BUILDING CONCEPTS THROUGH WRITING-TO-LEARN IN COLLEGE PHYSICS CLASSROOMS

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Abstract

This paper draws on an action research inquiry into my teaching practice featuring careful analysis of the experiences of some of the students in my college-level introductory college physics course. Specifically, the research describes and interprets the role of Writing-to-Learn pedagogies in a physics classroom with a view to exploring how such pedagogies can support meta-cognitive learning behaviours. The research concludes that while Writing-to-Learn tasks in physics classrooms can support the development of a conceptual understanding of physics, teachers should be mindful of the fact that students' prior experiences in tertiary education play a significant factor in their ability to engage in meta-cognitive writing tasks.

Introduction

This paper presents a portion of an action research conducted for a Master of Education degree into the efficacy of using active-learning teaching strategies to encourage conceptual change in physics students. The purpose of my action research was to investigate students' perceptions of their learning in an introductory college physics course. The study considers students' responses to three pedagogies intended to help them think about their learning: Predict-Observe-Explain, Interpretive Discussion, and Writing-to-Learn. In this paper, I focus on a subset of the data; namely, students' perceptions of the ability of Writing-to-Learn pedagogies to develop conceptual understandings of introductory topics in a college physics classroom.

Writing-to-Learn in Physics Classrooms

A review of Physics Education Research (McDermott & Redish, 1999) indicates that writing for understanding is a pedagogical tool that has not found its way into many physics classrooms. Often, physics teachers seem to rely exclusively on the language of mathematics to communicate the canons of physics. Personal teaching experience has led me to believe that the written word is every bit as important as mathematics for developing a conceptual understanding of physics. Written language, like mathematics, is an important type of symbolic technology that can allow us to systematically analyse our thought processes. The use of written language by scientists as a tool to extract general, abstract ideas from descriptions of concrete situations dates back at least as far as ancient Greece (Donald, 2001). More recently, scientists such as Einstein and Infeld (1966) remind us that language plays an important role in physics by providing an advanced yet non-mathematical treatment of physics concepts.

The expanding definition of scientific literacy also favours increasing the role of writing in the science classroom. Scientific literacy is no longer a matter of simply learning the definitions and procedures of science. The National Science Education Standards broaden the definition of scientific literacy to include not only knowledge of scientific concepts, but also the ability to engage in public scientific discourse using appropriate terminology (National Research Council, 1996). As well, the Ontario Curriculum points to this newfound emphasis on communication when it refers to science as "a subject in which students learn to weigh the complex combination of fact and value that developments in science and technology have given rise to in modern society" (Ontario Ministry of Education, 2000, p. 4). Hand and Prain (2002) suggested that, in order to engage in the expanded conception of scientific literacy, students should engage in a diversity of writing types and contexts.

It is not sufficient, however, to simply state that science courses should have a strong writing component. There are many different kinds of writing, and the utility of particular kinds of writing for science classrooms has been intensely debated (Hand & Prain, 2002). Traditionally, writing in the context of learning science has a goal of introducing students to the world of writing a proper laboratory report and using the terminology associated with formal scientific reporting. This traditional orientation holds that science writing should have the ultimate aim of giving students the ability to reproduce the type of writing expected in a particular discipline, such as biology, chemistry, physics, or Earth sciences.

In sharp contrast to the traditional view of the place of writing in the learning of science, other researchers (Hand & Prain, 2002; Hildebrand, 1998; Prain & Hand, 1996) have called for students to "write in diverse forms for different purposes" (Hand & Prain, p. 741). From this perspective, the place of writing in the learning of science is profoundly different. The Writing-to-Learn school of thought sees writing "primarily as a resource for thinking and learning … by which students clarify and consolidate knowledge" (Hand & Prain, 2002, p. 741). From this perspective, writing tasks in the science classroom should encourage students to explore communicative elements of science such as making arguments, clarifying positions, and justifying explanations.

Research Methodology

Action research has many definitions, most of which include the concept of learning from experience (Peters, 1997). Johnson (2005) defined action research as:

> the process of studying a real school or classroom situation to understand and improve the quality of actions or instructions. . . It is a systematic and orderly way for teachers to observe their practice or to explore a problem and a possible course of action . . . [It] is also a type of inquiry that is pre-planned, organized, and can be shared with others (p. 21).

