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The effects of using writing to learn activities and writing to varying audiences on conceptual understanding in science

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ABSTRACT

Much current research in science education is focusing on the development of practical, yet theoretically based teaching practices to improve student conceptual understanding. One area receiving considerable attention is using writing activities in the science classroom to facilitate conceptual growth. This study focuses on the theoretical underpinnings of using writing to learn in the science classroom, a model that is helpful in the development of these types of activities by teachers, and one particular component of that model, the audience. Findings from the study suggest that writing is beneficial in promoting better scientific conceptual understanding. In addition, while writing to different audiences outside of the teacher does not seem to hinder student performance, this study does not pinpoint one particular audience that significantly improves conceptual understanding.

CHAPTER 1. GENERAL INTRODUCTION

Purpose of Study

One scholastic field currently experiencing a marked amount of reform is science education. This field, in general, is undergoing a transition from a traditional philosophy emphasizing instructors imparting knowledge to students and moving toward a constructivist philosophy. This constructivist philosophy is based on a basic epistemology that students construct their own personal knowledge of science concepts by making connections between previous learning and the new ideas they encounter (Prain & Hand, 1996). This philosophical position, when applied to curriculum production is sometimes termed "conceptual change" (Andre, 1997) As instructors begin to adopt this conceptual change framework as their theoretical basis for instruction, pedagogy and methodology used by these instructors must begin to change as well. Traditional practices and activities need to be modified to fit this new perspective, and new activities and practices need to be developed for the classroom. One particular area of curricular change and modification that is increasingly the focus of much research is the use of writing in the science classroom (Monhardt, 1996).

If these curricular changes are to be truly beneficial, the proposed activities, practices, and applications need to not only match the constructivist philosophy, but they must also be shown to be beneficial in practical settings. In order to do this, these practices must be researched in a less biased fashion, studied without preconceptions determining outcomes, and considered within the context of actual science classrooms (Rivard, 1994). In addition, effective models for all practitioners to use to implement these effective writing activities must be developed and refined through research. The review of relevant literature and the research involved in this thesis are focused on these goals. The purpose of this study is to determine whether or not these constructivist based writing practices do lead to greater student understanding of particular science concepts in a biology classroom. This study is also concerned with examining if the audience the students are writing to as part of these writing activities is important.

Research Questions

This particular study is based on the following two research questions:

1. Does using writing to learn strategies and activities improve students' conceptual understanding of science concepts within a biology course dealing with the human nervous and respiratory systems?

2. Does the particular audience that a student writes to have an effect on the conceptual understanding gained by that student?

Background of Research Topic

Writing in science has received considerable attention in research, but consensus has not been reached on whether or not it is truly beneficial, what aspects of the process make it beneficial, and what is the best way to implement it in the classroom (Rivard, 1994). Much of this dilemma arises from inconsistent research findings, research done in situations not similar enough to classroom settings to provide practical feedback, and research tainted by preconceptions and assumptions of benefit not necessarily backed up by verifiable, quantitative results (Monhardt, 1996). Recent research efforts have attempted to provide studies free of these flaws that will ideally lead to more connections between the research findings and the practices employed in actual classrooms.

Writing has long been recognized as a potential teaching tool to help develop and shape student thought (Howard, 1988; Rivard, 1994). Studies on writing in educational settings in the middle 1970s (Britton et al. 1975; Donlan, 1974) led to a "writing across the curriculum" movement that emphasized the need for writing to permeate the entire school experience, not just as a part of English courses. This movement, while likely contributing to an increase in the amount of writing done in science classrooms did not necessarily lead to writing activities that promoted greater student learning (Rivard, 1994; Prain & Hand, 1996). To address this issue, recent research has attempted to focus on the cognitive aspects of writing in order to develop writing practices that are more in line with constructivist viewpoints and more likely to lead to improved student understanding.

