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Supporting Students' Writing in Elementary Science: Tools to Facilitate Revision of Inquiry-Based Compositions

Xavier Fazio & Tiffany Gallagher
Brock University
St. Catharines, Ontario, Canada
Email: xavier.fazio@brocku.ca, Tiffany.Gallagher@brocku.ca

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Brock University
St. Catharines, Ontario, Canada

Abstract

This article highlights the complementary cognitive processes found in writing to communicate and communicating in science. Writing in science is important for enabling students to clarify observed scientific phenomena, along with assisting them to construct new scientific knowledge from inquiry experiences. Maximizing teachers' resources, experience, and knowledge is necessary to support the intersection of instructional practices in writing and science. Two instructional strategies are proposed: a mnemonic acronym and an editing checklist, for teachers to use when helping students edit and revise their explanatory and persuasive writing products generated from scientific inquiry activities. A sample lesson outline for editing and revising inquiry-based compositions is also provided.

Key words: literacy/science school practice, elementary, teacher education, writing

Introduction

Writing is perhaps one of the more difficult academic skills for elementary teachers to address in the classroom. Teachers are often deluged with information on writing instructional approaches and teaching resources. Over the past few decades, three writing instructional approaches have come in and out of vogue: the process-centered (Tompkins, 2000), the genre-focused (Donovan & Smolkin, 2006), and the trait-based (Culham, 2003) which addresses the qualities of exemplary writing composition. While each of these approaches has made a viable contribution to writing instructional methods, elementary teachers appreciate pedagogical techniques that are both effective and efficient.Instructional efficiency is essential to adequately address challenging curriculum in subjects such as science, while integrating literacy skills such as reading or writing. Writing in science is important for enabling students to generate personal responses and clarify observed scientific phenomena, along with assisting them to construct new scientific knowledge from inquiry experiences (Klentschy & Molina-De La Torre, 2004). It is also evident that science and literacy in some ways are reciprocal processes. Inferencing, hypothesizing, predicting, and critical thinking are integral processes in science and language arts (Liu & Akerson, 2002). This point reminds us of the complementary cognitive processes in writing to communicate and, importantly for this article, communicating in science.

To help students write more scientifically, elementary teachers look for supports to streamline writing instructional approaches and offer students effective science learning strategies. Yet, one of the remaining challenges of writing in science is that when students are engaged in scientific inquiry, they may find it difficult to produce prose that will describe procedures, recount events, explain observations, report and propose expositions. While process-centered instructional models have been offered to promote writing in science (e.g., Miller & Calfee, 2004), there is also a need to contextualize a writing approach to effectively communicate science learning. Herein we propose two instructional strategies, a mnemonic acronym and an editing checklist, both of which hold the potential to assist elementary teachers in facilitating students to produce effective expository writing in science. This position paper offers concrete applications based on a brief review of the pertinent literature in writing instruction, scientific inquiry, and evidence-based practices.

Writing Instruction and Scientific Inquiry

Writing supports learning by engaging students in the cognitive processing of concepts; that is, a metacognitive approach to learning (Bereiter & Scardamalia, 1986). For instance, the process-centered writing approach is one that can support students as they move through the writing process. With this approach, there is an emphasis on differentiating instruction according to what students need at varied stages in their writing skill development. As a standalone instructional model, the process-centered approach is limited because the characteristics of writing compositions are not always emphasized by teachers. It is for this reason that elementary teachers are currently being encouraged to provide writing instruction that addresses both the process and products of students' writing (National Council of Teachers of English [NCTE], 2004).