Stringer (2004) characterized action research as a process of systematic inquiry that seeks to provide educational professionals with new knowledge and understanding of the mechanisms present in their classroom. The systematic nature of the inquiry helps to assure reliability (Patton, 2002). In addition to being systematic, Price (2001, p. 43) required that action research be "intentional, collaborative, and democratic in intent and process." Loughran, Mitchell, and Mitchell (2002) characterized action research as representing a shift from being a teacher to a teacher-researcher.

Peters (1997) stated that action research has multiple purposes. In particular, action research has the overarching goals of both understanding and improving one's own practice. By conducting action research, I hoped to gain a better idea of how Writing-to-Learn contributed to the quality of learning in my classroom and build on my understanding of my practice in order to improve my pedagogy.

Research Setting
The use action research in my teaching practice occurred while I was working in a metropolitan community college physics classroom between January and April of 2004. I taught an introductory physics course that contained material similar to the Grade 12 college preparatory physics course currently offered as a part of the Ontario secondary school curriculum. My students ranged in age from their early 20s to their late 40s. Students had diverse reasons for enrolling in the class: some required the course as a part of the optician or aviation programs, some were taking the course for work-related reasons, and others were simply interested in pursuing a science-and-technology-based post-secondary program and were trying to keep their options open. The gender ratio in the class was approximately even, as was the ratio of students in the class who had taken a post-secondary course versus those who were new to post-secondary education.

The data collection phase of my research occurred between January and April 2004. Students in my introductory physics class kept a learning journal in which they recorded their responses to Writing-to-Learn tasks. At the end of each unit, students responded to four questions that asked for their reflections on the Writing-to-Learn tasks as well as any other thoughts about teaching and learning in the classroom that they wished to share.

The students' learning journals were one element of the raw data under consideration for this study. The responses to the research questions were the basic unit of analysis for organizing and comparing the data. The second element of the raw data was my research journal in which I recorded my observations and reflections following each class. My research journal allowed me to identify some of my assumptions about the nature of teaching and learning, a critical feature of action research according to Peters (1997). The overall goal of my research was a better understanding of my personal teaching practices. To that end, I compared my own notes with those of the participants, in order that I might draw connections between the patterns and themes in the students' journals and the central ideas of my teaching practice.

Writing-to-Learn

In this section I present and interpret data from the students' learning journals and my research journal. All of the students in the class used learning journals for a variety of classroom activities, including Writing-to-Learn tasks. At the end of each curriculum unit, each student was asked to respond to 5 questions designed to encourage them to consider how they could improve the quality of their learning. The learning journal had been a regular feature of my pedagogy before I conducted the research because I believe that it is important for students to have a record of the development of their thinking about physics throughout a course. Of the 15 students in the class, 4 males and 2 females allowed me to use their learning journals as a part of my research data after the course was finished. Given that I had taught the course for 3 years prior to conducting this action research, I can safely say that the 6 participants represented a reasonable cross-section of students in my introductory physics course from the standpoints of academic ability, cultural background, prior experience with tertiary education, and age. All of the participants were reasonably successful in the course, which is typical of students who remain in the course until the end of the semester. Direct quotations are attributed to the appropriate author under pseudonyms. All responses were given between January and April of 2004.

The data presented often refers to the other pedagogies that were investigated in the research: Predict-Observe-Explain (POE) and Interpretive Discussions. Both of these pedagogies are taken from the Project for Enhancing Effective Learning (PEEL) (Baird & Northfield, 1992). Predict-Observe-Explain (POE) involves students in the process of accessing their prior knowledge of science and using that knowledge to make a prediction about what will happen in a given situation. After the observation, which is often designed to be novel or surprising, students attempt to explain their observation. The format of a POE can vary quite a bit depending on the lesson, but the core feature is that students are given a voice not only to express their prior conceptions about science, but also to develop explanations about science phenomena. An Interpretive Discussion differs from a traditional Socratic discussion in two critical ways. The first difference involves the teacher increasing the wait-time for student responses. The second and more important difference involves changing the orientation towards the discussion itself. Traditional classroom discussions are conducted with a predetermined endpoint in mind. Usually, a teacher encourages students who give responses that help the discussion along what the teacher has decided is an appropriate path. Students are familiar with this traditional method, and what often develops is a kind of game in which students try to find ideas that build on the responses that have already been validated by the teacher (Baird & Northfield, 1992). Often, Writing-to-Learn tasks were used in tandem with one or both of these PEEL pedagogies.

Upon consideration of the participants' responses, it became evident that the kinds of responses given by students fell into two categories based on their level of experience with tertiary education. Anne, Derek, and Evan all had significant prior experience with tertiary education and tended to show more evidence of metacognitive thinking in their responses. In contrast, Brian, Chander, and Farida were new to tertiary education, and tended to offer thoughts about the procedural rather than the metacognitive elements of writing. In this section, I offer an analysis of participants' responses using their level of experience as an organizing framework.