Research on the cognitive aspects of writing activities has led to the development of models describing what is happening in the writing process that makes it a useful tool for student conceptual change. Bereiter and Scardamalia (1987) and Galbraith (1999) have proposed models with considerable overlapping factors to explain the writing process. This

research focus on the process has in turn led to studies on the construction of models for the curricular development of writing activities that promote this cognitive growth. One such model is a five factor design by Prain and Hand (1996).

If the curricular models are to be successfully implemented in classrooms, they need to be critically examined. Each factor needs to be understood from a theoretical perspective, and its use needs to be explored in a practical setting. One factor that has been researched to some extent, but not explored fully in a practical sense, is the audience to which a student writes. Early research on this factor contained two competing theories on the conception of audience by the writer, the audience invoked theory and the audience addressed theory (Ede & Lundsford, 1989). The consideration of these two competing theories has led to the development of a compromise theory of audience conception that shares characteristics of the earlier theories and fits nicely with the emerging models of the writing process and its cognitive aspects (Ede & Lundsford, 1989). This study will use this compromise theory as an effective way for instructors to encourage their students to conceive of their audience when using writing to learn activities in science.

Significance of Research Topic

Research dealing with writing to learn is beneficial for the field of science education in a number of ways. It is critical to initially determine if writing to learn activities are beneficial to the student population. These activities cannot be promoted simply because they are different from what is currently being done and they cannot be used just for the sake of including some writing in the classroom. The conceptual benefits of these practices and the agreement of the practices with a theoretical background that has also been shown to be beneficial is an essential first step in gaining acceptance by educators.

Once the results of using these activities are shown to be beneficial, educators then need to be convinced that the activities represent a worthwhile methodology for their classrooms. This involves research based within science classrooms and focused on the classroom practices that allow these activities to be beneficial. Educators need to be shown that these activities can be done in a meaningful, but also practical and efficient, manner. This necessitates the development (through research and experience) of models that can be used by different teachers in different classrooms to accomplish similar curricular goals.

This will provide teachers with little experience or confidence in designing writing activities for their students a scaffold to aid them in the development of these activities.

Research cannot end with the development of these models. To be truly beneficial to the field of education in a long term sense, the models of writing activities must be continually refined, reviewed, and tested. Research must focus on the most appropriate matches of factors that promote student learning. Research must also continue to explore the theoretical backgrounds and the rhetorical aspects of each factor so that the models can increasingly become an educationally beneficial merging of science's conceptual content and appropriate writing skill.

Organization of Thesis

This paper represents a combination of a review of relevant literature dealing with the topic of writing to learn in science and a study designed around the research questions noted earlier. It is organized in three main sections:

Literature Review

The first section is a literature review of current research on the topic of writing to learn and the audience in relation to writing to learn activities. The literature review begins by exploring traditional views on and uses of writing in science classrooms. Many of these traditional views are currently employed by science instructors. The discussion then shifts to research detailing the theoretical background of writing to learn activities. This research focuses on the conceptual aspects of the writing, as well as the links to constructivist and conceptual change philosophies.

The literature review then deals with the implementation of writing to learn activities that are effective in promoting student learning. This section begins with research findings on benefits of the practice, as well as concerns raised about the practices in literature. It then moves into a discussion of a research-based model to aid teachers in designing effective writing to learn activities. One particular factor of the model, the audience, is then considered. Competing theories about how the audience is and should be viewed by writers from the literature are explored. A compromise position on audience is discussed and related to the previously discussed theoretical aspects of writing to learn.

Journal Article

The second section of this paper is a journal article detailing a study done to explore writing to learn in a classroom setting. The study was a two-staged study designed to explore whether or not writing to learn activities provided benefits to students and whether or not writing to different audiences impacted the students' conceptual understandings.

