An Argumentative Writing Prompt Model to Support Nonscience Major Students’ Learning in an Introductory Chemistry Course

By Claudia Aguirre-Mendez and Ying-Chih Chen

An argumentative writing prompt model is presented for use in a general chemistry class designed for nonscience major students. The purpose of this instructional model is to support students with rich experiences to strengthen their conceptual understanding, critical-thinking skills, and scientific literacy. Research in science education at the college level mainly focuses on creating great academic environments for science majors but is less focused on nonscience majors. Pedagogical strategies using argumentative writing prompts involve students in the context of applying essential scientific practices, such as answering questions, collecting and analyzing data, using and creating models, engaging in argument from evidence, and communicating information with peers. An open-ended questionnaire was used to examine students’ perspectives after engaging in this assignment. Most of the students who answered the questionnaire found the argumentative writing assignments helpful and appreciated their design. Students believed the writing assignments helped them improve their conceptual understanding, their understanding of argumentative components, and the connection with their future career. This study contributes to the evidence-based understanding of the connections between students’ perceptions and improved engagement in argumentative writing.

Nonscience major students represent a significant percentage of the college graduates in our society (Korn, 2015). One essential goal of science education in nonscience major courses is to prepare students to become scientifically literate citizens (Hemraj-Benny & Beckford, 2014). These citizens face increasingly complex questions that require scientific information to make decisions, such as climate change, the policy and strategy for addressing pandemics, and issues related to sustainability. Students need to be prepared to consume scientific information to justify their decisions on important societal issues. To accomplish this goal, they need not only a solid background in science but also critical-thinking skills to be productive and capable citizens (National Science Board, 2006).

However, both the nonscience major students and instructors in nonscience major courses face significant challenges. The literature mentions that students carry negative attitudes toward science into science classrooms (Bauer, 2008) and perceive science courses as a process of memorizing facts (Yang, 2010). They do not see the connections between scientific concepts and their careers. Nonscience majors do not believe they will apply what they learn from the science course to their lives or future careers (Gill, 2011). These students usually lack the motivation and engagement of taking science courses and learning science concepts, especially when exclusively being lectured to for an entire course (Fox & Hackerman, 2003; Fuller, 2017; Glynn et al., 2011; Turner & Peck, 2009). Many instructors who teach science to nonscience majors are reluctant to implement innovative teaching approaches in their class due to the high levels of uncertainty regarding the effectiveness of new approaches. Instructors may feel that students will not favor new approaches, which may impact their course evaluation.

Many researchers have been working on instructional strategies, approaches, and solutions to counteract the lack of engagement in nonscience major introductory courses. For example, studies in biology education have focused on redesigning courses to include approaches such as problem-based learning and service-learning in their course assignments.
(Tawfik et al., 2014). In the area of environmental health, Jin and Bierma (2013) used an approach called Process Oriented Guided Inquiry Learning (POGIL) to improve students’ engagement and scientific literacy. In chemical education, Choi et al. (2013) conducted writing-to-learn activities to help students reflect on what they learned from their laboratory experiences. Most of these studies attempted to prompt students’ learning outcomes and enable students to develop scientific literacy skills.

Similarly, this study used argumentative writing prompts to engage nonscience majors in learning science content and advance their scientific literacy skills. We had three goals when designing the courses for nonscience majors. The first goal was to facilitate students’ connection between the subject and their real-life applications (Miles & Bachman, 2009; Jin & Bierma, 2013; Logan & Rumbaugh, 2012; Park, 2018). The second goal was to prepare students to learn and apply the practice of science through mini-research projects (Neuman & Harmon, 2019). The third goal was to engage students in literacy practice by crafting argumentative writing assignments (Bozzone & Doyle, 2017; Chen, 2019; Moon et al., 2019). All of these goals aim to not only promote engagement with less memorization of the subject but also prepare students to be scientifically literate.