The data were analyzed with a view to giving voice to the participants (Stringer, 2004). My intention throughout the analysis was to "make the world of lived experience directly accessible to an audience" (p. 98). Rather than an objective truth, I sought to describe the subjective multiple realities that existed in my research setting, as suggested by Guba and Lincoln (1988). Patton (2002) provided a framework for categorizing and coding data that is characteristic of qualitative analysis. Students' responses to use of Writing-to-Learn tasks are reported and analyzed in the following sections. Responses from my research journal offer additional insight and link both my responses and students' responses to literature.

Students' Responses

Students were asked to describe how the writing tasks helped them learn physics. Two students commented that the "good amount" (Derek) of writing was enjoyable and motivating (Derek, Evan). Anne mentioned that it was difficult to put prior concepts of physics in writing, and hence "[the writing tasks] motivated me . . . it made me realize how little I know or should I say knew." Anne also mentioned the power of coupling writing with Predict-Observe-Explain (POE) pedagogy frequently employed in the course, coining the term "POE writing tasks." Evan was motivated by writing and mentioned how much he "enjoyed the writing tasks," particularly when they were linked "with the lab book entries."

Brian and Farida took a more technical view of the writing activities. Early in the course, Brian identified that "writing things down as we discuss or talk helps [me] to retain things. [I] can review written work at a later date to jog the memory." In his final journal entry, Brian elaborated on how mastery of the rote writing processes helped him throughout the course:

> Not knowing a lot about science [prior to the course] I found it [technical reading] difficult to digest. Writing things down after a video and throughout class discussions helped me in my notes.

For Farida, the technical view of writing was seen as essential to the learning process. At the end of the course, Farida commented that "writing things down definitely helped [me] because [I] would go back to them if [I] needed to."

Derek was the only student who explicitly stated that he did not enjoy the writing tasks, although he thought "the combination of the questions and the article review [that probed prior concepts] were excellent." Derek felt that the writing tasks did not do anything to further his conceptual understanding of the POEs done in class.

Anne was the only student who reported a significant change in the way she viewed the writing tasks. Her final journal entry elaborated on her viewpoint:

> The written tasks surprisingly helped me understand the material better. I didn't think that they would. After doing the POE on hydraulics, etc., I realized how valuable doing the explanation was. It gave me time to reflect on the experiments.

Anne viewed the writing tasks as a part of the POE process because she engaged in writing to reflect on what she learned from each POE. By the end of the course Anne saw writing as more than just a way to record information.

At the end of the course, I asked my students to write about how Writing-to-Learn tasks affected both their scientific literacy and their understanding of physics. Five students commented that their scientific literacy increased, although students had different opinions concerning the nature of scientific literacy. Two students mentioned specific reasons why they felt that their scientific literacy had increased. Anne stated:

> My scientific literacy has increased in the realm of physics! I did not know anything before the course. The book assignment and the supplementary readings helped tremendously. I understand key concepts or I can at least recognize the terms.

Derek provided a powerful commentary on how the increase in scientific literacy he experienced affected his world-view:

> Yes, my level [of scientific literacy] has increased, and I can see this by my unwavering curiosity to discover and know how and why everything works. I can better relate not only to the world, but myself better because I have a greater understanding of how and why things operate the way they do.

Three students reported that their level of scientific literacy had increased, but equated scientific literacy with "knowing definitions" (Chander). Farida commented that she "think[s] [her] scientific literacy has improved a bit, but [she] think[s] that [she] still has a long way to go." Brian mentioned that his "level of science has increased…some of the POE we [have] done I have shared at work – it also impresses my fellow co-workers."

Analysis of Students' Responses

Students who had experience with tertiary education focused on the power of writing for exploring their conceptual understanding of physics concepts. Early on, experienced students identified that writing tasks "helped [them] to understand the material a little better" (Anne). Experienced students recognized that they had prior conceptions about physics before the course even started, and that writing tasks "encouraged some self-examination of misconceptions" (Evan). Evan remarked on his insight in the electricity unit, commenting that writing "cleared up some misconceptions…regarding electron flow and power." Writing-to-Learn tasks helped build coherence among the concepts in the course, both from an organizational standpoint and in terms of creating links to the mathematical element of the course. Anne wrote that "the writing tasks helped me make sense of the concepts" and "the writing tasks hammered home the mathematical concepts."

