tower Engineering Challenge
https://www.teacherspayteachers.com/Product/Oreo-Tower-Engineering-Challenge-Project

Tennis Ball Tower
https://www.teacherspayteachers.com/Product/STEM-Challenge-Tennis-Ball-Tower

Freeze Pop Challenge

By Sara Roderick, Grade 5 Teacher, Oxford Elementary School

Three years ago my district began an initiative that partnered teachers in fifth and sixth grade to specialize in teaching either STEM or humanities. I teach two sessions of fifth grade STEM classes for roughly two hours daily. Of my 45 students, I have a pretty even mix of boys and girls. Six students have individual education programs and four others receive gifted and talented support. Oxford is a rural school with a low socio-economic demographic - 69% of our population qualifies for free/reduced lunch. Scores on standardized test results are low in all content areas district-wide.

In the first year of our STEM/Humanities initiative, STEM teachers were asked to participate in MSTE to help ease our transition to this new model and increase our expertise in engineering. I had no expectations because I didn't fully understand the project and felt like it was one more meeting to add to my plate. I entered the project blind. Each year, however, I greatly appreciated the conversations, working together to modify our instruction through an engineering lens and receiving feedback while brainstorming. Time to talk with colleagues is rare.

I have always battled time. There never seems like enough time to teach all that I need to teach. In my relatively short tenure, I've been subject to quickly changing to the "best practices" of the moment. One of those was to teach science content (and social studies also) through nonfiction reading instruction. This kind of integration helped but didn't seem authentic for the kids. Throughout MSTE, as I learned more about the engineering process and tried some challenges with my kids, it seemed like integrating science and engineering would provide that authenticity and save time. I can think about engineering as a way to get to science content, which is what I tried to do with my Year 3 MSTE project. Also, our work using a claim evidence reasoning (CER) framework to argue a stance or defend an opinion has changed the way I ask my children to write about their data. I find this approach more powerful than a traditional lab report. As I continue to become familiar and accustomed to using the CER format, hopefully it will transfer to my students' success using it. Further, the MSTE project expanded my view of formative assessment. Our district spent three years working with Cheryl Tobey, specifically looking at formative assessment in math. I was versed in the use of probes, making feedback meaningful to students to move their thinking forward, and making learning intentions transparent to students. Applying those principles to science has been a shift in my thinking.

There is no science curriculum in my district currently. As teachers, we can decide how to deliver content and we are guided by the *Next Generation Science Standards*. After attending the NSTA conference in Boston a few years ago and learning about one teacher's use of science notebooks, I have used them with my students. The notebooks are organized by strand and naturally integrate literacy and science when children write about and record observations, take notes from research, sketch and label design ideas and record results from experiments/challenges. The goal of my project, as a result of my work in MSTE, was to improve and maximize integration, specifically science content through engineering design. To do this, I revisited an engineering challenge I created last year - the Freeze Pop Challenge. Previously, the challenge was a stand-alone, end-of-year activity for fun. This time I was more purposeful about the science content being a part of it. Instead of a two-day experience, I created a series of seven lessons inspired by and adapted from *Inquiring Scientists, Inquiring Readers.* The work students did addresses the four physical science standards for fifth grade in the NGSS. Math was more difficult to integrate because I participated in a pilot of a new program our district was considering for purchase and had particular skills to focus on at this time, which didn't align directly. What follows in the next few paragraphs are brief descriptions of the lesson sequence.

property	ice	physical
matter	state	weight
color	change	solid
liquid	gas	shape
water	freezing	melting
evaporating	volume	energy
phase	steam	height

Concept (word) sort

Concept sort and Observation of Ice Cream Makers

I opted for a concept (word) sort (freeze pop concept sort) because of work my district is doing related to Lucy Calkins' *Writing Units of Study*. In recent professional development, a literacy coach worked with the STEM teachers on ways to integrate science and literacy. I identified content vocabulary and randomly organized them into cards that groups cut apart to begin the activity. Without further introduction to each word, children in each group decided how the words should be grouped together. It's always interesting to me to listen to children discuss the ways to categorize and sort vocabulary. Words have multiple meanings and though kids in my space should be thinking in a STEM context, they draw on what they know already which might not fit our work. In this case, they thought of gas as fuel for a car rather than a state of matter, and property as land instead of a characteristic to describe an object. Of course, this is exactly why a concept sort works the same way as a probe.