In this article, we present an instructional model to be implemented in a general chemistry class designed for nonscience majors. The model involves argumentative writing assignments aligned with topics of the class curriculum (conversion factors, atomic structure, gas laws, and diffusion). Although there has been an increased propensity to include argumentation in K–16 education, college students have not been exposed to the concept of argumentation as an important way to learn science (Çetin & Eymur, 2017; Choi et al., 2013; Finkenstaedt-Quinn et al., 2017). With this instructional model, we fulfilled all three goals by using argumentative writing assignments.

Argumentation is a core practice for science, technology, engineering, and mathematics (STEM) education that rarely happens in chemistry classrooms, especially for nonscience majors. In addition to argumentative writing prompts, we used online interactive simulations (Concord Consortium, n.d.; PhET, n.d.) to engage students in collecting, analyzing, and interpreting data as evidence to support claims.

The integration of argumentative writing and online interactive simulations might help students visualize invisible science properties, particularly in chemistry (Pallant et al., 2018; Trate et al., 2019). For example, in the general chemistry curriculum for the nonscience major in this study, there are several topics that students need to learn from the microscopic and particle view in order to understand chemistry concepts such as atomic structure and subatomic particles, as shown in the figure below.

**FIGURE 1**
Framework for argumentative writing prompts.

- **Core Concept:** One simplisitic statement that captures all essential concepts from the unit
- **Question:** An interrogative sentence that calls for discussion or investigation
- **Scientific Argument**
  - **Claim:** A statement about the solution, conclusion, or position to the question
  - **Evidence:** An explanation of data and reasoning to show how or why the claim is supported
  - **Data + Reasoning:** Analysis and interpretation of data gathered from observations, experience, or references from materials

**Note.** Adapted from Chen and Steenhoek (2014).
well as the behavior of gas particles and molecular mass concerning its diffusion rate.

**Context of the activities**

The implementation of the writing prompts took place at a state university in the Midwest in a general chemistry class for nonscience majors. Pre-nursing students made up 75% of the class, while the other 25% of students were in fields such as music, business, and recreation, among others. This class fulfills a general education physical sciences requirement. The enrollment of the class varies from spring to fall semesters. During the spring semester, the larger enrollment (90 students) is split into two sections. The participants in this study consisted of 163 students from four sections of the general chemistry course between spring 2017 and spring 2018; 146 of the students were female and 17 were male. All courses were taught by the same instructor, who is also one of the authors of this article. Although the total number of participants in this study was 163, only 29 were involved in this current study that aimed to understand students’ perspectives regarding argumentative writing used in the course. Our initial study that involved 163 participants found that students significantly improved their conceptual understandings of chemistry and epistemic understanding of argumentative writing (Aguirre-Mendez et al., 2020). Building on the positive results, we decided to explore how students perceived the role of argumentative writing in the development of their conceptual understanding of chemistry and their future careers. Therefore, we selected the general chemistry class, which is offered every semester; this particular offering took place in spring 2018 and had 35 students.

The instructor introduced these assignments to the students following a structured approach that involved a 15-minute discussion of the differences between scientific argumentation and arguing and a 15-minute explanation of the components of an argument and the relationship between them (Chen & Steenhoek 2014). After the instructor’s lecture, students were directed to use free interactive simulation sites such as PhET or Concord Consortium to address a series of questions.

**Questionnaire**

An open-ended questionnaire was designed and implemented to explore students’ perspectives regarding the connection between the argumentative writing activities and the improvement of their conceptual understanding of the topics, elements of arguments, and the connections between arguments and their careers. The questionnaire was administered at the end of the semester for the last cohort (spring 2018). We received responses from 29 out of 35 students (83%).

**Designing the argumentative writing prompts**

Argumentative writing prompts were designed following the framework suggested by Chen and Steenhoek (2014; see Figure 1). This framework consists of four components: big idea, question, claim, and evidence (Chen, Mineweaser, et al., 2018). We also used this framework to pursue the three goals mentioned previously. To explain how we integrate the three goals with the framework shown in Figure 1, we used the unit of Gay-Lussac’s law as an example to explain how we used the assignments in the classrooms. Students were able to engage in several scientific practices identified by the Next Generation Science Standards (NGSS Lead States, 2013), such as analyzing and interpreting data, engaging in an argument for evidence, developing and using models, and constructing explanations.

