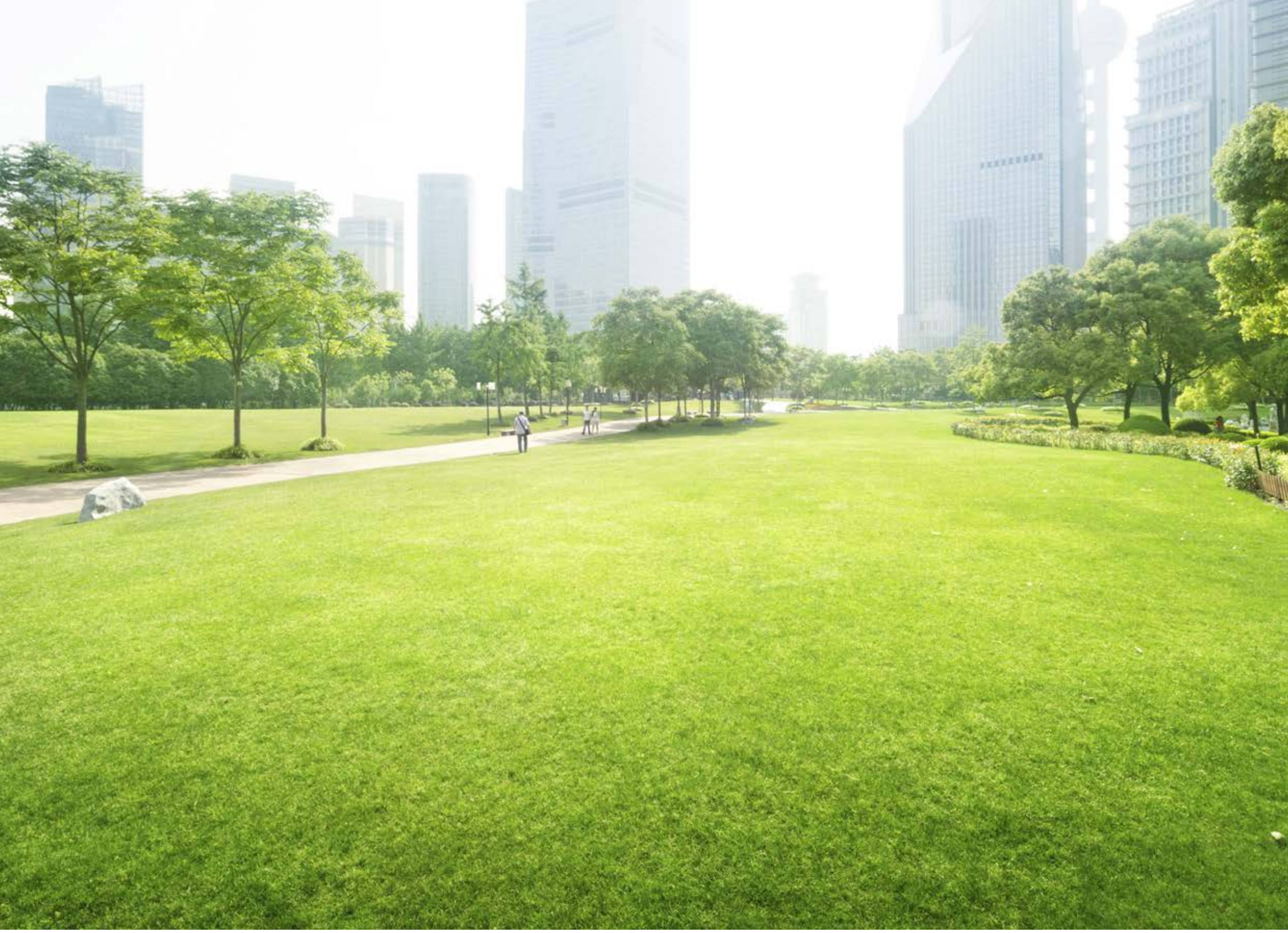
SEE LESS SEA-LESS SEAGULLS

Planning for an Interdisciplinary STEM Unit

by Katherine Ewalt, Brenda Dortch, and Virginia Russell

The *Common Core State Standards* (NGAC and CCSSO 2010) continue a long tradition of focusing on English literacy and mathematics understanding for K–12 students. But the Common Core has broken new ground by recommending that literacy in science and technical subjects be included in the English language arts curriculum. This has inspired a wealth of innovation from teachers who stepped out of their personal comfort zones to purposefully design crosscurricular lessons that incorporate integrative science, technology, engineering, and math (STEM) literacy. Integrative STEM literacy is the ability to incorporate the practices and content knowledge from engineering, technology, mathematics, and science to solve real-world problems in novel ways or to elicit answers that cannot be constructed by application of the individual disciplines alone (Sanders and Wells 2010). Instruction designed to teach integrative STEM literacy ensures students can positively direct their world by evaluating and synthesizing information with the intent of creating something new. It avoids the "mile



