Evidence-Based Writing: A strategy to promote high quality responses to open-ended questions.

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Introduction

Writing is a critical and necessary part of science instruction and curriculum. Most often, science class sparks reminisce of test tubes, Petri dishes, and complex equations. However, beyond hands-on experiences, high-quality inquiry requires students to explain their ideas and understanding with thorough evidence. Elaboration, detail, and explanation are expected from students, and as a consequence, it is essential that science educators participate in the development of those skills. Offering opportunities for students to write about their understanding of scientific concepts is vital.

Student responses to open-ended constructed response questions often lack necessary elaboration. A typical low-quality answer to an open-ended question traditionally resembles a single sentence. This response states one main point, lacks proper elaboration, and does not support the question with evidence from a data table, graph, or definition. Therefore, a strategy for success was generated to improve the quality of open-ended question responses. We term this strategy Evidence-Based Writing.

The Model

A model has been designed for teachers and students to promote higher-order thinking in conjunction with open-ended constructed responses. The model is graphically represented in **Figure 1**.

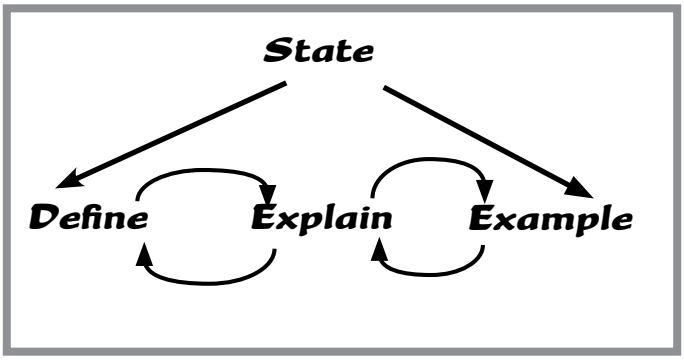


Figure 1. Evidence-based writing model.

The model begins with **STATE,** in which students makes a general statement in response to a question. Once they have taken a position or made their statement, they proceed to the **DEFINE, EXPLAIN or EXAMPLE** portion of the model. Note from Figure 1, that the flow from **DEFINE, EXPLAIN and EXAMPLE** is non-linear and recursive. The student may cycle through or skip steps of the model to meet the needs of their constructed response. This structured, yet flexible strategy guides students to providing high quality responses to open-ended questions.

Students in a science classroom are required to show evidence of understanding during learning activities. In order to assess understanding, students can be given open-ended questions. These open-ended questions are used as tools to gauge the comprehension and synthesis of scientific concepts as well as observational skills.

For example, students conduct a laboratory experiment that examines the reactivity of metals. Ideally, the reactivity of the metals should coincide with their position in the Periodic Table. The more reactive a metal is deemed, the further down and to the left it is located on the periodic table. In this heuristic laboratory experience, students are given six different metals (calcium, zinc, lead, copper, aluminum, and magnesium) and six different solutions (NaOH, HCl, H_2SO_4, H_3PO_4, KOH, and $HC_2H_3O_2$). The students combine one solution and one metal and record their observations in a data table. Their data must include specific observations to explain which metal is most reactive.

Once the data has been gathered, the students are to answer the following questions:

1. Which metal was the most reactive?
2. Where are the more reactive metals located in relation to the Periodic Table?
3. Rank the metals from least reactive to most reactive. If you were to test three new metals, tin, potassium and nickel, where would they rank amongst the list you have generated for question three?

"STATE"

The STATE portion of the model refers to the student taking a stance or making a specific conclusion. It is designed to gauge what students are going to discuss in the body of the writing. In most cases, this is the first sentence of their response. It is a brief, concise, clear sentence that answers the posed question. Furthermore, it sets the focal point of the writing and might be considered analogous to the thesis statement in English writing. The following are examples of the STATE portion of the model:

For example:

- Calcium was the most reactive metal.
- More reactive metals are positioned to the left on the Periodic Table relative to less reactive metals.
- The rank of the metals from least reactive to most reactive were lead, aluminum, copper, zinc, magnesium, and calcium.
- If the reactivity of potassium, tin, and nickel were tested, the ranking, from most reactive to least reactive, would be as follows: tin, lead, copper, nickel, aluminum, calcium, magnesium, and potassium.