**Argumentative writing prompt in the unit on Gay-Lussac’s law**

In this unit on Gay-Lussac’s law, students are expected to understand the kinetic molecular theory of gases and the relationship among several variables, such as pressure, volume, temperature, and number of moles. Learning the concepts of gas laws is intended to support students’ understanding of the laws and their connections and applications to health contexts. Students are expected to make the connections to practices they will enact in their future careers, such as measuring blood pressure and understanding breathing and respiratory therapy, among other clinical aspects that involve gases.

**Goal 1: Facilitate students’ connection between the subject and its real-life applications**

The first goal of the instructional model is to connect the core concepts to students’ lives. One way to achieve the goal is to problematize a phenomenon occurring in students’ everyday lives. Through problematizing the phenomenon, students can see how the concepts connect to their lives and become motivated to learn the concepts (Chen, 2020). This connection increases students’ interest and uncertainty and engages them in discussion of phenomena in relation to their prior experiences and knowledge (Chen, Benus, & Hernandez, 2019). For example, the instructor started the class by showing stu-
students a picture of a flat tire (as shown in Figure 2) and asked the following questions: Why did this tire become flat in hot weather? What is inside a tire? What specific properties of a gas can describe this phenomenon? Students answered that tires contain air and air is a homogeneous mixture of gases. (Students were integrating previous knowledge they learned about matter and properties of gases.) Students also responded that, in hot weather, temperature and pressure are the variables that explain the phenomenon. After that discussion, students were introduced to the main idea and equation of Gay-Lussac’s law. In this unit, the instructor covered several laws, and students had the opportunity to discuss and use formulas to solve mathematical problems. The next week, students had to complete their argumentative assignment, in which they were asked to click a link that took them to an interactive model from the Concord Consortium. The argumentative writing assignments are mini-research projects in which students collect quantitative data. Students must select dependent variables, independent variables, controlled variables, and estimated numbers for volume, pressure, and temperature. Students use and develop models, analyze the data, and engage in an argument based on the evidence. The final product is a digital file that students upload to a learning management platform. Through that platform, the instructor can provide immediate feedback for students.

Goal 2: Prepare students to learn and apply the practice of science through mini research projects

The argumentative writing assignments are mini-research projects in which students collect quantitative data. Students must select dependent variables, independent variables, controlled variables, and estimated numbers for volume, pressure, and temperature. Students use and develop models, analyze the data, and engage in an argument based on the evidence. The final product is a digital file that students upload to a learning management platform. Through that platform, the instructor can provide immediate feedback for students.

Goal 3: Engage students in literacy practice through argumentative writing assignments

In this assignment, students used models and created an explanatory graph in Microsoft Excel using the data collected from the Concord Con-

FIGURE 2

Photo of a flat tire used to show the connection between Gay-Lussac’s law and a real-life phenomenon.

FIGURE 3

Concord Consortium simulation to explore the temperature relationships of gas for the writing assignment.

How the temperature does affect the pressure exerted by a gas?

What is your claim?

A higher temperature produces higher exerted pressure.

What evidence support your claim?

Key terms are highlighted and underlined.

This experiment proves Gay-Lussac’s law (click the link to watch a video for more info on this law) that states that “for a given mass and constant volume of an ideal gas, the pressure exerted is directly proportional to its absolute temperature.” We can see this with the evidence provided in figures 1 and 2. We can see that our experimental results make a mostly linear line (dotted line is the best fit line). Experimental data is almost never perfect, but the averages of this experiment were pretty close to a nice linear representation. However, when we look at figure 1, we can see some anomalies data. For example, 260K and 500K both shared the value of 0.22. 750K and 1000K also share a value of 0.51. 1000K had a value of 0.43 which was lower than two of the values in the 750K column. There were a lot of values that were intertwined and mixed, but overall, the averages came out to prove the law. Using figure 3, we can test some of the values with the equation given. While the results are not perfect due to experimentation, there are many values that are good evidence for the law. For example, our first two plot points are .08 bar (P1) at 100 K (T1) and .20 bar (P2) at 250 K (T2) respectively. From this we can place these values into the equation and get the following results:

\[
\frac{0.08}{100} = 0.00088 = \frac{0.20}{250}
\]

