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Making Science Meaningful: A Literacy-Rich Sequence

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Making Science Meaningful: A Literacy-Rich Sequence

by Emily Cizmas

As someone who enjoys science—and learning in general—I never needed my secondary science teachers to motivate me to learn the subject. I appreciated when my teachers integrated real-world connections and interesting projects into their lessons, but I still considered science important when we did nothing other than worksheets and book problems. The same was true during my time as an undergraduate engineering student.

It is not surprising, then, that when I followed my passion to become a high school teacher, I expected all my students to share my immediate enthusiasm for science. It did not take long for me to recognize my naivete. Following an initial period of frustration, I realized that my students' lack of interest was not a deficiency of some kind. Rather, it is a fundamental part of a teacher's job to teach students not only content but also *why* and *how* the content is useful. In 1956, John Dewey argued that the subject matter students learn in school "must be returned to the experience from which it has been abstracted" (p. 14). Nevertheless, more than 100 years later many classes are still abstracted from reality.

The Next Generation Science Standards (NGSS), adopted in Michigan in 2015, mark a widespread shift in science education (NGSS Lead States, 2013). Rather than simply learning about science, the NGSS emphasize students doing science like scientists and engineers. This new approach leads to greater levels of understanding and engagement among students. The types of thinking and learning specified in the NGSS are rich with opportunities to integrate Common Core State Standards for English Language Arts, as well (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). However, the availability of high-quality lessons aligned with the NGSS has not yet caught up with demand (Sawchuk, 2018). This article provides an example of a

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tenth-grade physical science project I developed to meet NGSS requirements while also practicing students' literacy skills.

Physical Science Project

Background Information

Prior to this project students had learned about motion, forces, Newton's laws, and momentum. In addition to learning the core science principles in these units, students also practiced designing and conducting their own investigations, collecting and analyzing data, and communicating results.

This project introduced students to the concept of impulse. Impulse is the change in momentum of an object, and it is equal to the force of the collision multiplied by the amount of time that the force acts:

$$\textit{Impulse} = \textit{change in momentum} = \textit{force} \times \textit{time}$$

The important takeaway from this equation is that, for a given impulse, a longer collision time results in less force and a shorter collision time results in greater force. This project specifically investigated impulse for an object which is moving and comes to a sudden stop; this scenario is important because it represents automobile collisions and other cases when safety is a factor. Based on the impulse equation, if a small force is desired (e.g., on a passenger in a collision), the collision time must be maximized.

When we began talking about collisions I asked students, "If someone throws a water balloon to you, how do you catch it?" Most students responded by showing how they would move their hands back and cradle the water balloon as they caught it. When I asked them why they replied, "To cushion the balloon" or "To soften the catch," but they could not explain what they meant by "soften." The reason that moving one's hands back while catching the balloon helps prevent it from breaking is that it lengthens the time of the collision, resulting in a lower force on the balloon. My goal by the end of this project was for students to be able to accurately describe collisions in terms of impulse, force, and time, instead of "soft" and "hard." Communicating scientific ideas clearly and correctly is a literacy skill many of my students lack, and it is an essential part of the science learning process as students test the validity of their ideas by discussing them with others (Leach & Scott, 2003). This series of lessons provided students a chance to exercise these important skills. The lessons were designed to be both rigorous and engaging.

Lesson Sequence

In this project students worked in teams to develop an understanding of impulse, learn about real-world applications of impulse, and finally apply what they learned to build an egg-protection device. Table 1 shows the components of the project.

Days 1-2: experiment. The NGSS emphasize that students discover relationships for themselves as scientists do, rather than being given all the information up front. Therefore, instead of explaining impulse to students, I had students run an experiment in which they determined the inverse relationship between force and collision time (i.e., the longer the collision time, the smaller the force). This approach not only made the content more meaningful and memorable, but it also provided students an opportunity to practice data collection, analysis, and communication skills.

The only materials required for this experiment were smartphones (readily available to most students) and various collision surfaces. Free apps are available which allow students to use their personal devices as accelerometers, including Google Science Journal (Google LLC, 2018) and Lab4Physics (Lab4U, 2018). For the collision surfaces I used large pieces of fleece. Students varied the "hardness" of the collisions by first laying the fleece flat on a solid table (short collision time), then by holding it taut above the table to form a tight "net" (medium collision time), and finally by holding it above the table with less tension to form a loose net (long collision time). Other collision materials which could work for this experiment include foam, pillows, and inflated plastic bags.