The first stage of the study involved the study of the role of the nervous system in maintaining homeostasis for the human body. In this stage, four preexisting general biology courses were given traditional instruction in this concept as a normal part of their curriculum. At the conclusion of the instruction, all four classes did a writing activity in which they wrote an explanation of this concept to the instructor. They were given feedback and produced a final copy of the explanation. They were then given a post-test over the concept. A fifth class, the control group, was given traditional instruction with no writing activity and then given the post- test. The goal of this stage was to determine whether or not doing a writing activity positively affected the conceptual understanding of the topic acquired by the students. In addition, this stage provided all of the treatment classes with an initial writing experience, therefore in the second stage they would all have some previous experience with the practice.

The second stage of the study involved the study of a human anatomy unit on the coordination of the circulatory and respiratory systems. Again, all four treatment classes received traditional instruction in the topic and all four participated in a writing activity in which they wrote an explanation about the concept at the end of the unit. In this stage, each treatment class wrote to a different audience. One class wrote to a class of 3rd/4th graders, one class wrote to their parents, one class wrote to students in a high school English course, and one class wrote to the instructor. A fifth class, the control, again participated in traditional instruction with no writing activity. All classes were given a post-test over the material. The goal of this stage was to again determine whether or not writing benefited the student acquisition of conceptual understanding. In addition, the effect of the four treatment classes writing to different audiences was explored by comparing the outcomes of these four classes to each other.

General Conclusions

The final section of this thesis includes general conclusions. This section links the information in the literature review with the specific findings of the study undertaken. This section begins with a discussion of the findings in the study. Limitations of the study and changes that could enhance the credibility of the results are then discussed. A final section explores implications that this research has on the overall field of science education and what it means for the future of this field.

CHAPTER 2. LITERATURE REVIEW

Introduction

Writing is such a powerful educational tool that it has even been called the "father of thought" (Howard, 1988). The power of writing in education comes from many features of the exercise, including the vast permeance of the written word in society, the explicitness necessary for written communication to be successful, and the active nature of using written discourse (Applebee, 1984a). Writing also allows learning demands to be placed directly on the student as they attempt to organize language to achieve success (Hayes, 1987). These features combine to make writing not only a critical communication element, but also a powerful tool for shaping thought (Applebee, 1984a). Writing activities allow for opportunities to think through arguments, to use reasoning skills, and to attempt to persuade, which can promote the exercise of higher order thinking in students in many different disciplines (Resnick, 1987).

Science is one discipline in which research in regard to writing as a tool for learning has been growing. This literature review will examine current research in this area. First, the current research about, and discussion of, the theoretical background for writing to learn activities in science will be explored. This exploration will include an in-depth comparison of traditional views on writing in the science classroom with emerging ideas about this practice. Second, implementation of writing to learn activities in science classrooms will be discussed. Benefits and concerns associated with this practice will be noted and a practical model to use in developing these types of activities will be presented. Third, one particular aspect of writing to learn activities, the audience, will be explored in detail, with emphasis placed on its relationship to the previously discussed emerging theoretical ideas.

Theoretical and Research Background of Writing to Learn

Introduction

Research on writing in science has enjoyed recent popularity and momentum (Holliday, Yore, & Alvermann, 1994). Even though much has been written in this area, connections between writing activities and science achievement are still not well understood (Monhardt, 1996). Writing in any discipline can generally be thought of as a two-part process. First, it involves the author "polishing" his or her own thinking, and then it involves the author communicating his or her thoughts (Howard & Barton, 1986). Bereiter

and Scardamalia (1987) and more recently, Galbraith (1999) have further clarified this field by offering models of the writing process. In these models, the writing is not only creating a communication product on paper, but also creating new knowledge for the author.