Observing ice cream makers

Next, to keep them wondering, I placed 3 different styles of ice cream makers around the room for them to observe. Some knew immediately the purpose of each device and were eager to talk about how they worked. After observing all 3, the class shared some things that each ice cream maker had in common or how they were different. At this point, I refrained from telling my children that they'd be making their own freezer later.

Read *Ice Cream* by Elisha Cooper and then make ice cream in a baggie. This book describes the ice cream making process from "Moo to You." I read the book up until the point where the ice cream was made in a factory and stopped without finishing the book. I demonstrated how we could make ice cream by placing the ingredients in a baggie, surrounded that baggie with another baggie full of ice and salt, and gave each student an opportunity to shake. We charted observations before and after and recorded predictions or questions about why we were able to change the milky liquid into a sweet solid.

Solids

To begin their observations of this phase I projected the concept sort and linked some vocabulary to the making ice cream activity from the day before. I provided the terms for the changes involved, identifying the milk ingredients as a liquid, the ice cream as a solid and the phase change as freezing and revisited our unit question, "How do physical properties change during a phase change?" Next, I gave each table a set of 4 solids (ice, chocolate chips, a piece of chocolate, 2 Tbsp butter) to observe and the heading "Physical Properties Observations" to guide observations in their science notebooks. Thermometers were also available to record temperature of ice and butter. Collecting this type of data was a loose integration of math skills. After observing, I read aloud excerpts from two texts, *Properties of Matter: Physical and Chemical Changes* and *Matter*, and asked students to identify ideas that confirmed their observations or those they questioned. Students then had an opportunity to add notes to their science notebooks.

Student recording property observations in their science notebook

Liquids

I again referenced the concept sort to remind them of the prior lessons and link to today's activity observing liquids. Each table had a set of 4 liquids (water - melted from the ice, melted butter, melted chocolate and rubbing alcohol) to observe. They continued to record their observations in the same chart in their science notebooks. Temperatures of each substance were also taken and noted. After observing, I read aloud excerpts from two texts, *State of Confusion* and *Matter,* and asked students to identify ideas that confirmed their observations or those they questioned. Students then had an opportunity to add notes to their science notebooks. We ended by discussing similarities and differences of solids and liquids and whether any physical properties had changed in the water, butter or chocolate that they'd already observed in another state.

Observing properties of liquids

Gases

This lesson began with a review of our lessons so far while the concept sort was visible again. They were to observe a deflated balloon, a balloon filled with air, bubble wrap and a baggie. They tried to determine if air has mass by comparing the balloons. They also tested the idea that gas takes up space by popping the bubble wrap or closing the baggie.

After observing, I read aloud excerpts from two texts, *State of Confusion* and *Matter*, and asked students to identify ideas that confirmed their observations or those they questioned. Students then had an opportunity to add notes to their science notebooks. We ended by discussing similarities and differences of solids, liquids and gases.

Concept Sort (again) and Introduce Challenge

After the first 5 lessons I provided the same word sort sets to each group and asked them to try it again without looking back at their first attempt. I also asked them to categorize their new lists on a different sheet of paper. Our subsequent discussion proved that most students recognized the word sort terms as types of matter and could further identify each as a solid, liquid or gas.

Student's freeze pop design plan

There was less conversation and confusion about land or fuel than before. However, later when I introduced the challenge and provided prompts for their thinking (Freeze Pop Challenge), students demonstrated confusion identifying or describing a property. Students were excited to begin working on how best to use the materials and eager to create plans for their freezers but didn't yet transfer their ideas from this unit as easily as I'd hoped. I expected them to understand the properties of the materials available, to create a plan and procedure for executing their design the following day, and to predict what would happen. I provided time for them to work with their groups.

Build and Test

The next day, groups from both classes assembled and found a space to work in my room. Using their plans from the day before and the following materials: the same quantities of juice, ice and salt, identical buckets, pieces of newspaper and lengths of tape, the students tried to design a freezer that would freeze juice, thus making a freeze pop of sorts. Once made, the freezers were left for three hours. At that time, we all reassembled to reveal the results. After each group processed their own findings, they took turns sharing their designs and reflections with the whole group. While no group was completely successful, three out of ten achieved a slushy consistency. One group had been unsure of how to use their ice and included it with their juice. They were disgusted with their taste test! Several groups used their newspaper to wrap around the *outside* of the bucket. One group tore their newspaper to resemble wood chips once used as insulation in iceboxes but didn't have better results than any other group. Nearly every group related the design of their freezer to the structure of the ice cream makers they'd observed earlier.