wide and an inch deep" curriculum of the past (NGAC and CCSSO 2010).

For teachers in the classroom, big ideas and lofty descriptions often lack practical methods for how to design integrative STEM lessons and units that could captivate students and transcend classroom walls. Additionally, an integrative unit requires input and ideas from many teachers. Motivating teachers to take this challenge and finding time to implement it are the initial obstacles. A yearlong project at our small school actually began as a challenge from an administrator to create one integrated STEM unit. Fortunately, several of the teachers involved had prior knowledge and experience with STEM, so they served as leaders and recruited others to join the project. The team of teachers met for several professional development days and mapped out a problem-based theme meant to influence instruction for the entire upcoming school year. Planning was loosely based on principles of project-based learning, such as those put forth by John Larmer and John R. Mergendoller (2010) that include a need to know, a driving question, student voice and choice, 21st-century skills, inquiry and innovation, feedback and revision, and a publicly presented product. Teachers also decided that the STEM lessons and activities would put new life into the existing curriculum, replacing and refocusing select lessons, rather than being applied on top of everything already done.

A need to know and a local driving question

Seventh-grade science is focused on life science, which includes the study of ecosystems and how humans impact the environment. This can be a challenging area in which to incorporate engineering and technology concepts at the middle school level. When planning started for the STEM unit, teachers planned to use ecology as the theme. Because ecology involves the study of the world around students, it can be very engaging, and it can lead to an examination of local problems that may further draw students' interest into the STEM challenge. A mountain of trash growing in the local skyline provided the inspiration.

Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

Standard MS-LS2: Ecosystems: Interactions, Energy, and Dynamics *www.nextgenscience.org/msls2-ecosystems-interactions-energy-dynamics*		
Performance Expectations The materials, lessons, and activities outlined in this article are just one step toward reaching the performance expectation listed below. MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.		
Dimension	**Name or NGSS code/citation**	**Matching student task or question taken directly from the activity**
Science and Engineering Practices	Obtaining, Evaluating, and Communicating Information	Students proposed a use for the brownfield, created scale models of their proposed use, gave oral presentations about it and created a brochure explaining how their design addressed the challenges of the project.
Disciplinary Core Idea	LS2.C: Ecosystem Dynamics, Functioning, and Resilience: • Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. • Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.	Final projects required students to directly link the arrival of the seagulls to a human-provided food source (the landfill) and then explain how the seagulls competed with native species through the local food web. Students also had to trace the succession of the old dump from human waste to unused field and detail the impact on organisms in the area. Many of the final projects used ecosystem dynamics as a means of discouraging seagulls by encouraging owls and other organisms that would eat the seagulls.
Crosscutting Concepts	Patterns Influence of Science, Engineering, and Technology on Society and the Natural World	Patterns were used to help identify cause and effect relationships within ecosystems, including local food webs. The change in the dump site over time gave students a local example of how technology had influenced the area, and comparisons with the nearby modern landfill helped students see positive changes humans have made toward better waste removal techniques.

Connecting to the *Common Core State Standards* (NGAC and CCSSO 2010)

English & Language Arts
CCSS.ELA-Literacy.SL (Speaking & Listening)
CCSS.ELA-Literacy.WHST (Writing)
CCSS.ELA-Literacy.RST (Science & Technical Subjects)

Mathematics
CCSS.Math.Content.7.RP (Ratios & Proportional Relationships)
CCSS.Math.Content.7.G.A. (Geometry)
CCSS.Math.Content.7.SP.A. (Statistics & Probability)

In the 1930s, the town opened a dump to take care of its garbage. By the 1970s, the dump was filled and a landfill was opened across the river for several surrounding cities. Unfortunately, as the trash mountain began to rise, it also began attracting unexpected visitors from the coastline approximately 100 miles away—seagulls. These seagulls compete with native species in surrounding areas and can be a nuisance to customers of local retailers, as the gulls swarm the parking lots. The landfill itself has caused some rather smelly problems as well. Questions about the impact of the seagulls on the habitat and the future use of the old dump site sparked the seventh-grade STEM project. This yearlong collaborative project included all seventh-grade students and all seventh-grade core subject teachers.

