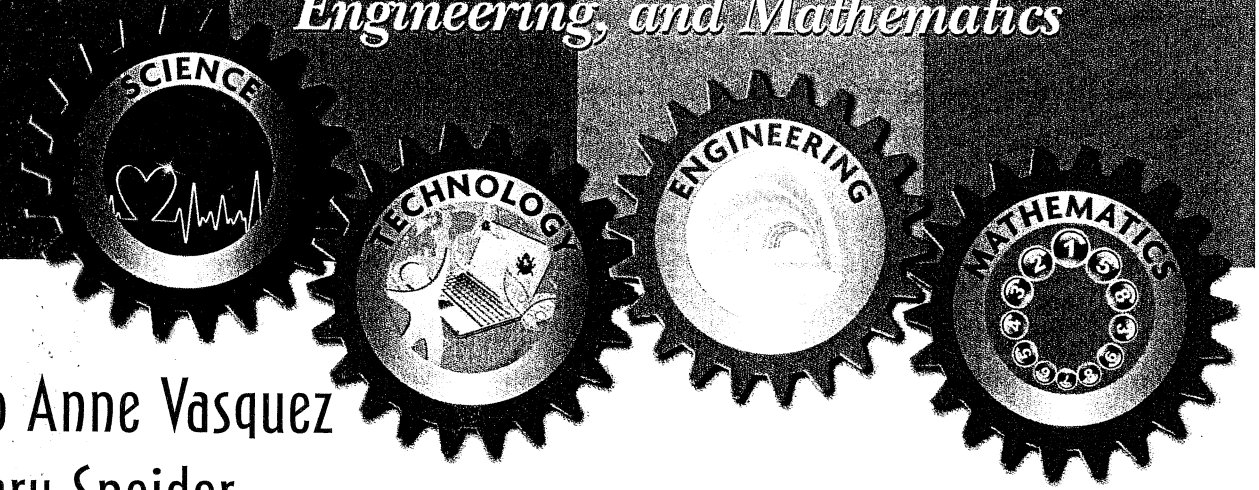
GRADES 3–8

Foreword author RODGER BYBEE

TEAM Lesson Essentials

Integrating Science, Technology, Engineering, and Mathematics



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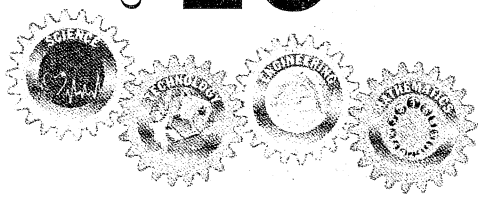
CHAPTER 15



Implementing STEM in a Middle School

This chapter was written by Jake Foskop, a District Resource Teacher.

BEFORE READING THIS CHAPTER

about interdisciplinary teaching at Buchanan Middle School in Tampa, Florida, reflect on times that you've had students read a story and think about its implications for our lives today. *Frankenstein*, the story that is featured in this chapter about teaching across the middle school curriculum, is especially relevant in light of today's technologies for engineering new life forms.

Considerations of the historical, social, cultural, and ethical aspects of science and its applications, as well as of engineering and the technologies it develops, need a place in the natural science curriculum and classroom [32, 33]. The framework is designed to help students develop an understanding not only that the various disciplines of science and engineering are interrelated but also that they are human endeavors. As such, they may raise issues that are not solved by scientific and engineering methods alone.

—*A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council 2012, 8)

Welcome to Buchanan Middle School

Buchanan Middle School is an average grade 6–8 school with diverse demographics. The STEM Institute is a small school within the walls of Buchanan Middle School, based on the "Career Academy" model. It is one of eight STEM Institutes in the district, each with a different theme, such

as engineering, premedical, maritime, or environmental resources. The theme of the STEM Institute at Buchanan is biotechnology. Because students can earn high school credit for some of the eighth-grade courses at the STEM Institute, students must first apply and meet high academic performance standards on the Florida Comprehensive Achievement Test.

All of the teachers at the STEM Institute work together and teach the entire cohort of sixth to eighth graders. Students have the same teachers for all three years while participating in the program. The teachers have a common planning time and common lunch time to allow for developing coordinated curriculum plans. Because the STEM Institute's theme is bioengineering, the teachers infuse or "flavor" the curriculum with topics relevant to biology and engineering. Over time the teachers have naturally evolved programs that embody the five guiding principles outlined in Chapter 3. They integrate courses with the common theme of biotechnology; establish relevance by frequently noting the real-world applications of biotechnology; emphasize twenty-first-century skills by providing opportunities for students to work together on creative projects; challenge the students with engaging activities that require higher-level thinking; and mix it up by providing a variety of ways for students to learn and to express their growing understanding of STEM.