For students, the STATE portion of the model enables them to focus their evidence on an argument or a position. Often, students take the proverbial *throwing a bunch of darts at the dartboard and hope to hit the bulls' eye* approach. They will mention many related points, but in the end do not answer the question because of the lack of connection to a focal point. In essence, the STATE part of the model is geared toward students answering

the posed question.

"DEFINE"

DEFINE is intended for two purposes. First, this step allows students to think about the science concepts that are aligned with the question. For example, if the question is asking about reactivity, the students must display evidence that they know what reactivity is.

Second, DEFINE is presented in the model to see if the students understand their chosen terms. For example, students find that calcium was the most reactive metal from an inquiry experience, they should question, "What makes a metal reactive?" The reactivity of a metal must be defined in order for the previous statement to be valid. Unless defined, the proposed argument is weak. Listed below are some examples that are defined:

1. Least reactive metals will be the metals that do not show any signs of chemical change.
2. The most reactive metals will produce the most amounts of gas and/or precipitate.

In addition to defining the terms in their statement, students must also define any other terms they use while explaining their point. This does two things. First, it demonstrates student understanding via a confident statement. Linking a statement with a definition makes the evidence stronger. In addition, it presents the necessary information to connect the practical concepts with the theoretical.

More importantly, having students define their terms enables them to make connections with scientific concepts. The constructed responses require students to take what they know about the concept and apply it to a different situation. Their definitions are used to strengthen their statements, thus applying their ideas to new situations proposed. This is the foundation to higher-ordered thinking.

"EXPLAIN"

EXPLAIN provides justification for reasoning. Students must be able to logically explain how their statement and their definition fit together to make a coherent argument. For example, if the student claims that calcium was the most reactive metal, a logical explanation would be as follows:

1. Calcium is the most reactive metal because it gave off the largest volume (10 ml) of gas.
2. Lead is the least reactive metal because it gave off no measurable volume of gas (0 ml).

EXPLAIN makes connections with data, observations, and definitions. The ability to make connections with definitions and observations is imperative to developing problem solving and higher-ordered thinking skills. If students do not give an explanation to their reasoning it sparks questions such as "Does the student understand the concept?" or "Was this a guess?" By applying this model, students are required to explain their thought processes to gauge their understanding. This gives the students experience to apply their concepts to authentic experiences.

"EXAMPLE"

Students can provide evidence for their statements by using examples and reference from their data, observations and definitions:

- For example, once the calcium was placed into the solution, it took 3 seconds for the metal to react and produce a gas. In contrast, the lead, zinc and copper did not release any gas after waiting for a total of five minutes.

The response elaborates the ideas fully to emphasize the main point of the response: calcium is the most reactive metal. In the example, the response also provided data indicating that the other metals were not reactive. This is a more holistic interpretation as it does not discard other valid evidence. The data provided in the response strengthens the argument, therefore strengthening the overall response to the open-ended question.

Assessment

One of the challenges associated with an evidence-based approach to writing is an effective method for assessment of responses. Providing consistent, unambiguous feedback to students is critical to assist them in determining and understanding the quality associated with a thorough answer. In addition, a simple, regular method for scoring provides teachers with a simple, reliable method for evaluating student work. We elected to institute a holistic rubric-based approach to evaluating student work. It was decided that a consistent, general approach, specifically tailored for individual questions, was the best strategy to provide students with common expectations.

We began our assessment strategy utilizing the State's constructed response rubric (see Figure 2.B.) (CSDE, 2008) *See page .6*. However, we quickly realized that we were having issues determining differences in scoring, especially to differentiate between scores 2 and 1. Since reliability between raters was inconsistent, we decided to construct a flow chart (see Figure 2.A.) *See page 6*, originally based off of a State math flow chart (CSDE, 2006a), to better differentiate student performance.