The hands-on, problem solving approach of engineering, prepares students for technical opportunities available in our middle school and high school and keeps kids hooked while they wait for those opportunities. This type of learning is more project based and less "skill and drill" or worksheet based. My students enjoy hands on work and it's an authentic opportunity to apply their knowledge. They get to be creative and they don't know they're learning - it's such a different structure. Because of the work my colleagues and I completed in MSTE we have new resources, more conversation among ourselves and even with primary teachers who want to experiment, and my school hosted a Family Engineering Night with materials provided through MSTE training.

I am continuing in this position next year as a STEM teacher while my district continues to debate this model for future use. I will continue to use engineering challenges and tweak for the purpose of integration as I did in my Freeze Pop Challenge. I look for new opportunities for engineering design experiences that incorporate science, technology, and math, as ways to address curriculum demands. I even hope to find collaborative opportunities with my new humanities partner. It also happens that my school has been hosting an annual career fair, which is only one day, and has included one representative from an engineering field. I'd like to make connections with professional engineers from all domains who could help students see the links between classroom engineering and real-world employment opportunities, whether by attending our career fair or visiting the classroom at other times.

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Resources

Find the student notebook prompts for the Freeze Pop Challenge, Freeze Pop Concept Card Sort and the Physical Properties Observation chart headings at www.mmsa.org/MSTE.

The Great Roller Coaster Challenge and Gravity

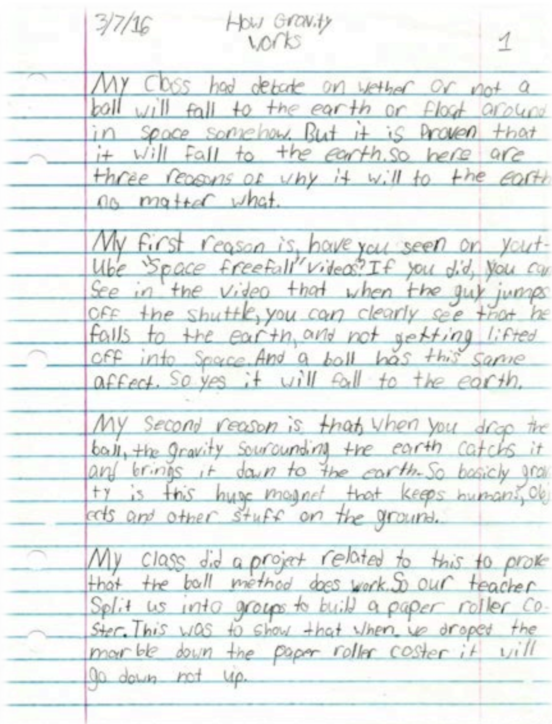
By Mary Delorenzo, Grade 5-6 Teacher, Oxford Elementary School

Oxford Elementary School serves grades preK-6 in a rural setting in Oxford, Maine. There are approximately 400 students throughout the school with approximately 68 fifth graders and 65 sixth graders. In addition to students from Oxford, the preK, fifth grade, and sixth grade classes consist of students from the town of Otisfield. Currently, I am teaching fifth and sixth grade STEM (science, technology, engineering, and math). This is my second year and the district's third year of implementing this STEM and Humanities classroom setup for the fifth and sixth grade students.

When I first joined MSTE, I was not sure what I was getting myself into. It was recommended by a colleague, who had participated in the first year, and said it was beneficial and worthwhile. I joined in the second year of the program, and wanted to gain knowledge about integrating the STEM fields in my upper elementary classroom.

Since joining MSTE, my instruction in STEM has been getting stronger, especially with integration. At first, I had a hard time figuring out how to incorporate math and science into engineering and make it meaningful for all of my students (not just making it a "fun activity"). My participation in MSTE has helped me put together everything I have learned to successfully create meaningful, integrated engineering activities for my fifth grade class.