The STEM Institute provides a "family-style" feeling that lowers the student's anxiety about the school system. This characteristic of the program creates an atmosphere of trust and caring that encourages students to take academic chances in class. They participate in discussions, are willing to answer questions even when they are not sure, and support each other by clapping, cheering, and saying "good job" when one of their classmates provides an answer or works a problem on the board.

To prepare the teachers for their work in the STEM Institute, they attended a workshop, which provided training in cognitive psychology as well as guidelines and tools for designing units that will help their students advance to higher levels of thinking. One of the practices that the teachers found to be most helpful is to design units that span across all of the content areas, so that

students can see the connections among the subjects that they are learning and how their learning relates to the real world beyond the walls of the school. They also came to agree on the following core idea, which they called a "STEM mindset," for infusing into all of their classes:

> STEM is the manipulation of our natural world (science) through the engineering process, using mathematics as the tool for creation of the human made world (technology).

The teachers emphasize to the students that this idea is highly relevant to their lives because they will eventually join the community of adults who will apply STEM processes to help shape the human experience. The teachers have developed a number of creative units to communicate these important ideas and to challenge their students' preconceptions about the world around them. One of the most engaging is the unit that begins with the Frankenstein story, as described in the next section.

A Unit on Ethical Issues

One of the integrated units focuses on how people manipulate the natural world and the related ethical ramifications. This unit is implemented at the beginning of the school year for eighth graders and really kicks it off with a bang! For many students, it is the first time that they have considered human behavior and technological advancements from an ethical perspective. These considerations are a stepping-stone for the students as they begin to establish their personal beliefs. The cross-curricular design allows the students to explore their ethical positions from various angles. This allows the students to solidify and question their beliefs while they participate in the various activities.

To prepare for the beginning of the school year, the students are required to read the novel *Frankenstein* over the previous summer. Once school begins, there is very little organizational downtime and the students dive right into the

integrated unit. This approach sets the academic and classroom management standards for the entire year.

The unit spans all subject areas, and each of the teachers incorporates ideas from the Frankenstein novel into their standards-based curriculum. In math class, the students design a Frankenstein "monster" using their own bodies as templates. They use tools to measure their own bodies, derive body proportions from their measurements, and then use the proportional relationships to create a scale drawing of their personal monsters, illustrating how it might be composed of various pieces. In science class, the students use the scale drawings from math class to design plans for assembling and activating their monsters.

In social studies class, the students' responses to the *Frankenstein* book provide a springboard for discussing three ethical issues that have been in the news: (1) euthanasia, (2) universal health care, (3) responses to bioterrorism. Their discussions of the ethical issues are enriched by work in their information and communications technology class, where they conduct research and build presentations to illustrate their findings. The students also design and conduct a schoolwide survey on current ethical issues. The survey results are analyzed and plotted using basic descriptive statistics toward the end of the unit in math class. And, of course, the language arts class focuses on the novel itself. All these activities combine to help students develop their ideas about complex ethical issues as they hone their skills in critical thinking, in addition to specific skills in mathematics, language arts, science, social studies, and information and communications technology.

Field Trip to a Hospital

One of the most important parts of this unit is the culminating field trip to a local hospital where students have an opportunity to discuss ethical issues and how they apply to real cases with doctors, including the head of the ethics committee. To prepare for the field trip, the teachers talk with their partners at the hospital and identify contemporary issues at the intersection of science and

society that the students are expected to research and discuss in advance of the trip. The most recent list of questions includes:

- Should animals be used in pharmaceutical research?
- Should we inject women in their sixties with hormones that will allow them to have children?
- Should new life-forms be created to try to solve world problems such as hunger and pollution?
- Should we allow doctor-assisted suicide to hasten the death of terminally ill patients?
- Should stem cell research be continued?
- Should vast amounts of money be spent on space exploration when many people worldwide live in substandard conditions?
- Should we treat hereditary diseases by replacing defective genes?
- Should we use gene therapy techniques to improve an unborn child's appearance or intelligence potential?

Knowing that they will soon have an opportunity to talk about these issues with medical professionals helps to motivate the students to learn as much as they can before the field trip. These questions, combined with the novel's theme of right and wrong, moral and immoral, and what power people have over life and death make for some lively conversations in the classroom. The conversation at the hospital also provides assessment data to the teachers, as they witness how effectively the students are able to apply what they have been learning during a real-time conversation with professionals.

As students work across the curriculum, they begin to see the connections among the subjects and how each of them contributes to a broad understanding of important contemporary issues. This combination of content, activities, relevance, and performance assessment is one that the STEM Institute strives to achieve with every integrated unit. A table showing the sequence of the entire unit is shown in Figure 15.1.

Figure 15.1 Sequence of ethics unit based on Mary Shelley's *Frankenstein*.