To run the experiment, students dropped their devices from a height of one inch onto the different fleece setups with the accelerometer running. After the collision students analyzed their data on the accelerometer and recorded the total time of the collision as well as the maximum acceleration. My students had already learned about Newton's second law and the direct relationship between unbalanced force and acceleration (i.e., greater force results in greater acceleration), so they understood that acceleration is an indirect way to measure the amount of force acting on the phone during the collision. My students also run experiments frequently, so they knew how to identify experimental variables and what should be done with each. In this experiment, the independent variable was the fleece arrangement (flat on table, tight net, or loose net). The dependent variables were the collision time and acceleration measured from the app. The controls included the height from which the phone was dropped, phone orientation, and anything else which needed to remain constant.

Table 1
Impulse Unit Overview

NGSS Performance Expectation
HS-PS2-3: Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

Literacy Connections
CCSS.ELA-Literacy.RST.9-10.1: Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. CCSS.ELA-Literacy.RST.9-10.2: Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text. CCSS.ELA-Literacy.RST.9-10.3: Follow precisely a complex multi-step procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

	Student Task	NGSS Practices
Days 1-2	Investigate the relationship between force, collision time, and collision material	Planning and carrying out investigations, Analyzing and interpreting data, Developing and using models
Day 3	Discuss real-world applications as a class, students choose their own articles related to an impulse application and share their summaries with the class	Obtaining, evaluating, and communicating information
Days 4-5	Select a controversial topic related to impulse and write a four-to-six page argumentative essay taking a position on the issue	Engaging in argument from evidence
Days 6-9	Use the engineering design process to design, build, and refine an egg lander	Constructing explanations and designing solutions

Students exercised multiple forms of literacy during this experiment. They read and interpreted accelerometer readings, analyzed the acceleration and time data they collected, expressed their data in a new graph, and described their findings in words (CCSS.ELA-Literacy.RST.9-10.3). Students also practiced spoken literacy skills as they communicated with their group members during the entire process.

Day 3: real-world applications. In the preceding experiment students discovered that, for an object in a collision, a longer collision time resulted in a smaller force on the object and vice versa. On day three of the unit, I began by asking students where this may be relevant in daily life. Good examples include airbags, packing peanuts and bubble wrap, and padded football helmets. In each case I asked students to explain how the application relates to the results of their experiment. This encouraged students to be more scientific in their explanations and to practice clear verbal communication. For example, students said things such as, "Football helmets are padded because its softer than hitting your head on another head." I then asked the student guiding questions related to the experiment until they refined their explanation to something like, "Football helmets are padded because the padding increases the collision time, resulting in a lower force on your head." Through repeated practice, I witnessed my students refine their scientific statements and think more deeply before making claims.

After we discussed as a class, I instructed students to work with a partner to find an article online about a real-world application related to impulse. They were instructed to read the article, summarize the important points on their whiteboards, and then share with the class. Allowing the students to select their own articles provided them some control over their learning and increased the variety of topics presented to the class. Students exercised their literacy skills by reading their informational (and possibly technical) articles, writing summaries, and verbally communicating with their partners and the class (CCSS.ELA-Literacy.RST.9-10.2).

Day 4-5: argumentative essay. After students had discussed some applications of impulse, they were asked to select a controversial topic related to impulse and write a four-six-page argumentative essay taking a position on the topic. Some example topics I provided to students were, "Should wearing a seatbelt be required by law?" and "Should children be allowed to play football?" To provide students ownership over their learning, they were given the option of choosing one of these topics or developing one of their own.

While arguing for their position, students needed to accurately explain how the topic was related to impulse in terms of force and collision time, and they had to use this explanation as a basis for their arguments. They also had to address counterarguments with facts and scientific explanations (CCSS.ELA-Literacy.RST.9-10.1). Students were required to cite at least three sources in their papers. This assignment allowed for extensive literacy practice through reading and writing, and it forced students to evaluate their personal views through a scientific lens.

Day 6-9: egg lander design challenge. As a capstone for our impulse unit, students worked in teams to design an egg lander. The egg drop project is common in physical science classes, but often students do not learn the physics of impulse prior to the project. In these cases, students do not apply scientific knowledge to their designs; the project is nothing more than a craft project with the goal of a "soft" landing. In this unit however, students investigated and applied impulse in a variety of ways prior to the egg lander assignment, so they were comfortable with the concept. Students were also required to justify their designs in terms of impulse, force, and collision time prior to testing.