In the past two years with the program, I have done many engineering activities with my classes, and have tried to tie these to my math and science lessons. One of the first integrated engineering activities I did was with fifth grade in the fall of 2014. I assigned student groups an animal, and they had to design a zoo-like habitat/ecosystem where that animal could survive, using materials given to them, including: paper plates, pipe cleaners, glue, sticks, leaves, rocks, colored pencils or crayons, and the picture of the animal to put into the habitat. My students made the connection to what we were learning about in our read-aloud (*Hoot* by Carl Hiaasen), and to what we were learning about in our ecosystems unit. I also made strong ties with math and science in engineering projects. For example, with my sixth graders this school year, I read aloud the book *Pythagoras and the Ratios: A Math Adventure* by Julie Ellis. I had them make their own straw pipes, using ratios to determine the length of each pipe so that every student's pipe had the same pitch. I also taught them about why the length changed the pitch of each straw and addressed some physics with the project, such as volume of air and airflow. This was not one of my original instructional goals, but students were so interested that I took the time to teach them the information. I have learned that students want to know the connections between the STEM fields in their projects because they are curious to know how their ideas work scientifically and mathematically, which has been fantastic from a teacher's point of view.



3/7/16 How Gravity works 1

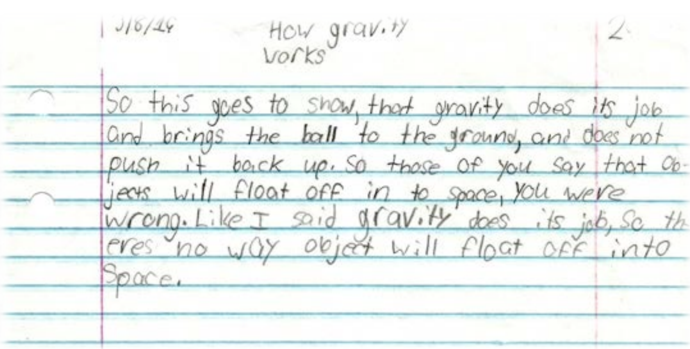
My Class had debate on wether or not a ball will fall to the earth or float around in space somehow. But it is proven that it will fall to the earth. So here are three reasons of why it will to the earth no matter what.

My first reason is, have you seen on yout-ube "Space freefall" video? If you did, you can See in the video that when the guy jumps off the shuttle, you can clearly see that he falls to the earth, and not getting lifted off into Space. And a ball has this same affect. So yes it will fall to the earth.

My Second reason is that when you drop the ball, the gravity sourounding the earth catchs it and brings it down to the earth. So basicly gravi-ty is this huge magnet that keeps humans, obj-ects and other stuff on the ground.

My class did a project related to this to prove that the ball method does work. So our teacher Split us into groups to build a paper roller Co-ster. This was to show that when we droped the marble down the paper roller coster it will go down not up.

Examples of student writing about gravity



3/6/16 How gravity works 2

So this goes to show, that gravity does its job and brings the ball to the ground, and does not push it back up. So those of you say that ob-jects will float off in to space, you were wrong. Like I said gravity does its job, So th-eres no way object will float off into Space.

My final MSTE project tapped into my students' curiosity. This year, I chose to do a project with my fifth graders that related to the *Next Generation Science Standards* concept of gravity. The students made connections between what they were learning about gravity and the paper roller coasters they were asked to design.

I started the unit using a probe from *Uncovering Student Ideas in Physical Science* called "The Tower Drop." Using the Four Corners Jigsaw from *Science Formative Assessment, Volume 2,* I had students discuss with peers what they thought would happen if a ball dropped from space. This exercise got students engaged in the idea that gravity is a force that pulls toward the Earth. This concept was transferred to the roller coaster engineering project where a marble drops to the bottom of a roller coaster, which is toward the Earth. Overall, my students were extremely engaged in this project, which also helped them engage with the content. They were asking great questions while building the roller coasters, and learned about speed, how speed affects the turns and loops, and how the force of gravity makes the marble go down. We had a competition at the end with each roller coaster. Students earned points for coaster components such as loops, turns, how long the "ride" through the coaster took (each second was a point), and the durability. The group with the most points won the competition. Students were not too concerned about winning, but liked the competition aspect. This project helped me realize that students can make these engineering connections, and that providing an engineering context makes their overall knowledge of a concept even more meaningful. Their motivation to complete the project while learning new science concepts was great to watch as a teacher.

While putting together this project for my fifth graders, MSTE had a large impact. In my first year in MSTE, which was year 2 of the MSTE project, I participated in a book study on *Science Formative Assessment Volume 2*. While reading that book, there were multiple formative assessment strategies I wanted to use in my teaching. I used the Four Corners Jigsaw from the book thinking it was a great formative assessment strategy to probe students' thinking. The strategy was a great success, and I would not have known the strategy existed were it not for the book study. I also learned strategies from MSTE project staff to strengthen connections between engineering and other content that made the "building" part more than just a fun activity. When I first joined the MSTE project, I was not sure how engineering should be assessed. Between discussions with my MSTE group and discussions with Lisa, I felt more comfortable being able to assess engineering both formatively and summatively, especially for this final project.