On the first day of school, a bulletin board teased students' interest in the STEM project with aerial images of the landfill and surrounding properties and the words, "It's Coming." A few weeks later, all seventh graders attended a STEM kick-off assembly where YouTube star Sam the Seagull set the stage for students' year of inquiry. An edited video clip of "Sam, the shoplifting seagull" showed him pilfering food from a market and helped bring students' attention to the seagulls that are seen swooping around local parking lots. The assembly required interaction and students wrote in their STEM design journals about the abundance of seagulls, despite the city's distance from the ocean. Several students shared their journal writings and, as if on cue, one student eagerly waved her arm and stated that she thought the landfill had something to do with the seagulls. (For the field notebook template, rubrics, transect field investigation, and other supplemental materials, see *www.nsta.org/middle-school/connections.aspx*.)

The remainder of the assembly introduced to students how a landfill is designed, which includes linings and safeguards to help contain any possible toxic substances that could leak from disposal of waste. The original city dump was designed before these safeguards, and problems can occur when a previous dump becomes a brownfield, (an unused former industrial site that can be used again). Environmental contamination must be addressed. Students were presented with the design challenge for the year: design a use for the brownfield that will encourage native species, discourage the seagulls, and provide a use for humans.

Designing a STEM-themed year

Arrival at this particular local challenge resulted from a brainstorming session during professional development. Starting with the question, "What topic in my subject is a keystone and could use extra reinforcement?" For life science, ecology is a core concept. The math teachers mentioned fractions, decimals, percentages, and geometric formulas as topics needing additional support, and this fit well with calculations done in ecology.

From the concepts raised during these brainstorming sessions, the teachers generated ideas for final products. They considered the question, "What would students create by the end of the year to show their results?" It was decided that, in small groups, students would create scale models of their proposed use for the brownfield, give an oral presentation, and create a brochure explaining how their design addresses the challenges. After determining concepts to be addressed and final desired products, teachers listed necessary vocabulary and specific objectives in which students would need proficiency in order to fulfill the design challenge. Google Drive helped immensely to plot the year's activities and lessons; the school had just transitioned to Google for collaborative efforts. Having a shared cloud server enabled teachers to work together, despite distance or lack of physically shared planning time. One matrix showed the general lessons, resources, assessments, and objectives that teachers had planned for individual classes (Figure 1), and a second showed how the lessons fit together throughout the course of the year (Figure 2). Last, teachers sifted through all the planned lessons and activities, deciding what subject standards were actually covered by the STEM theme.

An epiphany from the collaboration was discovering how much current curriculum already supported the theme. Still, teachers had to be willing to change. The mathematics teachers did lab activities in their classroom; the English teachers did scientific research. Students conducting ecosystem energy-transfer simulations in science class came prepared with knowledge of percent calculations that they learned in math class. In math class, students saw that learning about area and volume has a real-world application. Because the entire project was based on a local problem, teachers reached out to the community for support and invited local experts to share knowledge with students as well.

By the end of the year, a significant number of standards were supported by various activities related to the project. The *Next Generation Science Standards* (*NGSS*) MS-LS2 Ecosystems: Interactions, Energy, and Dynamics strand related most directly to the final project. Students needed to develop an in-depth understanding of how resource availability related to population life cycles, as well as the importance of biodiversity in designing an ecosystem. The crosscutting concepts of Patterns, Cause and Effect, and Stability and Change underpinned many explanations