Writing to learn, therefore, is different from writing only for the sake of communication, as writing to learn emphasizes the changes taking place in the conceptual understanding of science concepts in the author (Holliday, Yore, & Alvermann, 1994). This more meaningful writing is characterized by the demonstration of connections between old and new learning, by using authentic and uninformed audiences, by the manipulation and establishment of new conceptual ideas in the author, and by an emphasis on metacognition (Santa & Havens, 1991). The goal of writing to learn practitioners is to create learning situations and environments in school settings that allow for this type of meaningful writing, thereby encouraging critical thinking and the evolution of conceptual understanding (Holliday, Yore, & Alvermann , 1994). Obviously, the way that the instructor structures and presents a writing activity will go a long way in determining the perception of the value of the writing activity for the writer. Therefore, if student learning is to be truly enhanced, instructors need to be first convinced of the importance of writing to learn in science. Importantly, an understanding of the theoretical framework for using writing needs to be outlined. This can be established by first contrasting writing to learn to traditional writing in science classrooms, and then exploring emerging research findings in this area.

Traditional Views on Writing in Science

Using writing as a pedagogical tool in science classrooms is not a new or novel idea. Studies dating back to the middle 1970s (Britton et al. 1975; Donlan, 1974) show that writing is often used more in content areas than in English classrooms. In addition, many researchers have consistently argued that not only can writing help improve science comprehension and learning, but also that writing is intimately associated with thinking. Therefore, if in-depth student thought is a desirable outcome, writing in the classroom can help achieve this (Rivard, 1994). These research findings combined with widespread "writing across the curriculum" movements have led to increases in the amount of writing and the time spent on writing in science classrooms (Monhardt, 1996). However, the traditional writing that is often employed in science classrooms does not necessarily take into account new findings about the cognitive connections involved in writing and many of

the beneficial aspects of the practice (Rivard, 1994). Consequently, the increased use of writing has not necessarily translated into increased student learning (Prain & Hand, 1996). Importance is placed on addressing the current state of writing in science classrooms and the practices used so these practices can be compared with current research into this area and, ultimately, the theoretical findings can begin to guide the practices used by instructors.

Traditional writing activities in the science classroom are typically communication tools with an evaluative purpose. Monhardt (1996) reports that writing in general can be categorized in three main ways. Some writing is informational or transactional that intends to convey or test information that is already known, normally through note taking, summaries, or explanations. A second type of writing is reflective or expressive and involves the author concentrating on and writing about their own feelings, reactions, or interpretations. A third type of writing is poetic or imaginative, with the intent being to elicit an emotional response from the audience (Monhardt, 1996). The majority of writing used in science classrooms is informational/ transactional (Applebee, 1984; Moore, 1994), and is generally used by the audience (the instructor) for evaluation purposes (Prain & Hand, 1996). The focus is on the finished product, a formal written piece that tells what the author (the student) knows (Tchudi & Yates, 1983). Marshall (1984) points out that when this is the case, students tend to disregard writing, even if the instructor asks for a personal opinion or feeling. This lack of personal involvement happens because students have been indoctrinated with the idea that the purpose of writing should be solely for evaluative situations.

As the majority of writing in science classrooms has traditionally focused on the communication aspect of writing (Holliday, Yore, & Alvermann, 1994) students are not required to use higher order thinking skills. Writing is used simply as a means of communicating to the instructor a bit or piece of scientific information. Writing for communication is typically a mechanical task like filling in blanks or answering recall questions at the end of a chapter (Rivard, 1994, Applebee, 1984b). Most note taking and even essay writing involves students copying what someone else or an "authority" says (Moore, 1994). This often leads to students placing more emphasis on the form of their writing than on the content of the writing. Since most of the writing is directed to the instructor, students will be most concerned with making sure they communicate what they

think the instructor wants them to say rather than on making their own meanings or connections (Moore, 1994; Monhardt, 1996).

A further aspect of "traditional" science writing that has impeded the implementation of writing to learn strategies is its reliance on the use of "proper" scientific terminology. Many past science educators and theorists have held the position that science writing should consist of learning the appropriate "technical language" of science, in order to be able to create "impersonal" reports that, according to them, promote the acquisition of scientific literacy (Halliday & Martin, 1993; Christie, 1989; McKenna, 1995; Sturgiss, 1994; White & Welford, 1987; Wignell, 1987). Language is seen as a "labeling system" in which students use language to tell and report (Sutton, 1993). This conveys to students that, in science, proper terminology should be used to label information rather than that student language should be used to interpret what is happening in a scientific context (Monhardt, 1996).