Genre-focused instructional approaches emphasize the written product (or writing form) as well as the purposes for writing. Traditionally, elementary students have received a disproportionate amount of instruction on narrative forms of writing (e.g., recounts of events; fictional stories), even though expository forms of writing (e.g., explanatory reports, persuasive prose, procedural text) can be taught explicitly with the same degree of success (Chapman, 2002). In particular, students require explicit instruction to understand the purpose and structure of expository writing compositions (Christie, 1993; Gee, 2001). For example, a persuasive genre composition asserts a position and provides evidence and examples to strengthen the case (Education Department of Western Australia, 1994). Students who do receive explicit instruction in expository genres, such as persuasion, will produce written compositions consistent with this form and apply their skills to new contexts (Kamberelis & Bovino, 1999; Wollman-Bonilla, 2000). However, teaching argumentative and persuasive writing can be challenging for some teachers in that they press their students beyond surface-level expositions (Nystrand & Graff, 2001). These expositions are often basic compositions of information and details that are not always related to claims. To be sure, linking information and claims is pertinent and integral to expository writing in science and one that we contend is teachable.

Recommendations that connect writing and science also allow students to connect their life world with the specialist world of science (Gee, 2004; Harlen, 2001). Therefore, instructional writing strategies that assists elementary students to articulate their experiences with prior scientific phenomenon and cognitively juxtapose them with classroom inquiry experience, help to promote scientific literacy. In addition, in recent years, studies have shown science learning gains that are attributable to various writing interventions (Cleland, Rillero, & Zambo, 2003; Hand, Prain, & Wallace, 2002; Rivard & Straw, 2000).

It has been previously documented that when integrating subjects such as science and language arts, explicit instructional strategies are required to support conceptual transfer (Guthrie, Van Meter, Hancock, Alao, Anderson & McCann, 1998). Such writing-to-learn science strategies are viewed by many educators as critical to helping students construct deeper understandings of the science concepts being studied (Yore, Bisanz, & Hand, 2003). In fact, Miller (2007) found that when presented with explicit instruction in the transfer of cognitive skills, even kindergarten students are able to internalize the processes involved in science inquiry and content area writing. Helping elementary teachers to better *integrate* writing instruction that supports science processes (i.e., doing scientific inquiry) will help achieve both language and science literacy goals such as those that are stated in National Standards documents (NCTE, 2004; National Research Council [NRC], 1996).

Two forms of expository writing, *explanation* and *persuasion*, are particularly pertinent to students doing inquiry investigations. For instance, when engaged in an inquiry activity, students are expected to demonstrate expository writing skills, such as: recounting events, describing procedures, communicating and explaining observations, and proposing persuasive explanations based on evidence (NRC, 2000). Ultimately, students are often required to write a report to synthesize and communicate their inquiry and also model scientific practices. Typically, the following headings are used to format their report: purpose, methods, observation, conclusions. This traditional format has been challenged as a "myth" for modeling authentic practices of scientists (McComas, 2000). Furthermore, this report format fails to encourage students to effectively justify the relationship between evidence and explanations in their writing. In science, the analytical and dialectical process between providing evidence and explanation is referred to as *argumentation*—a critical yet often deemphasized component of teaching science as inquiry (Driver, Newton, & Osborne, 2000). Recently, the development and use of a *Science Writing Heuristic* (Hand, 2008) as a tool to embed language practices within scientific inquiry, has helped promote an explicit and metacognitive approach to the conceptual understanding of science, and also supported the teaching and learning of argumentation in elementary classrooms (Norton-Meier, Hockenberry, Nelson, & Wise, 2008).

Maximizing teachers' resources, experience and knowledge is necessary to support the intersection of instructional practices in writing and science. Akerson & Flanigan (2000) found that when teachers recognized that their instructional strengths in literacy can be used to help their science teaching, they were willing to devote more time to teaching science. One instructional focus might be on teachers providing students with writing prompts to promote deep thinking in science. Indeed, Cleland, Rillero and Zambo (2003) found that when teachers integrated writing prompts that helped students focus on prior learning in science that students' written responses clearly articulated key concepts. Other researchers have suggested that writing process models help to promote writing in science (e.g., Akerson & Young, 2005). Nonetheless, there currently is a need to provide teachers with aids to support the explanatory and persuasive writing that students generate from scientific inquiry activities. In this position paper we present two common instructional strategies: a mnemonic acronym and an editing checklist, which hold the potential for teachers to assist students to produce effective products of writing when learning science.