In my school, three teachers participated in MSTE during year 2, and two teachers during year 3. Being able to communicate with others who were part of the project was helpful, because we could discuss and expand on the ideas from our meetings. It has also helped the teachers in my school who have not been a part of this project, because I have communicated with them about what I have been doing in my classroom. This collaboration has been helpful with planning and organizing units. Multiple parents asked if they could come in during the roller coaster project because their child was sharing what they were doing in the classroom. Parents were excited to come into my room and see what their child was working on. Not only was it great to see students sharing their roller coasters, but they were also sharing content connections. After this experience, I hope to make it so parents can come into my classroom again, and students can share their learning through their engineering projects.

Next year, I am moving to fourth grade at Oxford Elementary. I want to use what I have learned through the MSTE project, and implement it into my STEM lessons at the fourth grade level. I want to remember the formative and summative assessment strategies for engineering, to make connections between science and math and engineering, and to continue with the student engagement through engineering projects.

Title: The Great Roller Coaster Challenge and Gravity

Overview

Students will make connections between making a paper roller coaster and learning about the concept of gravity (objects on Earth are directed down because of the force of gravity). Students will use the probe in *Uncovering Student Ideas in Physical Science* called "The Tower Drop" to start the unit to see what students already know about the concept of gravity. This will lead to groups of students building a paper roller coaster that shows the force of gravity in action, ending with a class competition. To end the unit, students will write a piece about the force of gravity directing objects on Earth down using a reading assignment, the engineering project, and real-world examples. This unit will take approximately six days to complete.

Learning Goal: I can use evidence and real-world experiences to describe that the gravitational force exerted by Earth on objects is directed down.

Day 1:

- Introduce gravity. Use Four Corners Jigsaw as a formative assessment strategy for the probe "The Tower Drop." (30-45 minutes)
- Introduce the paper roller coaster activity, using an adapted version of *The Great Paper Roller Coaster Challenge*. Put groups together. (5-10 minutes)
- Provide planning time, including determining the "cost" of building the roller coaster, which ties into decimal addition in math. (20 minutes)
- Homework for students: Reading about gravity.

Days 2 and 3:

- Show students all the possible cardstock pieces of the roller coaster. Show students how to build the pieces. Go over a turn with the whole class for practice. (15-20 minutes)
- Start building paper roller coasters based on plans from the day before. They can test and revise as needed. (45-60 minutes per day)
- Introduce the roller coaster competition to the class, after first day of building.

Day 4:

- Competition. Give each group points based on the time to complete the "ride," reliability, height, construction, etc. Competition criteria were adapted from the Testing section of the Great Paper Roller Coaster Challenge sheet.

Days 5 and 6 (more if needed):

- Summative Assessment: Writing based on science content.

  Write a piece stating that the force of gravity exerted by Earth on objects is directed down. Use evidence from your Paper Roller Coaster project, the gravity reading, and real life experiences to support your claim.

Connection to *Next Generation Science Standards*

5-PS2-1. Support an argument that the gravitational force exerted by Earth on objects is directed down.

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

References

Keeley, P. 2014. *Science Formative Assessments, Volume 2: 50 More Strategies for Linking Assessment, Instruction and Learning*. Thousand Oaks, CA: Corwin Press.

Keeley, P. 2010. *Uncovering Student Ideas in Physical Science: 45 New Force and Motion Assessment Probes*. Arlington, VA: NSTA Press.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, by States*. Washington, DC: National Academies Press. www.nextgenscience.org/next-generation-science-standards.

Online Resources

The Great Paper Roller Coaster Challenge
http://paperrollercoasters.com/The_Great_Paper_Roller_Coaster_Challenge.pdf

Integrating Engineering in the Classroom with Maine Junior Solar Sprint

By Tom Light, Grade 6 STEM Teacher, Paris Elementary School

Two years ago our district had our grade 5 and 6 teachers specialize. I teach STEM to two groups of sixth grade students, and a colleague teaches humanities. Our district requires that we spend 90 minutes per day on math, so the time available for science, technology, and engineering is about 150 minutes a week.

Paris Elementary School is in a rural area with a fairly high poverty rate. Currently, all of our students receive free lunch and so we do not collect data on whether students qualify for free and reduced lunch, but in the past the numbers were high. Oxford County also has high levels of alcohol and drug use and abuse.