FIGURE 1 Planning table of lessons supporting STEM theme

Subject	**Objectives** Specify skills and information that will be learned	**Lesson(s)**	**Other resources**	**Verification** Steps to check for student understanding
Science	Create a food chain from knowledge of an ecosystem, label the trophic levels of the food chain, predict effects of changes in an ecosystem on food web	• Food chains, food webs, and energy-flow lesson • Owl Pellet Lab	Textbook Owl Pellet Gizmo	Food-chains worksheet
Science	Define carrying capacity and limiting factors, estimate the effect of limiting factors on an established ecosystem, calculate the carrying capacity of an ecosystem for a given species	• Carrying capacity and limiting factors lesson • Picky Eaters Lab • Owl Pellet Lab	Textbook Picky Eaters supplies	Lab results
Science	Explain the relationship between seagulls and their native competitors	• Competition/ Cooperation lesson	Textbook	Design journal
Science	Compare and contrast the nitrogen, carbon, and water cycles; determine the role of producers and consumers in the cycles; relate the cycles to eutrophication; and explain how the cycles relate to the life cycle of trash and landfills	• Cycles Lesson • Cycles/Landfill Poster	Create-a-Landfill buckets from math class Bill Nye "Garbage" Landfill Blues song	Poster showing cycles and where trash/ landfill disposal fits in
Science	Identify causes for eutrophication	• Cycles lesson • Eutrophication and Google Earth	Google Earth	Labeled picture
Science	Simulate the movement of pollution through the ecosystem, explain the process of bioaccumulation and determine the effect on the rest of the ecosystem	• Bioaccumulation Simulation • Picky Eaters simulation (carrying capacity and effect of predators)	Pipe cleaners Masks/hats for parts	Food chain
All	Determine the quality of water from local pond, leachate, other sources	• Brownfield Field Trip	Water-quality test kits	Field notebook (pasted into design journal)
All	Conduct a transect of the brownfield to determine species present	• Brownfield Field Trip	Transect equipment, binoculars, journals	Field notebook (pasted into design journal)

FIGURE 1 Planning table of lessons supporting STEM theme (continued)

Subject	**Objectives** Specify skills/information that will be learned	**Lesson(s)**	**Other resources**	**Verification** Steps to check for student understanding
Math	Measure the area of the school using Google Maps, then predict the area of land covered by the brownfield, compare the size of the landfill to other landfills in the area, and measure the size of other places of interest (baseball field, sports park, soccer field, playground, etc.)	• Google Maps activity	Google Maps	Labeled/marked map from city design journal notes
Math	Use proportional reasoning to estimate the population of a species by mark and recapture method	• Goldfish Mark and Recapture activity	Goldfish	Lab results
Math	Calculate the amount of energy available to consumers at each level of the energy pyramid	• Energy Pyramid activity	Gizmo	
Math	Design a juice box that increases the volume without increasing the surface area (purpose: conservation)	• Jumbo Juicebox		Juicebox design
Math English	List the effects of a landfill on the native ecosystem, infer which materials will decompose easiest, describe the source of leachate	• Build a landfill • Research in English	Soil testing, rulers for measuring and calculating landfill volume	Reflections in journal
Math English	Each group will present their model and chosen use for the brownfield	• Oral presentation unit in English		Rubric for oral presentations
English	Create a persuasive brochure to convince the city to use the brownfield for their chosen purpose	• Persuasive writing		Finished brochure rubric
Math classes, in groups	Plan a use for the brownfield, support uses chosen, explain how the use will improve the environmental issues, support chosen use with research	• STEM exhibition	Design journal	Brochures Scale model
STEM Exhibition	Model the area, showcasing the chosen use(s) and including the scale	• STEM exhibition	Design journal	Scale model Brochure Oral presentation

developed for students' final projects, as they used research to predict ways their designs would ultimately support the native populations without causing changes that might tip the balance of the ecosystem elsewhere in the city. Because students competed with each other to produce the "best" proposal, much like development companies, students had to present solid evidence for their arguments, based on data such as the amount of uninterrupted space a local hawk would need to hunt, or the results of experiments in other locales to get rid of seagulls. Students engaged in a number of *NGSS* science and engineering practices, including developing and using models; analyzing and interpreting data; constructing explanations and designing solutions; and obtaining, evaluating and communicating information. Because students' final project must persuade audience members to "invest," they had to engage in argument from evidence as well. The mathematics and English standards supported these crosscutting concepts and science and engineering practices, as students learned how to find and evaluate research, how to understand collected data, and how to interpret the data to support their final ideas.

Student voice and choice

At the conclusion of the assembly, students were given time to begin brainstorming ideas for repurposing the brownfield. Most students focused on the human-use portion of the design challenge. This was expected. A lot of students wanted some sort of theme park at the site. Roller coasters, Ferris wheels, and even skate parks were discussed by many students.