The Mnemonic Acronym: "P.O.W.E.R."

In a recent survey of elementary teachers' theoretical orientations concerning writing instruction, the majority of teachers emphasized the role of explicit instruction (e.g., teaching planning and revising) in teaching writing composition (Graham, Harris, MacArthur, & Fink, 2002). Explicit strategy instruction includes metacognitive information explaining when and where to use a learning strategy, and has been found to be a viable venue to instruct students in writing (e.g., Harris & Graham, 1996). Since expository writing does not come naturally to many students (Gunning, 2002), memory mnemonics such as acronyms, can be used as a strategy to reinforce the steps of the writing process (Stevens & Fear, 1987). For example, the mnemonic acronym *"P.O.W.E.R"* may used by teachers to assist students to remember the steps of the writing process by providing a letter to cue each step in the sequence (Gallagher, Forgrave, McAnanama, Woloshyn, & Bennett, 2001):

P is for planning generated ideas
O is organizing the ideas in a logical fashion
W represents writing the first draft
E is editing to ensure that all necessary components are included
R is the rewriting phase in which the students complete their final draft copy

For teachers' use, see *Appendix A* for a sample lesson outline of the *"E"* editing and revising step.

The mnemonic acronym, *"P.O.W.E.R"* is a tool that teachers can offer to students to be used in any expository writing context, and is of particular interest is that it can be used by students when doing a scientific inquiry activity. *"P.O.W.E.R."* can guide students through the steps of writing a meaningful exposition of their inquiry activity. For example, here are some suggestions that teachers might consider for each of the steps:

***P* -** graphic organizers such as a *KWL* chart to find out what students already know about a science topic (e.g. plants, animals, weather).
***O* -** concept maps can be used by students to organize their knowledge of a topic and formulate scientific questions that can be tested in the classroom.
***W* -** prompts can be used to help students organize and write their procedure, observation, and explanations into a draft composition.
***E* –** self- and peer-editing checklists may be introduced to assess the quality of students' compositions that are produced from inquiry activities, noting the effectiveness of the claims, evidence, and explanation, as well as the scientific and writing conventions used.
***R* -** rewriting can be promoted as an integral final step in the process in which the composition is prepared for final communication to peers and the teacher.

It is important to note that each of the steps of *"P.O.W.E.R."* will require explicit, teacher-directed instruction; however, teachers are advised to incorporate strategies and offer students tactics to support each of these steps. Teachers are encouraged to consider strategies that promote self-regulation in learning so that students may become independent writers. A plethora of strategies, guides, checklists, and rubrics exist for each of the steps of *"P.O.W.E.R."* Here we present teachers with a lesson plan (see *Appendix A*) and a formative assessment tool (see *Figure 1*) for the *"E"* step.

Focusing on "E" - Editing Process

Teachers often find it challenging to support students as they edit and revise their writing. To address the "*E*" step above, self-editing and peer-editing are espoused instructional practices that complement teacher-directed editing and revision (Tompkins, 2000). While editing is thought of as a strict administrative process (e.g., correcting conventions), revisions require an in-depth assessment of the purpose and content of the writing composition. In general, editing and revision is often a neglected step of the writing process especially when communicating outcomes from a scientific inquiry.

Indeed, scientists themselves are involved in a variety of writing tasks to meet their responsibilities in research and teaching. These writing pieces range from the common research report to editorial and research grants (Yore, 2004). Clearly, purpose and audience are important heuristic guideposts for effective expository communication in science. Subsequently, the consistent application of *"P.O.W.E.R."* may ensure that students adequately complete all steps of the writing process and, accordingly, demonstrate an understanding of the purpose and audience of writing in science. Furthermore, when teachers provide a focus on revising, this offers students an opportunity to highlight the quality of the explanatory and persuasion process during a scientific inquiry as they negotiate and communicate with their peers and teachers. These components are what distinguish expository from narrative writing and challenge students who are not accustomed to arguing, substantiating, and explaining their conclusions with credible data (Nystrand & Graff, 2001). The following are brief descriptions of the features of expository explanations and persuasive writing products (Hand, 2008; NRC, 2000) stemming from most scientific inquiry activities. These should be highlighted by teachers during the editing and revision steps of writing:

- Claims are authentic conclusions students derive from a scientific inquiry investigation. The merits for claims are judged by the evidence.
- Evidence is the data (observations) collected by students from inquiry activities using their senses and instruments. Accuracy and precision affect the quality of the evidence.
- Explanations are based on the evidence collected. Students elaborate upon their explanations by describing the persuasive relationship between claims and evidence.
- Sharing and critiquing written observations and explanations helps students to justify their claims. Furthermore, students should verify the validity of their explanations with current scientific knowledge.
- Communication of students' explanations requires adherence to accurate scientific conventions, including terminology and symbols. Furthermore, using age-appropriate writing language conventions supports effective communication of outcomes from their inquiry activity.

An editing checklist may provide specific, language-oriented feedback that may help teachers express their comments to students on the revision process and ensure that these features of expository explanations and persuasive writing products are honoured by students. Figure 1 is a formative assessment tool for teachers to use when helping students edit and revise their explanatory and persuasive writing products based on their scientific inquiry activities. In the sample lesson outline provided for the *"E"* step, explicit instruction of editing and revising are provided.

This checklist is not meant to replace other tools such as checklists that assess process skills in scientific inquiry, or rubrics that assess the performance or understanding of scientific inquiry. Rather, it is intended to complement those tools while providing feedback to students about the essential components of expository writing products that they have composed from a scientific inquiry activity.

Nevertheless, better writing in science should also link all communication modalities. For example, a think → talk → write strategy which has been adopted in England to promote literacy in science (Department for Children, Schools and Families, 2005) may help students to make connections between their peers, teachers, and the science phenomena under investigation, thereby linking literacy processes. Indeed, an expectation of the National Curriculum for England (Quality Curriculum Authority, 2004) is that teachers should teach students to use the patterns of language vital to understanding and expression in different subjects (i.e., science). These patterns include the construction of sentences, paragraphs, and texts that are often used in a subject's discourse to express various characteristics of expository text such as: causality, chronology, logic, exploration, hypothesis, comparison, and how to ask questions and develop arguments. Using assessment tools such as the *"P.O.W.E.R"* Science Writing Editing Checklist above may encourage teachers to support students in linking their science ideas, discussion, and expository writing.

Is this POWERful Science Writing?

Look for the following qualities and check ✓ those that you observe:

Elements of Science Writing	*Present*	*Developing*	*Absent*
Claims • Based on scientific questions and student's scientific inquiry activity • Authentic statements based on student's empirical data			
Evidence • Data (observations) are relevant • Interprets data accurately and precisely			
Explanations • Elaborates upon the claims and evidence • Formulates a persuasive link between the claims and evidence			
Feedback from peers • Examines and compares explanations with peers			
Research-based information • Examines and compares explanations with scientific sources • Connects explanations to scientific sources			
Scientific Conventions • Uses correct scientific vocabulary • Uses accurate numerical and data display conventions			
Writing Conventions • Uses effective sentence structure • Utilizes correct language mechanics			

Figure 1: "*POWER*ful" Science Writing Checklist for *"E"* Step

Conclusion

In this position paper we have presented a brief review of the relevant literature in writing instruction and scientific inquiry. Based on evidence-based practices, we have put forward a mnemonic acronym *"P.O.W.E.R."* and editing checklist "*POWER*ful" Science Writing Checklist for *"E"* Step to assist students with the writing process and to focus on editing and revising components of expository explanations. We are reminded that reciprocal processes such as inferencing, hypothesizing, predicting, and critical thinking are integral processes in science and language arts (Liu & Akerson, 2002). Yet, when students are engaged in scientific inquiry, they may find it difficult to produce prose that will describe these processes. In particular, elementary students often find it easier to express their ideas through talking rather than writing (Patterson, 2001). However, it is impractical for elementary teachers to perform interviews with all their students in order to effectively assess the outcomes from scientific inquiry activities. Therefore, it is imperative that students are encouraged to independently write about their science learning. Overall, we are encouraged by these practices and are continuing to explore the confluence between literacy and science in other research projects involving instructional and resource supports for elementary teachers.