Students new to tertiary education unanimously thought that the meta-cognitive writing tasks occurred every time they were asked to write. These students tended to focus on the rote writing that is part of almost any student experience, as opposed to the Writing-to-Learn tasks. Chander commented that "the writing tasks, [occurred] by taking notes from the blackboard." Indeed, the physical act of writing notes was a pivotal experience for these three individuals: "Writing things down as we discuss or talk… helps to retain things" (Brian). Inexperienced students saw the creation of a good set of class notes as a primary goal in the course so that they would be able to review properly for a test or exam. Without exception, the three inexperienced students talked about how writing "helps to retain things … [I] can review written work at a later date to jog memory" (Brian). Writing tasks, as defined by these students, were seen as the creation of reference material that they could "turn back and look at" (Chander). Farida echoed the comments of Brian and Chander, stating that "writing tasks helped [me] learn better since [I] can come back to it as reference."

Differences in ability to see writing as a way to gain access to prior concepts were revealed in the responses given by students with different levels of experience in tertiary education. When asked to comment on writing tasks in general, those with less experience in tertiary education identified the writing associated with traditional transmission-based pedagogy, such as taking notes from the board and making notes from their text. For these students, writing seemed to be a way to help them memorize bits of information. In contrast, two of the three experienced students saw writing as a way to explore what they knew about a given concept. These same two students also wrote about the motivational element of the writing tasks, indicating that they realized what they did not know and hence were able to develop a plan to explore concepts further.

Although five of the six students commented that their level of scientific literacy increased by taking the course, they had different conceptions about the nature of scientific literacy. Students who were new to tertiary education made comments indicating that scientific literacy was equivalent to scientific knowledge. Students who had experience with tertiary education, however, equated scientific literacy with the reconceptualization of scientific phenomena.

Teacher-Researcher Responses

I started the course with a writing task that asked students to comment on both the importance of scientific literacy and their prior notions of what the study of physics entails. This early Writing-to-Learn task demonstrated that writing could be a valuable tool for exploring prior conceptions and clarifying thinking, as suggested by Hand and Prain (2002). Writing was used to probe students' prior conceptions throughout the course.

The Writing-to-Learn tasks were rarely performed in isolation from either a POE or an Interpretive Discussion. Although this link between writing and another active learning pedagogy was never an explicit plan when I began, I soon became "convinced of the power of writing for providing people with scaffolding to talk about esoteric concepts." The writing tasks in my class were exploratory and they also provided students with security when they explored physics ideas verbally, either in small groups or in front of the class. By asking students to have something written down, I felt that it "reduced the stress of participating in the other PEEL (active learning) procedures."

There was an ongoing element of the writing tasks that troubled me throughout the course: "If I expect students to learn about writing, should I not be giving explicit instruction in how to write?" Students were at very different levels in their ability to write from an exploratory, reflective stance. By focusing on the Writing-to-Learn pedagogies, students who were less comfortable with writing could have been at a disadvantage in terms of their access to learning about physics.

Some Conclusions about Writing-to-Learn

Students should engage in a variety of writing tasks in physics classrooms to support the development of a conceptual understanding of physics. This study found that students were able to create meaningful understandings of physics through writing and that direct instruction in writing would be beneficial to students of whom writing is expected. Additionally, Writing-to-Learn tasks enabled some students to monitor their understanding of physics concepts throughout the semester, from initial examination of prior conceptions to drawing links between philosophical and mathematical understandings.

The study shows that some of my students were not clear about the different uses of writing tasks. When asked to comment on how writing tasks helped them learn, some students focused on tasks that Martin and Veel (1998) associated with the writing-for-indoctrination perspective. Students who wrote about writing tasks such as note-taking believed that the primary reasons for writing were to create a written record of knowledge and help them memorize important material. Students who described these rote learning tasks did not have prior experience with tertiary education and were probably focussed on what they saw as the reason for coming to class: taking notes so that they could study later. In contrast, the students who had prior experience in tertiary education wrote about the power of writing to clarify understanding, a view consistent with the Writing-to-Learn perspective described by Hand and Prain (2002). The students who were new to tertiary education may have felt pressure to engage in behaviours that they associated with doing well in school, such as taking notes, because they were experiencing the same fear of doing poorly in school that Holt (1964) described.

Writing skills were not taught explicitly in my college physics classroom. I erroneously assumed that my students could use writing as a medium to explore their own learning. In retrospect, I believe that I should have taught students how to write in diverse forms so that they could engage more fully in the writing-to-learn experiences. Toussaint (2003) noted that students were better able to self-monitor their reasons for writing when they had a sound knowledge of writing genres and structures.