Feedback and revision, inquiry and innovation

The size of the area could not support a theme park of any substance, and it would also fail to address the issue of the seagulls, but teachers did not directly explain this to students. Frequent STEM team meetings helped teachers develop more lessons that would guide students to an acceptable final product. Students needed to see the space for themselves and get a better understanding of the size of the area compared to something like a theme park. The teachers concluded that a combination of an in-school, out-of-school field trip would allow students to explore the space, and by guided inquiry, they could relate the size to known objects.

The STEM field trip day was a key component to the yearlong project. Success for the field trip day depended on planning. The math teachers divided their entire roster of students into small teams of four or five students. These small teams were then placed into larger "conference groups" that moved together to their stations, where students broke into their small teams to complete the inquiry activities. During the field trip, students completed field logs at the site. Leading up to the day required many hours of planning, preparing materials, coordinating buses and schedules, and collecting permission slips, as well as communicating with students, parents, staff, and community volunteers. The payback was an exciting day of collaboration, inquiry, investigation, research, and discovery for our students.

During the field trip, students rotated through inquiry activities that directly supported the project. The day began with the city coordinator, who spoke to students about the former dump site and fielded questions about potential uses and environmental concerns still present. Four conference groups took a bus trip to the nearby brownfield site to conduct investigations into the community of organisms present and to test water quality. Students saw firsthand the condition of the land. A flurry of questions and ideas followed. Meanwhile, four conference groups stayed in the school to conduct research with English teachers, make geometric measurements using Google maps, and use scale model manipulatives to compare with the dimensions of rides from a theme park. At midday, groups traded places. To end the day, conference groups met in classrooms to watch part of *National Geographic's* "Human Footprint," which visually laid out the amount of waste one family can produce (Watts 2007).

Many other activities during the school year supported the theme. Science classes ran simulations to find out how predators and food availability affect the carrying capacity of the ecosystem. Students conducted a lunch time "waste audit" to measure the quantity and type of garbage that is typically thrown away in the school cafeteria. Students became far more aware of how their actions contributed to the landfill, and a model landfill built in the math classes showed what happened to materials once they were in the landfill. An owl-pellet lab took on new focus as students discussed the use of owls to help scare away seagulls. Some science classes were able to take field trips to explore a local waterway by canoe. Students compared water quality differences in locales with riparian buffers to help reduce erosion and pollution to those without, and discussed how this might affect the choices of their brownfield design.

Twenty-first century skills

Students collaborated during multiple lessons within the year, and the final product is designed for teams of three or four students. Critical thinking is encour-

FIGURE 2 Timeline planning table for lessons

Activity	**Class**	**Time**
Recycling program	Schoolwide	Ongoing
See-Less Sea-less Gulls board • students get to post questions and ideas		Ongoing
Introduction • compost project Mini Landfill	Math	First two weeks
Problem of the Gulls • journal entries • landfill research	Seventh-grade assembly	Second week of school
Area 51/Area of Irregular Figures • group work training • pattern blocks	Math	September
Energy Pyramid • Gizmo energy pyramid (powers of 10) • unit rate equilibrium point	Math	September/October
Google Earth and Area area • latitude/longitude • measure landfill and pond • record in journal	Math	December
Science Ecology Unit • food chains/webs • cycles and landfills • Carrying Capacity: Picky Eaters • bioaccumulation • competition (gull competitors) • eutrophication and Google Earth	Science • Focus on landfill life cycle related to other cycles	October/First week November
Owl Pellet Lab	Science	End October/begin November
Lunchtime Waste Audit	Science	November
Future Landfill Technology Challenge	Science	November
Mark and Recapture • estimation, proportion	Math	November/ December/ January
Design technology to count the seagulls at various malls using robotics kit • direct observation • data analysis through histograms	Math	November/December
In-school/out-of-school brownfield field trip	All	December
Oral presentations	English	December–May ongoing

FIGURE 2 Timeline planning table for lessons (continued)