Although these results are perfectly representative of Gay-Lussac’s law, if we look at the values at 500 K and 1000 K, we can see some counter evidence. In a perfect scenario, all values would equal 0.0008 (or they’d at least all be some value that is the same). The of the results are as follows:

\[
\frac{0.27}{500} = 0.00054, \quad \frac{0.43}{750} = 0.000573, \quad \frac{0.51}{1000} = 0.00051
\]

We see that the first two values, are a decent amount different than the last three. Although, the final three values really further prove Gay-Lussac’s Law. Although they are not identical, they are very similar especially for how many significant figures there are and the nature of experimental imperfection. The final piece of counter evidence to this specific experiment is that we don’t know for sure that this experiment had a constant volume and mass. You can see, however, that there are the same amount of molecules that are floating around. But there was no option to change, or given values, for volume and mass in this simulation. However, our data shows that these values must have been constant in nature to receive the results that we did. There also wasn’t very exact measurements that were given to us. The temperature was a slider with no middle values given which made it up to interpretation and guessing what temperature we were at. The pressure bar also only had increments given not an exact reading. Those could have played a role in the experiment and maybe even a factor of anomalous data.
sortium simulation. The next stage also involved some different argumentative components. The guiding question was “How does the temperature affect the pressure exerted by a gas?” Students once again needed to provide their initial claim and scientific evidence in support of their claim in their argument. The assignment required students to answer a question related to the specific content of the gas law, such as which law explains the relationship between temperature and pressure. The prompt guided students to explain how the interactive simulation was useful and to look for an example from their daily experiences in which Gay-Lussac’s law has an application (How did the model help you understand the phenomena? What is a real-life application that demonstrates this specific gas law?). Finally, we asked a question designed to investigate students’ self-reflection on their learning: What did you learn from this writing activity? Figure 4 provides a short version of a student’s high-quality writing sample. The detailed evaluation and criteria of the writing prompts can be found in Aguirre-Mendez et al. (2020).

**Evidence of effectiveness**

**Students’ perceptions of argumentative writing assignments**
The questionnaire included three open-ended questions designed to explore students’ experience with the intervention:

---

**FIGURE 4**

**Argumentative writing assignment student work sample and example of scoring. (continued)**

<table>
<thead>
<tr>
<th>Writing Component</th>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The accuracy of the claim</td>
<td>3/3</td>
<td>Makes one or multiple claims which are scientifically correct and complete</td>
</tr>
<tr>
<td>The relationship between claim and question</td>
<td>3/3</td>
<td>Makes a strong connection between claim and question</td>
</tr>
<tr>
<td>The sufficiency of evidence</td>
<td>3/3</td>
<td>Provides three or more pieces of evidence</td>
</tr>
<tr>
<td>Counter evidence</td>
<td>3/3</td>
<td>Provides more than two pieces of counter evidence with an explanation</td>
</tr>
<tr>
<td>Anomalous data</td>
<td>3/3</td>
<td>Points out anomalous data and gives a sufficient and appropriate explanation</td>
</tr>
<tr>
<td>The relationship between claim and evidence (reasoning)</td>
<td>3/3</td>
<td>Provides appropriate and adequate explanation partially based on interpretation of data</td>
</tr>
<tr>
<td>The connection between argument to theory</td>
<td>3/3</td>
<td>Connects argument stated in the paper to the appropriate theory and gives a scientifically accurate and appropriate explanation of the connection</td>
</tr>
<tr>
<td>Multiple modes</td>
<td>3/3</td>
<td>More than one mode (text) is used in explaining the concept(s) and is tied to the text</td>
</tr>
<tr>
<td>Multiple examples</td>
<td>3/3</td>
<td>Examples or modes are used to explain the concept(s) throughout the writing</td>
</tr>
<tr>
<td>Integration of Concepts</td>
<td>3/3</td>
<td>Demonstrates a strong line of concepts throughout the text and shows a close relationship between the concepts</td>
</tr>
<tr>
<td>Grammar and Conventions</td>
<td>3/3</td>
<td>Sentences are grammatically correct, flow smoothly and are fairly easy to read</td>
</tr>
<tr>
<td>Key Terms</td>
<td>3/3</td>
<td>Key terms are identified through underlining or highlighting</td>
</tr>
<tr>
<td>Audience Language</td>
<td>3/3</td>
<td>Language is appropriate, easy to understand, and meets the demands of the audience</td>
</tr>
<tr>
<td>Match of writing type</td>
<td>3/3</td>
<td>The characteristics of the text perfectly match the intended writing type</td>
</tr>
<tr>
<td>Main theme</td>
<td>3/3</td>
<td>Conceptual scientific knowledge and big ideas are evident and correct throughout the writing</td>
</tr>
<tr>
<td><strong>Total Score</strong></td>
<td>45/45</td>
<td></td>
</tr>
</tbody>
</table>
1. How did the argumentative writing model help you understand each of the topics?
2. How did the argumentative writing model help you understand the main elements of a scientific argument?
3. How is the argumentative writing model important in your career?