Day of Unit	Math	Language Arts	Social Studies	Science	Biotech
1	Sets/Subsets and Timeline	Bioethics Vocabulary	Concept Mapping	Science Concept & Assessment	Bioethics PowerPoint
2	Make Venn Diagram	Bioethics Vocabulary	Concept Mapping	Engineering Concept & Assessment	Walk a Mile
3	Ratio/Rates	History–Mary Shelley	Current Event #1	Design Brief	Bioethics Beat on the Street
4	Proportions	Elements of a Story	Interpret Statistical Data	Design Prototype	Finalize Survey Questions
5	Similar Figures	Movie Poster	Interpret Statistical Data	Design Prototype	Conduct Survey
6	Scale Drawing of Monster	Bioethics Readings	Current Event #2	Movie Poster	Conduct Survey
7	Graph Math Relationships	Test–Frankenstein	Socratic Seminar	Create Monster from Scale Drawing	Analyze Survey Data
8	Field Trip	Field Trip	Field Trip	Field Trip	Field Trip
9	Scatter Plot and Biotech Data	Writing Prompt	Follow-up Activity	Complete Monster from Scale Drawing	Follow-up Activity

Putting the Pieces Together

Integrated units that stretch across the entire school curriculum take much planning, professional development, and district support. All of these components have to be clearly communicated so there is a shared understanding of expectations among the teachers and administrators. This level of planning can be difficult to achieve but is possible when the focus of the program is on creating the best possible educational experience for the students.

Professional development has also been essential to the success of the STEM Institutes. In addition to an initial workshop during which teachers from all of

the institutes developed a common vocabulary and adopted common tools for creating integrated units, the teachers had opportunities to meet and plan during subsequent workshops. These additional professional development opportunities included updates on current educational research, time to work with industry partners to formulate new ideas, and a chance to bring new industry partners into the STEM Institute.

Working with industry partners also takes time, and two general methods evolved. In some cases a small group of teachers arranged to visit a partner's facility, where they could tour the facility and work with their partners to begin developing a unit. In the second method, teachers from all eight of the district's STEM Institutes came together at a school site to collaborate on ideas for new units with the help of industry partners. The second approach allowed the partners to see all the different STEM Institutes and network with a variety of teachers. The engagement by the industry partners generated by these collaborations has been tremendous and has helped to generate industry support for the entire school year.

At the beginning of each school year, all the STEM Institute teachers meet to work on their annual goals. The teacher teams create action plans and presentations about their institute and expectations for the school year. Action plan items include timelines, delineation of responsibilities of each task, marketing materials, classroom norms, classroom procedures, and other pieces based on our educational standards. These action plans are revisited each year to allow for districtwide goal inclusion, expansion, and modification of past practices. Each of the teachers expresses a commitment to professional development. Teachers who are not self-regulated lifelong learners struggle in this fluid environment, but the great majority of teachers thrive in our community of practice, based on values of family, trust, creativity, innovation, and desire to bring relevance to every lesson every day.

District-level support is essential to the success of these STEM Institutes. Due to the nature of curriculum integration, a large number of administrators are involved in fiscal and curricular decision making. These administrators hold

decision-making power that can impact the future of these programs, teacher attitudes, and public opinion of the school. Indeed, the road is filled with potholes. To create a viable and effective support structure, one person is designated to be the communication gatekeeper for the STEM Institute. This lead teacher is responsible for all communication regarding field trips, media, needs from the district office, parental involvement, marketing, and internal communications at the school site. The system is designed so everyone knows who is responsible for each task.

Full Circle

The STEM Institutes are jewels in the Tampa Bay area, supported by district leaders and collaboration among a core team in science, career and technical education, and mathematics. Participation by language arts and social studies teachers in support of the STEM platform has greatly enriched the programs, helping students increase their skills in communication and civic engagement. Since the STEM Institutes were started four years ago, virtually all of the teachers have found the work to be tremendously exciting. In fact, one teacher retired and petitioned the superintendent to allow her to return to work as a volunteer so she could continue to work in this system.

The STEM Institute design is deeply rooted in the surrounding community. The parents have appreciated how excited their students are to go to school, even though they are expected to work hard to succeed in rigorous courses. And community partners have come to understand how an integrated curriculum model makes sense. This last observation has come as an epiphany to many of us. We have realized that we do not live in a well-structured world. We constantly face challenges in our daily lives, and we also encounter opportunities. These challenges and opportunities do not come neatly wrapped in packages labeled "science," "math," or "language arts." By learning in an integrated way, our students will be better prepared to solve the challenges and take advantage of the opportunities, using whatever knowledge and skills are appropriate to the task.

Reflection

- What do you think about the idea of creating STEM Institutes in your school or district? Is it desirable? Is it feasible? If so, how might you go about it?
- The integrated unit described in this chapter does not require that it be taught within a specially organized school, except that teachers do need to have the same students in common. If this is possible in your school, how might you go about developing and implementing an integrated unit that stretches all the way across the curriculum?
- Keep in mind that although it is best for a team of teachers to work together, individual teachers can also implement integrated lessons on their own. Are there some specific ideas in this chapter that you'd like to try?

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