Good Writing Is All About Momentum

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Many current state-adopted math and science standards highlight the importance of interdisciplinary teaching and seek to build connections between different content areas (NGSS Lead States 2013; NGAC and CCSSO 2010). Students who experience interdisciplinary pedagogy tend to be more engaged and show higher achievement (Halpin et al. 2005). Interdisciplinary connections both within humanities disciplines and between science and other STEM subjects tend to be more common. Modern standards like the *Next Generation Science Standards (NGSS)* provide educators with a framework to connect science learning to other disciplines and standards, including literacy and writing. These are incorporated within the *NGSS* in several of the science and engineering practices, and each of the performance expectations connect directly to the applicable *Common Core State Standards* literacy standards. Conversely, Advanced Placement (AP) science courses, which fall outside the guidance of the *NGSS*, do not include such clear guidance or connections for how an educator might incorporate strong writing opportunities. As a high school science teacher I have noticed that there are few teacher-created curricular resources and lesson activities that make use of the provided frameworks to make connections between science and literacy in ways that allow students to meaningfully engage in both simultaneously.

Connecting science and writing can help engage students who enroll in both *NGSS*-aligned courses and AP science courses. While some students in AP science are personally interested in science content, others are more motivated by having credit for such a course on their transcript. This can lead to many conversations with students about how they prefer humanities courses over STEM courses or that they prefer more opportunities to demonstrate their knowledge through creative writing rather than the strict analytical approach of many advanced science courses. While it may have been common in the past to separate science courses and humanities courses, that approach no longer makes sense with the shift toward interdisciplinary pedagogy.

As an AP Physics 1 and 2 teacher, I wanted to create a curricular unit that would authentically connect literacy, opportunities for writing, and science standards while engaging a 21st-century student. This article provides an example of how I incorporated writing into one of my AP physics units, and it could serve as a useful model for teachers in any high school science course. Writing and literacy standards can very effectively connect to science content and develop increased student achievement in both areas (Dew and Teague 2015). Using online remote learning tools to engage students, I developed a unit covering the law of conservation of momentum that also incorporated instruction on the use of argumentative and creative writing as an alternative means to demonstrate mastery of science content. When I implemented this unit in my AP Physics course, I found that students enjoyed the experience—effectively communicating their knowledge of the law of conservation of momentum through a variety of writing styles—and showed similar learning outcomes as in previous years using a more traditional end-of-unit assessment.

Unit Design

When designing my interdisciplinary unit, I focused on the intersection of literacy in science and technology-based pedagogy. Several guiding principles emerged based on my review of research in these areas:

- The use of literacy and writing skills must be authentically connected to science content, such as using argumentative essays as an assessment for a learning task (Thier 2010).
- Specific strategies must be used to support students' development of writing skills in science, such as structured responses, dedicated writing time, and in-class peer writing workshops (Morabito 2017).
- Regardless of the choice of technology, the most effective use of instructional technologies occurs when a group of diverse learners work collaboratively (Erdogan 2016). This collaboration can take place in shared physical space or through online communities.

TABLE 2

Student reflections.

Student 1	"It was helpful to me in learning about momentum because I had to break it down more simply. I don't think my story would explain the physics concepts completely to a child, but it still forced me to put it in simpler terms so that I could understand what it meant outside of just calculations."
Student 2	"Alright, it says be honest so I'll be honest. I absolutely despise writing and any form of it, it's always been like that, and I could never really take it seriously… It was pretty fun thinking of what to write to the safety division as I went from changing the world by replacing everything with bumper cars to attaching giant magnets onto cars."
Student 3	"I think the momentum writing assignment was helpful in the way that it encouraged me to think about it in the sense of a real-world example rather than the usual numbers and calculations that we do in the class. This was also a challenging part of the assignment because I am used to dealing with the information that we learn as calculations and fictitious scenarios, and this assignment pushed me to change the way I looked at it."
Student 4	"Some positive things are that it provided a new way to gain understanding on a concept previously only done on paper and practice problems. It was definitely more fun and creative than just doing practice problems."

- The benefits of using technology depend, to some extent, on using technology that is relevant to the experiences of students (Holubova 2015).

I incorporated the design principles summarized above to create a unit on the law of conservation of momentum for my AP Physics 1 course, which is the fourth unit of study in my course. Table 1 (see Online Connections) includes the science and literacy standards that align with this curricular unit (NGSS Lead States 2013; NGAC and CCSSO 2010). Prior to beginning the unit, my students had a strong understanding of basic kinematics and dynamics, as well as experience with conserving energy throughout interactions in a closed system. The specific tools and simulations that I used are examples of possible classroom technologies. The crux of the unit lies with the collaborative nature of the explorations and the supported use of writing tasks. This unit took seven instructional days of one-hour class periods to complete.