These questions were developed based on the three areas that involve learning science (Millar & Osborne, 1998): the acquisition of scientific knowledge, the application of knowledge to new contexts and situations, and the use of an understanding of scientific practices.

All digital versions of the questionnaires were imported to Nvivo Plus 11 for analysis. The data were analyzed following the guiding themes: conceptual understanding, understanding of argument, and the argument’s relevance to the students’ future careers. We used the constant comparative method (Creswell, 2014) to compare and contrast students’ responses. Several codes emerged based on the definition of each theme (see Tables 1 through 3).

### Theme 1: Conceptual understanding

In Table 1, we present the codes and examples from students’ perspectives about how helpful the activities were regarding learning the selected concepts. Most of the students agreed that the writing assignments clarified their conceptual understanding primarily via the use of the simulation and visualization representations (59% of the students). Students mainly expressed that the writing assignments helped them understand the concepts more completely. The simulations also helped students visualize abstract models (gas particles, molecular particle, subatomic particles) and concepts through operating interactive online simulations. Students perceived the argumentative writing assignments as a tool to foster their critical thinking, elaborate on an explanation of the concepts, and develop their conclusions through data interpretation.

#### Table 1

<table>
<thead>
<tr>
<th>Code</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Application of concepts to real settings</td>
<td>The writing samples greatly helped in terms of learning how to apply and use various concepts. For me being able to look at a concept at a slower pace, instead of just trying to memorize a bunch of facts, helps greatly in my learning of the material.</td>
</tr>
<tr>
<td>2. Develop critical thinking</td>
<td>Each writing sample after the first one helped me to better understand the topics because it uses visuals and hands-on learning. Then it allowed me to critically think about the subjects to explain them and apply them to real-life situations.</td>
</tr>
<tr>
<td>3. Elaborate explanations of concepts</td>
<td>These writing samples have helped me to understand these topics because almost all of them had hands-on interactive models. By using these models, I was able to clearly see the concepts that I was supposed to be explaining. They also helped me because they made me have to explain the concept, which further expanded my understanding.</td>
</tr>
<tr>
<td>4. Enhancing knowledge through visualization</td>
<td>These [writing assignments] were helpful in giving me a visual representation on how these different laws acted. It is hard to just learn through PowerPoint so these assignments help in really hitting home the concept.</td>
</tr>
<tr>
<td>5. Fostering to generate self-conclusions</td>
<td>These four writing samples helped me understand the topics because they allow me to conclude for myself if they helped me remember and learn the concepts easily.</td>
</tr>
</tbody>
</table>
dents’ perspectives was the relevance they found between the writing samples and their future career as nurses. Forty-five percent of students considered the argumentative writing assignments as a tool that supported their communication skills to explain diagnosis and treatment to future patients. Other non-nursing students believed that “any form of writing” is beneficial for improving their communication abilities, so it is important to engage in argumentation activities for students pursuing any career because these activities allow students to observe, explain, and use data for creating evidence about the world around them. Table 3 shows the codes and examples for this theme.