Traditional science writing also tends to neglect the role of writing as a clarifying tool for a student (Lloyd, 1990; Pearce, 1984). Studies have shown that when science classes are compared with other classes, the science classes have writing assignments that are much less likely to be set up to encourage further learning or growth on the part of the student (Rivard, 1994). The thought processes that the student author goes through as a consequence of writing are ignored and the process of writing is often abbreviated or neglected all together. In doing so, once again, instructors send the message that the only "important" aspect of the writing is the final draft read by the teacher.

A final characteristic of traditional writing in science is that it often does not convey an appropriate view of the nature of science (Sutton, 1993). Traditional activities, like lab reports, may emphasize procedural and process aspects of science over thinking and interpretive aspects. These types of traditional writing activities can convey to students that science involves doing things in the right order or way and then waiting for the results to appear. Little consideration is given to students writing about their own reactions to, questions about, or interpretations of what is happening in a particular lab activity (Monhardt, 1996).

Traditional writing activities are not necessarily promoting the science learning hoped for. In order to develop new activities that will take into account the cognitive aspects of writers as they go through the writing process and will encourage an appropriate connection

between the writing beliefs about the nature of science, new research in writing to learn must be addressed.

New Perspectives on Writing in Science

Constructivist viewpoints are beginning to challenge the traditional notion of writing in science. Research from this philosophical position is encouraging the use of writing activities as clarifying tools, in which "emerging" student understandings are expressed and possibly manipulated (Gunstone, 1995; Driver, 1988; Fenshman, Gunstone, & White; 1994, Treagust 1995; Northfield & Symington, 1991). These researchers argue that this type of focus in the writing would naturally encourage the use of students' own language, rather than "proper" scientific terminology. This, in turn, would make the learning of scientific concepts more accessible (Sutton, 1993; Lock, 1994) and would be a natural way for the "scaffolding" of student conceptual ideas (Prain & Hand, 1996). Further, this would lead to writing activities more in line with the nature of scientific learning.

With the aforementioned goals of writing to learn science as a guide, research has begun to focus on determining specific characteristics of writing activities that enable students to learn about and clarify science concepts and allow for the evaluation of that knowledge (Prain & Hand, 1996). This research has focused on the cognitive activities associated with writing. Earlier work by Bereiter and Scardamalia (1987), and more recent work by Galbraith (1999) attempt to describe the writing process in terms of cognitive interactions between content knowledge (science knowledge) and rhetorical knowledge (writing knowledge) that may lead to better conceptual understanding. These ideas are at least partly collaborated by new hypotheses on writing by Klein (1999). If instructors are to develop appropriate writing activities to enhance student learning, consideration must first be given to theories concerning what is happening cognitively as students write. Then these theories can guide procedures to set up effective writing to learn activities and provide justification for the use of writing in the science classroom.

Bereiter and Scardamalia (1987) discuss the interaction of content knowledge and rhetorical knowledge taking place in one of two ways. Some writing involves what they term "knowledge telling". This model is used to describe what happens when novice writers compose, or when the author simply restates previously learned material or previously made cognitive connections. This would be typical of the informational / transactional writing

normally associated with traditional science classrooms (Monhardt, 1996). In these cases, the author has some preconceived content knowledge (in the case of science learning, scientific conceptual knowledge) and they are simply concerned with using correct rhetorical techniques to report this knowledge. The writer may use what Bereiter and Scardamalia call "spreading activation", in which they retrieve as much knowledge as they can about the topic at hand. This type of writing process simply involves making these bits of content knowledge fit into the assigned writing type so that the reader can evaluate what the writer knows. This type of writing results in no new cognitive connections and no development of new conceptual knowledge. It relies only on what connections and conceptual knowledge the author already possesses (Bereiter & Scardamalia, 1987; Monhardt, 1996; Hand, Prain & Keys, 1999).