This action research taught me the importance of explicitly modelling Writing-to-Learn tasks in the college classroom. The study showed that students who were new to tertiary education were at a disadvantage when they engaged in meta-cognitive writing tasks because they tended to focus on the more technical elements of writing. Simply asking students to write about their conceptions of physics was not sufficient because students came into the class with different levels of writing experience. In addition, the data indicate that Writing-to-Learn tasks are most effective when combined with other pedagogies that support active learning. Active-learning pedagogies designed to elicit students' prior conceptions about physics, such as POE, seem particularly well-suited to Writing-to-Learn activities. It is equally important to use Writing-to-Learn activities to encourage students to write about what they learned, so that the way they think about science can become more sophisticated over time. Writing-to-Learn tasks are also a valuable way to encourage open-ended discussions.

As a teacher in a post-secondary setting, I am now much more cognizant of the need to model the kind of writing that I expect. In particular, I often construct an example of how someone might write about their scientific thinking before, during, and after a POE I would like to introduce more opportunities for meta-cognitive writing tasks in my post-secondary teaching because I believe that Writing-to-Learn is a powerful way to encourage students to think about their learning. It is advisable, however, to provide explicit structured writing instruction in tandem with exploratory writing activities. The use of Writing-to-Learn tasks in physics is generally unfamiliar to students, so care should be taken to explain not only the different types of writing tasks in the class, but also the reasons for engaging in such tasks. Writing-to-Learn activities can be a powerful resource for thinking about physics because such activities allows students to expand their cognitive capacity to access, manipulate, and organize their conceptions about physics.

References

Baird, J. R., & Northfield, J. R. (Eds.). (1992). *Learning from the PEEL experience.* Melbourne, Australia: Monash University Printery.

Donald, M. (2001). *A mind so rare: The evolution of human consciousness.* New York: W. W. Norton and Company.

Einstein, A., & Infeld, I. (1966). *The evolution of physics.* New York: Simon & Schuster.

Guba, E. G., & Lincoln, Y. S. (1988). Do inquiry paradigms imply inquiry methodologies? In D. M. Fetterman (Ed.), *Qualitative approaches to evaluation in education: The silent scientific revolution* (pp. 89–115). New York: Praeger Publishers.

Hand, B., & Prain, V. (2002). Teachers implementing writing-to-learn strategies in junior secondary science: A case study. *Science Education, 86,* 737–755.

Hildebrand, G. (1998). Disrupting hegemonic writing practices in school science: Contesting the right way to write. *Journal of Research in Science Teaching*, *35,* 345–362.

Holt, J. (1964). *How children fail*. New York: Pitman Publishing Company.

Johnson, A. P. (2005). *A short guide to action research* (2nd ed.). Boston: Pearson Education, Inc.

Loughran, J., Mitchell I., & Mitchell, J. (Eds.). (2002). *Learning from teacher research*. New York: Teachers College Press.

Malpass, J. R., O'Neill, H. F., Jr., & Hocevar, D. (1999). Self-regulation, goal orientation, self-efficacy, worry, and high-stakes math achievement for mathematically gifted high school students. *Roeper Review, 21*, 281–290.

Martin, J., & Veel, R. (1998). *Reading science: Critical and functional perspectives on discourses of science.* London: Routledge.

McDermott, L. C., & Redish, E. F. (1999). Resource Letter: PER-1: Physics Education Research. *American Journal of Physics*, *67*, 755–767.

National Research Council (1996). *National science education standards*. Washington, DC: National Academy Press.

Ontario Ministry of Education. (2002). *Ontario curriculum: Grades 11 and 12 (Science).* Toronto, Canada: Queen's Printer.

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage.

Peters, J. M. (1997). Reflections on action research. *New Directions for Adult and Continuing Education*, *73*, 63–72.

Prain, V., & Hand, B. (1996). Writing to learn in the junior science classroom: Issues arising from a case study. *International Journal for Science Education*, *18*, 117–128.

Price, J. N. (2001). Action research, pedagogy, and change: The transformative potential of action research in pre-service teacher education. *Journal of Curriculum Studies*, *33*, 43–74.

Stringer, E. (2004). *Action research in education*. Upper Saddle River, NJ: Pearson.

Toussaint, D. (2003). The footnote: Getting kids to think of the “what?” and the “why?” *PEEL SEEDS¸67*, 36.