Days 1 and 2

On the first day, the students watched a compilation video of particularly forceful tackles from professional football games. I asked students to write about two of the interactions and very explicitly describe any interactions of forces and motion. To establish a baseline of their literacy skills, I did not provide much guidance for this first writing task. Next, the students collaboratively analyzed a simulation (Henderson 2021) of an egg-drop experiment. Students met online in virtual breakout rooms and tested various combinations of dropping the egg from a height onto different surface types. The brief analysis guided the students through recognizing that each egg experienced the same change in its motion but could survive the fall if the time of impact was increased. This activity also acted as a pre-assessment of their knowledge about momentum, which I used to group students into teams of three for the extended exploration of momentum over the next few days. Students that demonstrated stronger understanding of the interactions were grouped with those who were still developing this understanding. Before class on Day 2 students watched a brief set of videos that covered key terms and equations that helped them understand the next simulation and the required mathematical calculations.

On Day 2, students explored various collisions using a second simulation (University of Colorado 2020) that is more abstract but models a wide range of one-dimensional collisions where students can alter elasticity, mass, and initial velocities. The students explored each of the major types of collisions and determined how impactful each variable was on the resulting motion.

Days 3 and 4

The third day of the unit was devoted to practicing using data to make scientific claims. Working in their same teams, students wrote an informal lab report about their findings. Students included a brief summary of the data collected, a claim about the conservation of both kinetic energy and momentum, as well as potential applications to real-world scenarios. This group writing activity was scaffolded to provide a place for built-in peer editing and discussion. I monitored each team and encouraged discussion that strengthened the analysis of the data. This helped develop students' writing skills and prepared them for the larger individual writing assignment. The students also had a set of practice problems to solve using mathematics and traditional physics problem solving.

Using the knowledge from the simulations and analysis, each team signed up to create an in-depth explanation of one individual concept idea to post to a resource wiki web page on Day 4. These concept ideas included each type of collision, conservation equations and example problems, and how energy can be lost in a collision. Students consolidated different ideas on the wiki web page where they organized and pieced together how each topic is related to others.

On the following day students began the in-depth writing assignment by choosing an individual writing task to demonstrate their knowledge and understanding of momentum and how it is conserved. The choices included an argumentative essay (similar to a formal lab report); an original, creative short story that uses momentum concepts as integral parts of the story; or a fictitious letter to a company that uses momentum concepts to improve a particular safety feature on a product. Accompanying the explanation and rubric of each option was a brief description of how argumentative writing differs from creative writing. Students were tasked with addressing the same essential questions regardless of their topic choice.

Days 5–7

To support students and improve their writing skills, I used specific, purposeful strategies on both Day 5 and 6 of the unit. Once students selected their task, I created small groups of students who chose the same prompt. Day 5 was entirely devoted to writing time and peer workshops within those groups. Students brainstormed, outlined, wrote, and revised while I floated between the different groups. On Day 6, students arrived with a mostly completed draft of their assignment. I then paired a student who chose the argumentative essay with one who did not to peer edit each other's work. From the peer edits, writing workshop, and devoted writing time, the students were able to create well-developed ideas during class. This writing assignment was scored using a rubric that was aligned to the *Common Core State Standards* for grades 11–12 (Chu and English Professional Learning Council 2012). The final day of the unit included a more traditional assessment that reflected the questions they will be asked on the AP test at the end of the course.

Student Responses

Many students really enjoyed learning physics concepts under this new framework. I asked students to write a personal reflection on this unit prior to taking the final assessment and many comments showed that this type of interdisciplinary unit has a lot of student buy in. Table 2 shares excerpts from

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their personal reflections. This is not to imply that all students had a positive reaction to this assignment. One student mentioned that having the choice of a creative assignment was incredibly beneficial, while another student commented that such a technical content area as physics does not allow for creative writing. A different student commented that "writing is not a part of physics," and so this assignment was unpleasant for them at the beginning.

Regardless of their personal beliefs, the students overall did really well on this assignment and created unique pieces of writing. Thirteen students chose to write argumentative essays; eight wrote a letter to a company; and six chose to create an original story. Table 3 (see Online Connections) provides excerpts from students' writing. I found that the students successfully described a fundamental law of physics in a way that was clear and relatable to the real world. Far too often we live in the hypothetical world of perfect physics, so it is important that students can describe where these physics concepts occur in their own lives.

The final assessment metric of incorporating literacy into AP physics included comparing the final traditional assessment scores to the data from the previous two years of teaching this unit in a more traditional manner at my current high school. The average score on this assessment was 82.5% for the past two years; this year's assessment score average for this unit was 84%. Because this unit was taught remotely, the format of delivering assessments has changed from those previous years. But the fact remains that by incorporating literacy into AP science, student learning did not suffer and most likely increased. This unit has room for improvement. I now have exemplar writing samples to show, and I have identified weak areas of the rubrics and areas of confusion that I can preemptively avoid. This process has thoroughly convinced me, and my students, that writing should not only happen in the science classroom but should also be an integral part of the learning process.

ONLINE CONNECTIONS

Table 1. Connecting to the Next Generation Science Standards: *https://www.nsta.org/sites/default/files/journal-articles/TST89-4/Crumley/Table_1_NGSS.pdf*

Table 3. Excerpts from student writing: *https://www.nsta.org/sites/default/files/journal-articles/TST89-4/Crumley/Table_3_excerpts.pdf*

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