Engaging students in argumentative writing in introductory courses for non-science majors is not only possible but well received by students. In the beginning, they might not favor this instructional strategy due to the cognitive demands involved (Klein & Boscolo, 2016). However, our findings indicate (specifically from students’ responses on the questionnaires) that the design is well received when students had more opportunities to engage in the writing activities.

### TABLE 2

**Codebook for students’ perspectives on how writing assignments enhance understanding of arguments.**

<table>
<thead>
<tr>
<th>Code</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is a claim</td>
<td>Before these writing activities I did not know what a claim was or how to write one. I learned that the claim should only be a sentence; it is the thesis statement of the argument.</td>
</tr>
<tr>
<td>2. What is evidence</td>
<td>Evidence is what data and reasoning can support your claim.</td>
</tr>
<tr>
<td>3. How to write a scientific argument</td>
<td>These four writing activities helped me on how to write the scientific argument essays. It made me think more and made my essay more persuasive.</td>
</tr>
<tr>
<td>4. Understanding how to interpret data as evidence</td>
<td>These activities helped me understand the main elements of argumentation because I had to define what each one was and give a real example from the experiments I performed. Evidence is data + reasoning. Evidence supports my claim.</td>
</tr>
</tbody>
</table>

### TABLE 3

**Codebook for students’ perspectives on writing assignments and their relevance to future careers.**

<table>
<thead>
<tr>
<th>Code</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Improve communication skills</td>
<td>Any form of writing is a form of communication, so in a way this helped me better my communication skills.</td>
</tr>
<tr>
<td>2. Elaborate about diagnosis and treatment</td>
<td>Writing arguments are important to my career because when dealing with a patient I will have to explain my reasoning behind how I handled certain situations. For example, explaining how I came to the solution I did and why I recommended a certain medication or care plan.</td>
</tr>
<tr>
<td>3. Connect to real-world situations</td>
<td>Science is a very broad and important topic because science is found all around us and explains things that take place within our everyday life, and this is why we, as humans, need to have verified data and evidence that support each theory or claim made about the phenomena that take place around us.</td>
</tr>
<tr>
<td>4. Important to all careers</td>
<td>Being able to explain one’s thinking and observations and do so backing it up with evidence and data are important in all fields and careers.</td>
</tr>
</tbody>
</table>
In addition, the online simulation allowed them to understand complex concepts and visualize abstract structures. Some of the challenges of learning chemistry are related to invisible properties and, particularly in chemistry, students facing the issues of scale (Trate et al., 2019).

Argumentative writing prompts combined with online simulation can be used in introductory science courses for nonscience majors in which students may not have opportunities to get into the lab to explore the practices of science. Through the argumentative writing prompts and online simulation, students can collect data, analyze data to shape evidence and claims, create models to explain their conceptual understanding, and write arguments based on scientific evidence. These experiences prepare nonscience majors for developing critical-thinking skills and their abilities to make scientific decisions.

Conclusion
In this article, we present an argumentative writing prompt model used to promote students’ engagement and active learning in an introductory chemistry course. The findings from students’ questionnaires indicated that students valued these writing activities as part of their chemistry curriculum. The activities described can be used as a model for any other science content courses. We suggest these activities be aligned with the course content curriculum so students have alternative ways to expand their scientific knowledge and make sense of scientific practice. We continue to explore the power of writing and argumentation as critical learning tools for promoting scientific literacy for nonscience majors in ways that give instructors and students the motivation and disposition to pursue these activities in their classrooms.

References


PhET. (n.d.). Interactive simulations for science and math. https://phet.colorado.edu


---

Claudia Aguirre-Mendez (caguirr2@emporia.edu) is an associate professor in the Department of Physical Sciences at Emporia State University, and Ying-Chih Chen is an associate professor at Mary Lou Fulton Teachers College at Arizona State University.