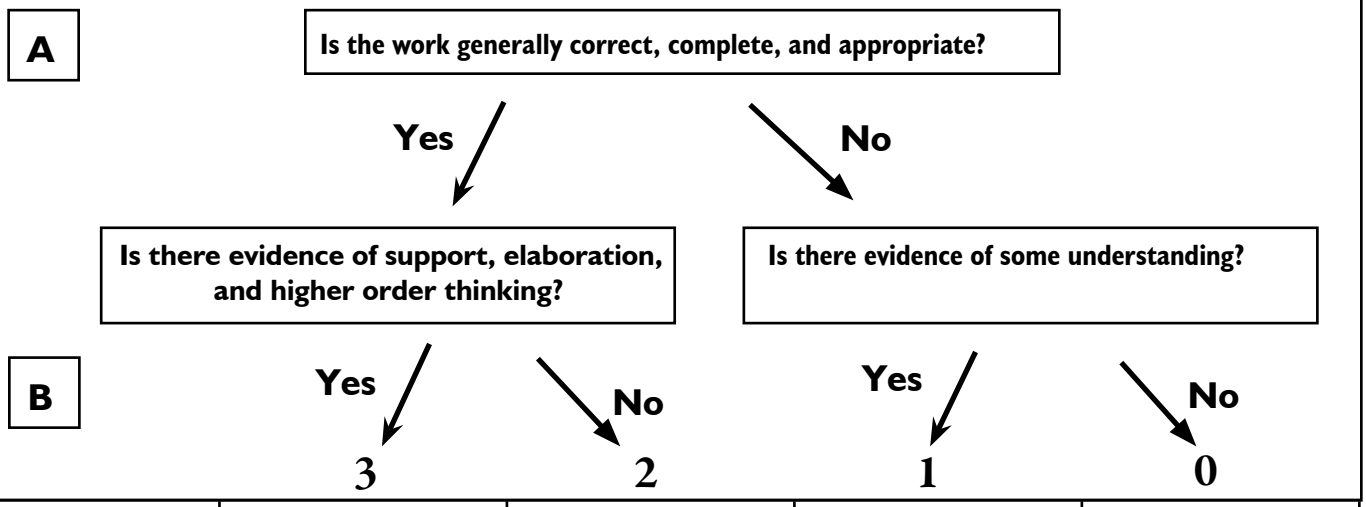
We find we can rate student work extremely consistently. Perhaps more important, students can easily use this flow chart to evaluate their own work. They also have a clear understanding of where their deficiencies and strengths are.

We can tailor our evidence based on the constructed response question so we have a consistent understanding and expectation for what support, elaboration, and higher-order thinking in a written response justifies a specific score.

Connecting to Other Disciplines

Using an evidence-based writing approach has benefits beyond the science classroom. These strategies easily apply to other disciplines, and we have found that teachers of other subjects easily understand and can adapt their evaluative techniques to incorporate these criteria. This is good because, in essence, teachers of a wide variety of disciplines recognize that evidence-based writing is part in parcel with other 21st-century learning skills like

Figure 2. Holistic Science Scoring Rubric for Open-ended (Constructed) Responses



Score	3	2	1	0
Evidence				
	The response is an excellent answer to the question. It is correct, complete, and appropriate and contains elaboration, extension, and/or evidence of higher-order thinking and relevant prior knowledge. There is no evidence of misconceptions. Minor errors will not necessarily lower the score.	The response is a proficient answer to the question. It is generally correct, complete, and appropriate although minor inaccuracies may appear. There may be limited evidence of elaboration, extension, higher-order thinking, and relevant prior knowledge, or there may be significant evidence of these traits but other flaws (e.g., inaccuracies, omissions, inappropriateness) may be more than minor.	The response is a marginal answer to the question. While it may contain some elements of a proficient response, it is inaccurate, incomplete and/or inappropriate. There is little if any evidence of elaboration, extension, higher-order thinking or relevant prior knowledge. There may be evidence of significant misconceptions.	The response, although on topic, is an unsatisfactory answer to the question. It may fail to address the question, or it may address the question in a very limited way. There may be no evidence of elaboration, extension, higher-order thinking, or relevant prior knowledge. There may be evidence of serious misconceptions.

critical thinking and problem solving, which certainly are not discipline specific.