Activity	Class	Time
History timeline	History	January
Jumbo Juice Box • increase volume while decreasing surface area	Math	January–March
Science Ecology Unit • food chains/webs • cycles and landfills • Carrying Capacity: Picky Eaters • bioaccumulation • competition (gull competitors) • eutrophication and Google Earth	Science • Focus on the results of the landfill model	March
Determine volume of landfill models	Math	March/April
Owl Pellet Lab	Science	March (end)
Lunchtime waste audit	Science	March
Future landfill technology challenge	Science	April
Canoe trip: select students		April 13
CBF island trip for students		April 17–19
History timeline	History	May
Design brief • groups formed • challenge reiterated	Math	May
Practice presenting	English	End May/June
Research former landfill uses and native species	English	End May/June
Design and build models	Math	End May/June
STEM exhibition	Visit in math classes	June 8 in gym

aged as students develop their ideas for the site and apply knowledge gained from the classroom to designing their final solutions. Communication skills are vital and part of the oral presentation unit designed by the English teachers and necessary for the creation of a brochure to showcase the benefits of students' design proposal. Select classes also undertook additional challenges that reinforced 21st-century skills. Some science classes designed a future technology related to a landfill issue of their choice and created websites and ad-campaign posters to highlight their ideas. In select math classes, students used a robotics kit and created a program that could potentially be used to count seagulls. These classes were test groups, with intent that in future years, more classes could participate in these activities as part of the STEM theme.

A publicly presented product

The project culminates in a June STEM exhibition. For about a week, students work on design proposals. In English, they hone presentation skills, conduct research into native species and seagulls, and determine what has previously been done with brownfields. In math, students build a scale model of their design using a variety of donated materials. Teachers contacted local businesses and civic organizations to procure prize donations. The projects are presented in math classes, where the teachers use a scoring rubric and students give input to determine individual class winners. The class winners are judged by guest judges (provided with a rubric) at the STEM exhibition. The judges' scores determine one overall winning group from the classroom winners. Parents and community are invited to the STEM exhibition, visitors vote to determine winners in additional categories (favorite, "greenest," etc.), and all awards are presented in a ceremony along with the donated prizes.

Outcomes

Students experience the relationships among technology, science, engineering, and mathematics and learn that these are not separate "subjects," but interrelated fields that are used holistically to solve problems and find solutions to human needs. Not every student was pleased; one child lamented, "I miss the old days when math was math and science was science," but even he understood these integrated STEM class activities better matched real-world processes. It is also more evident to students that reading for information, oral and written communication, and presentation skills are integral to working collaboratively, solving problems, and persuasively advocating the advantages of a solution. Students learn the engineering-design process, including the understanding that real-world problems can have a variety of solutions. Students learn to use math and science knowledge to inform their analysis and evaluation during the engineering-design process.

Teachers gain many benefits from collaborative planning, including a better understanding of standards taught in other classes. This improves their ability to connect learning from one class to another, making students more likely to remember what they learn. Listing the many ways the curriculum overlapped, it was easy to adapt or substitute lessons so that the overall curriculum maps did not have to change, an important step for integrating STEM given the magnitude of demands on instruction time. Making this yearlong theme a success required significant teamwork. Shared planning tools, such as Evernote and Google Drive, helped keep all teachers informed and delegate the work so that no teacher felt too much extra pressure. Communication with parents and community also ensured success, as there was little money in the school budget for acquiring supplies; the community gave generously. The local newspaper wrote articles, which made contacting community organizations for donations easier. Shared planning time was vital, as many teachers started a kernel of an idea, and through group brainstorming, the idea was able to grow into an activity. The collaboration also helped reinvigorate the teacher's commitment to the theme as the year progressed.

Conclusion

The yearlong STEM theme has helped our small school greatly expand its STEM initiative. Students' integrative STEM literacy improved as they were able to pull ideas from more fields. Overall, students responded well to breaking down the classroom walls. Teachers were challenged to redesign curriculum and adapt as gaps in student knowledge arose, but collaboration helped lessen the stress and lead to a synergistic result that grew beyond the single unit goal. ■

References

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Resources

Sample websites created by students in Exploravision-style projects for a future landfill technology:

http://newtrashtech.weebly.com

http://goo.gl/Rt6oJg

http://goo.gl/jX0lZX

http://copperyakchms.weebly.com

http://recyclingisimportant3.weebly.com

Katherine Ewalt *(katherine_ewalt@colonialhts.net)* is a seventh-grade life science teacher, ***Brenda Dortch*** is a seventh-grade mathematics teacher, and ***Virginia Russell*** is a seventh-grade English teacher, all at Colonial Heights Middle School in Colonial Heights, Virginia.