A second model proposed by Bereiter and Scardamalia, however, describes writing processes in which new construction of knowledge on the part of the writer is a product of the writing process. They call this model the knowledge transforming model of writing (Bereiter & Scardamalia, 1987). In this situation, the writing is characterized by a dynamic cognitive interaction between the author's content knowledge and rhetorical knowledge spaces. The content knowledge includes not only previously learned ideas, but also new data that is in need of interpretation. This content information is considered in conjunction with information about the correct rhetorical techniques needed to communicate the information. As the writer constantly considers the content in relation to the rhetorical constraints, he/she is constantly engaged in a cognitive revision process. Writing activities that would encourage this revision process resulting from the interaction of the two knowledge areas result in the writer forming new connections and new conceptual understandings (Bereiter and Scardamalia, 1987).

Galbraith's (1999) model, what he calls the knowledge constitution process, is similar to Bereiter and Scardamalia's knowledge transforming model as it also involves interaction between the writer's content knowledge and the writer's rhetorical knowledge. According to this model, writing causes activation of some part of the author's content knowledge. In order for this to become "text", the author's rhetorical knowledge must also be activated. The new bit of written text then causes this process to continue over and over as the composition progresses. This continual feedback and recycling eventually results in

the text containing knowledge organized in a way that is different from the way it was originally stored cognitively in the writer. This new arrangement of knowledge represents a new conceptual understanding of the topic.

Galbraith asserts that the essential component of this process is a "dispositional dialectic" (Galbraith, 1999) that takes place between the writer and the text. This dialectic is limited by two main factors: the writer's knowledge and the writer's strategy for translating the information into text. The writer's knowledge is in turn impacted by three main characteristics of every individual writer. These characteristics are the degree of complexity between the different conceptual units in the writer's memory, the overall number of units of conceptual knowledge that are activated throughout the writing process, and the writer's individual linguistic ability and skill. The writer's plan for translating the conceptual knowledge into text will be impacted by the way the writer plans for the task, the writing type that is used for the task, and the goals the writer has for the task (Galbraith, 1999; Yang, Hand, & Bruxvoort, 2002). The characteristics of the assigned piece of writing will ultimately determine the extent to which each of these factors will impact the student's writing. The learning that results from writing is dependent upon interactions of all of these characteristics throughout the writing process and culminates in new conceptual understandings that will be potentially different for all writers, even ones working on essentially the same tasks.

Klein (1999) discusses a total of four hypotheses describing the cognitive and metacognitive aspects of writing activities. While all of Klein's information does not perfectly match the models of Bereiter and Scardamalia and Galbraith, there are many similarities and particularly strong connections between these earlier ideas and two of Klein's hypotheses.

The first hypothesis of Klein's that is connected to Bereiter and Scardamalia's and Galbraith's models is what he calls the "forward search model". Of Klein's four hypotheses, this is the only one that applies exclusively to written communication, because it requires that there is a permanent (written) record of the different, or evolving conceptual understandings of the author. This hypothesis posits that there are two main "states" involved in the writing process, an initial problem state and a goal state. The initial problem state in writing situations would be a writer's current text. This would represent a "current"

description of the writer's conceptual understanding about a particular topic. As the writer rereads this initial state in order to redraft, it may cause him or her to reconsider some of his/ her conceptual ideas and he/she may be induced to change the text to better represent a new or emerging understanding. This action would be moving toward a goal state, or a better representation of the writer's conceptual understanding. This goal state would likely include knowledge that is new to the writer (Klein, 1999). This idea fits nicely with Galbraith's dialectic approach in that it recognizes the evolving interaction between mental conceptual knowledge and rhetorical idea or, as Klein calls them, "operators", that can help reshape the text that is representing the writer's understanding. It is also similar to Bereiter and Scardamalia's ideas, in relation to this dynamic interaction. However, while Bereiter and Scardamalia's model relies on the goal state providing the "primary stimulus and constraint" for writing, the forward search model asserts that the initial problem state or current draft is that primary stimulus (Klein, 1999; Bereiter & Scardamalia, 1987).