It is important to remember that the integration of two subjects such as science and writing enhances the meaning making in both domains (Libidinsky & Kumar, 2008) and facilitates the forging of explicit connections between science inquiry and communication (Liu & Akerson, 2002). In particular, teaching argumentative and persuasive writing genres and encouraging students to justify relationships between evidence and explanations may support them as they write to communicate in science (Nystrand & Graff, 2001). Hand (2008) has written extensively on the use of a *Science Writing Heuristic* which offers a strategy to promote the conceptual understanding of science while practicing the skill of argumentative science writing.

While some teachers might hold apprehensions about the time that writing activities might consume at the cost of covering curriculum content (Hays & Davis-Harris, 2003), it is encouraging to note that they also found that when provided with ongoing professional development, teachers' science lessons consistently included opportunities for students to be engaged in producing complex writing. Furthermore, we believe that language teaching in elementary classrooms can also be enhanced when knowledge of scientific inquiry processes are used to inform approaches to teaching writing. This can be a powerful and equally beneficial process for both students and teachers. For this reason, students should be encouraged and supported to write more scientifically—an important goal for both science and language literacy.

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APPENDIX A
Lesson Outline

WRITING MNEMONIC: *"P.O.W.E.R."*

Focus on "*E*" with a Writing Editing Checklist

CONTENT and PROCESS OBJECTIVES

Students will:

- review the significance of the mnemonic "***P.O.W.E.R.***" for writing composition, "***P***" or planning stage to elicit ideas for writing, "***O***" or organizing stage, with a graphic organizer to ensure that all expository components are included, "***W***" or writing stage, in which the first draft or rough copy of an expository piece
- edit the first draft of their expository piece with assistance from their teacher employing the Writing Editing Checklist during the "***E***" or editing stage

PREPARATION

1. Graphic Organizer (previously student generated)
2. Example of an expository composition
3. Example of the mnemonic, "***P.O.W.E. R.***"
4. Writing Editing Checklist

INSTRUCTIONAL PLAN

1. Review the purpose of the acronym, "***P.O.W.E.R.***" to help remember all of the steps of the writing process.
2. Using a sample of writing generated from a scientific inquiry (e.g., a recycling investigation) in students' science notebook, review the criteria of the editing checklist (see Figure 1.) with the students.
3. Using the checklist, begin to review their writing for the claims. The claims should be based on scientific questions and any inquiry activities that we have done in science. The claim statements should be based on empirical data that students have collected. Prompt students: *"Are there claims present in your composition or do you need to work on developing your claims?"*
4. Then guide the students to evaluate their writing for evidence. Evidence may be data that they have collected through observations. The data should be relevant to their claims and they should

interpret these data accurately and precisely. Prompt students: *"Is the evidence present in your composition or do you need to work on developing your evidence base?"*

5. Using the checklist, have students check their writing for explanations. Explanations are the connections between the claims and evidence. Explanations elaborate on the claims and evidence. Explanations can be persuasive. Prompt students: *"Do you have strong explanations in your composition or do you need to work on developing your explanations?"*
6. Provide students with an opportunity to get feedback from their peers in the class. Students should examine each others' compositions and focus on the explanations. Students should have a conversation with their peers to compare explanations.
7. Provide students with time to consult some research-based information about their topic. Impress upon them that they need to gather information from credible scientific sources and compare these explanations with their explanations. Students should make connections between these scientific sources and their own explanations.
8. Guide students to review their data display conventions. They will need to consult a science dictionary or textbook to evaluate these two criteria. Prompt students: *"Do you have accurate scientific conventions or do you need to make some corrections?"*
9. Finally, students should review their writing composition for sentence structure and correct language mechanics. Prompt students: *"Do you have these two aspects of writing conventions in your composition or do these aspects need to be further developed?"*