Conversely, science educators can play an important role in providing support for other disciplines' needs. For example, the Response to Literature (RtL) is an integral part of humanities instruction. Standard questions provided by the State are used for assessments (CSDE, 2006b). From a science standpoint, students need to effectively read for information and analyze content. Therefore, modifying these questions can provide an appropriate strategy for improving students' ability to critically respond to their reading across content areas. Our department collaboratively generated the questions in **Table 1** on page 7. These questions, while making connections to other disciplines, can still be answered using the Evidence-Based Writing strategy and assessed using the holistic rubric.

Conclusion

Science educators strive to supply the proper learning tools to promote independent thinking and problem solving strategies. Science instruction that incorporates inquiry and authentic writing develop students' higher order thinking 21st-Century skills. These skills are a necessary part of producing responsible, productive, contributing members of society.

The strategies presented here are intended to articulate well

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Table 1.	
Dimensions of cognitive processes associated with evaluating authentic writing samples	
Dimensions	**Questions**
Forming Understanding	**State RtL Question**
	What are your thoughts and questions about the story? You might reflect upon the characters, their problems, the title, or other ideas in the story.
	Alternative Science Questions
	What are the main scientific concepts presented in the article? What information is given that you need to solve the problem? What information is given that you do not need?
Developing Interpretation	**State RtL Question**
	Choose one of the following quotations from the story. Explain what you think the quotation means as it relates to elements of the story such as the characters or the theme. OR How does the main character change from the beginning of the story to the end? What do you think causes this change?
	Alternative Science Questions
	What data and information did the author give to support these main ideas? Did the author present any opposing concerns? Support with an example from the article.
	What key words or phrases are needed to give the best answer? (i.e., round, convert, pattern)
Making Connections	**State RtL Question**
	What does this story say about people in general? In what ways does it remind you of people you have known or experiences you have had? You may also write about stories or books you have read or movies, works of art, or television programs you have seen. Use examples from the story to explain your thinking.
	Alternative Science Questions
	What implications or applications does this article have to everyday life? How might it influence your behaviors? Are multiple responses or computations required to arrive at a complete solution? (i.e., give an answer and graph it, show calculations and then explain in words how the answer was derived.)
Demonstrating Critical Stance	**State RtL Question**
	How successful was the author in creating a good piece of literature? Use examples from the story to explain your thinking
	Alternative Science Questions
	How successful was the author in providing a well-supported, well-documented scientific argument? What evidence should be present to further support this position? What questions do you have regarding the validity of the author's position?
	Is there enough information provided to successfully solve the problem? Is more information needed from an outside source? Use examples from the problem to explain your reasoning and/or thinking? (i.e., formula not included)

Assessment Continued from page 6

with both quality instruction and State test expectations. Well-designed open-ended questions can potentially have a wide variety of valid responses, and having a systemic way to answer and evaluate them is beneficial for teachers and students alike. Implementation of this design for responses sets high standards which emphasize the importance of quality work in the classroom and on State testing.

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their supportive teachers can join in the process of discovery that is at the heart of biology, helping us to better understand how the world works.

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The waste water operator has to test to measure the status of organisms to know what to add back into the beginning of the secondary clarifier to keep the population where it needs to be. The excess organisms are wasted or sent to the solids handling area, where they are mixed with the primary solids. The laboratory technician and operators will frequently look at the organisms under the microscope and document the types that are present and their apparent health. Treatment plants have to be very aware of the possible pollutants that the plant could expect to receive. If somebody discharges something to that plant that is poisonous to these organisms, secondary treatment can be wiped out and discharge permit requirements of the plant will not be reached. Fines may be given to the treatment plant if permits are not adhered to.

Waste water treatment plant LAWPCA

Waste water plants have helped many water bodies recover or maintain good water quality and are very important in keeping our valuable water resources clean.

Resources

To explore this topic in more depth, a web search of "Wastewater Treatment Plant Operations" will lead to many useful websites. Several useful sites are listed below.

http://www.gocolumbiamo.com/PublicWorks/Sewer/wwwtppg_4.php
http://www.sandiego.gov/mwwd/facilities/ptioma.shtml
http://www.lakelandgov.net/water/nothsidewrf.html
http://www.encinajpa.com/?page_id=ll

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