This was the first major design challenge in my physical science course, so I introduced students to the Engineering Design Process (EDP) for the first time (NGSS Lead States, 2013). An overview of the EDP is shown in Figure 1. The NGSS performance expectation specifies that students "design, build, and test" their devices.

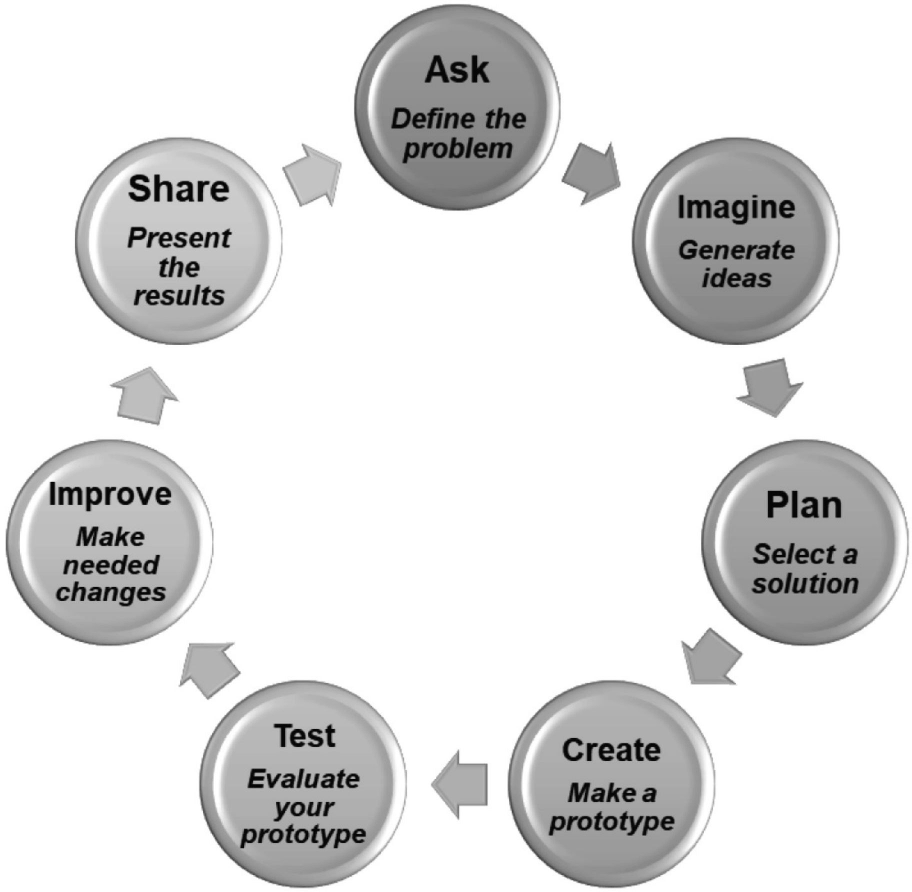

Figure 1. The Engineering Design Process (EDP).

Therefore, I did not want students to simply throw together a design and hope it worked. I explained to students that any engineering project, large or small, is similar to the process of writing a paper. The final product does not happen immediately; there must be brainstorming, planning, and revising. I asked students to imagine what would happen if engineers tasked with designing a multibillion-dollar bridge simply threw together a design and immediately started building without any planning, testing, or application of scientific principles. This helped students view the task as a scientific and engineering challenge rather than a craft project.

Initially, students completed the “imagine” and “plan” stages of the EDP. They recorded their brainstorming thoughts and their final design plan on a poster, along with the scientific justification based on impulse. The next day students began building, and the following day they ran a preliminary test of their device and made necessary improvements. All intermediate results and changes had to be recorded on the poster. Finally, we went out to the bleachers and dropped the eggs from the top to the ground to see how well students’ devices protected the eggs.

Students practiced literacy during this assignment as they recorded their progression through the EDP using words and diagrams. They also communicated with each other extensively.

Conclusion

This lesson sequence successfully led to mastery of the NGSS performance expectation, required students to apply several literacy skills, and engaged students in the process. A similar sequence can be applied to many of the NGSS performance expectations at all grade levels. The model can also be used for cross-curricular projects between teachers.

When students discover and apply science with their peers rather than receive pre-digested information, both science and literacy skills get a workout. Tasks that require students to investigate problems that are relevant to their lives are engaging and effective in the classroom. These are the types of tasks which prepare students for the complex challenges they will face outside of school. If we hope to graduate students who can think critically and make informed decisions, we must challenge them to apply scientific and literacy skills simultaneously.

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