I have participated in MSTE for several years now and it has had a large and important impact on my teaching. One result is that I spend more time on a regular basis teaching engineering. The program has also provided support to find and develop engineering challenges that link to the science and math that we are charged with teaching. Students find engineering challenges very engaging, so it increases their motivation to understand the science and math concepts that connect to the engineering challenges. Since my involvement in MSTE I have devoted at least an hour each Friday to an engineering activity. These activities sometimes solely focus on the engineering design process, but more often they connect to the science curriculum. The activities also lend themselves to math concepts; I especially find opportunities to connect to ratio concepts.

One illustration of how MSTE has impacted my teaching is the evolution of the solar sprint activity. My students have participated in the Maine Junior Solar Sprint for several years. Students build small cars powered by a small solar panel. When I began this activity, it was connected to the science curriculum, but not integrated with it. Over the last few years I have strengthened this connection by focusing on the science behind solar energy. I have also made connections to the math curriculum. One important focus of sixth grade *Common Core* math is ratios. This project lends itself well to this mathematical concept. Students consider the gear ratio of their vehicle and the trade off (an engineering concept) between power and speed.

Another impact has been finding other engineering activities that mesh with our science curriculum. Our district is using the *Next Generation Science Standards* to provide a framework for our curriculum. Standard MS LS2: Ecosystems: Interactions, Energy, Dynamics is one that the sixth grade focuses on. I was having a hard time finding an engineering activity that would address this standard, but with the support of MSTE found an unit, “Don’t Runoff,” that meshes very well with some of the elements within this standard. Students learn about how environmental engineering can help protect ecosystems from impacts of stormwater runoff. They watch video vignettes of various ways to mitigate runoff and then experiment with altering a model cityscape with vegetative buffers and permeable pavement to reduce runoff.

Example of Junior Solar Sprint Vehicle

Our engineering activities also give students the opportunity to gain experience with important learning habits such as those described in the mathematical practices of the common core. Practices that overlap with our work in engineering include: MP.1. Make sense of problems and persevere in solving them (although students love engineering activities, there are times when their plans don’t initially pan out and perseverance is necessary); MP.2. Reason abstractly and quantitatively, and MP.3. Construct viable arguments and critique the reasoning of others. For example, students always present their product and the class discusses the strengths and weaknesses of various designs.

In this third year of MSTE I chose to focus on implementing an afterschool robotics program. I choose the afterschool model as it is more affordable; we’d need too many kits for a class program. I worked with our afterschool program to obtain funding for four LEGO EV3 kits. Our technology person installed the LEGO software on laptops. The program started the winter of 2016 with one meeting a week. Students built the basic robot and met several challenges that required them to write code to control the robot and complete different missions. Math and coding skills are both important in developing programs that accomplish their task. As kids work, they often start with the "guess and check" method, but then the youngsters start to use structure and patterns to plan. We did not work with sensory input this year, but as the program continues I expect we will. Hopefully over time robotics can be incorporated into the school-day curriculum.

Kids love engineering activities. They enjoy the challenge of solving engineering problems. By designing engineering activities that align with the curriculum students learn the science and math content painlessly. The engineering activities that I have incorporated into our school program have resulted in increased engagement and interest in science and mathematics.

References

The Engineering is Elementary Team. 2013. *Don't Run Off: Engineering an Urban Landscape*. Boston: National Center For Technological Literacy, Museum of Science.

National Governors Association Center for Best Practices and Council of Chief State School Officers (NGAC and CCSSO). 2010. *Common Core State Standards*. Washington, DC: NGAS and CCSSO.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, by States*. Washington, DC: National Academies Press. www.nextgenscience.org/next-generation-science-standards.

Online Resources

Junior Solar Sprint
http://www.usaeop.com/programs/competitions/jss/

Resources

Find an example of a student Engineer's Notebook for Solar Car Design and slide deck introducing the Solar Car Design Challenge at www.mmsa.org/MSTE.

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Maine Maritime Academy

Husson University (Years 2 & 3)

TERC

Maine Space Grant Consortium (Years 1 & 2)

Auburn School Department

Lake Region School District/MSAD 61

Oxford Hills School District/SAD 17

Ridge View Elementary School/AOS 94 in Dexter (Years 1 & 2)

Biddeford Middle School (Years 2 & 3)

Appleton Village School/Union 69 (Year 3)

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MMSA
Maine Mathematics
and Science Alliance