Bereiter and Scardamalia's ideas about the "knowledge-transforming model" of writing would actually be more closely related to a second hypothesis offered by Klein that he calls the backward search model. This model also recognizes that in some writing there is an interaction between content information and rhetorical information. In this hypothesis, it is the rhetorical information that is identified as driving the writing process that eventually results in new knowledge for the author. From this point of view, writing begins with rhetorical goals. The rhetorical goals are then accomplished by setting subgoals in the content area. These subgoals will work together to accomplish the overall rhetorical goals. The attempt to accomplish these rhetorical goals may actually lead to the author developing new conceptual understandings. For example, as a writer looks for rhetorical ways to move from one area of the text to the next, connections and interactions between the content represented in those two areas may be identified and used by the writer in his / her text. Or, if a writer is attempting to accomplish the goal of clarifying or defining particular terminology for the reader, they themselves may have to go through a clarification and definition process. This hypothesis of writing is more often associated with expert writers (Bereiter and Scardamalia, 1987; Galbraith, 1999) than with novice writers.

While there is not total agreement in the research community about the exact cognitive procedures associated with writing to learn activities or the exact procedures that

lead to conceptual benefits, there is a definite overlap among the ideas being presented. This overlap has resulted in new theoretical understandings emerging about the writing to learn process. When these new theories are considered, many of the traditional writing activities used in science, and their characteristics (such as emphasis on an evaluative purpose, a lack of higher order thinking skills, an over-reliance on terminology or the neglecting of the author's thought process) are called into question. One final characteristic of traditional writing that is being questioned by recent research is the relationship between writing activities and the nature of science (Hand et al. 1999).

The cognitive interactions associated with writing activities in science must also be considered in the context of what the nature of science is and what the nature of science learning should be in classrooms. The type, purpose, and characteristics of writing assignments are a reflection of the instructor's outlook in relation to the nature of science and can impact the students' outlook as well (Hand, et al. 1999) Writing to learn activities should be designed to not only gain the cognitive advantages they may afford, but also to represent alignment with an accurate outlook on how science is done. Recent National Science Education Standards promote the idea that science as a whole is best viewed from a standpoint in which all claims in science should be considered changeable and all work in science should be toward not only understanding claims, but also exploring alternative explanations. These claims should then be communicated to others. Writing tasks in science should be viewed and designed in relation to this goal. If writing activities convey to students a framework that science findings are absolute, or that knowledge "imparted" from an instructor is absolute, students will not be likely to adopt an evaluativist point of view. If, however, students are asked to engage in writing processes that require them to first clarify their own knowledge, then to evaluate their findings, and finally to communicate these findings to others, who are often non-science audiences, there is more likelihood that an evaluativist outlook will be gained and appreciated by the students.

Emerging research and theoretical perspectives on writing to learn activities in science consistently point to beneficial cognitive opportunities and increased student construction of new conceptual understandings of science concepts. In addition, an appropriate epistimological outlook on the nature of science can be promoted through writing to learn activities. However, for these benefits to be realized and for writing to learn in science

classrooms to move in beneficial new directions, the theoretical findings and beliefs must be implemented by practitioners in classrooms.

Implementing Effective Writing to Learn Activities in the Classroom

Introduction

As the theoretical framework for writing to learn in science continues to be clarified, research indicates that science instructors are beginning to implement a variety of writing activities in their classrooms. Using abstracts (Davis,et al, 1991), learning logs (Coles, 1991), journals (Clemons, 1991), question and response (Stanesco, 1991), and analogies and metaphors (Sorianno, 1989), along with other types of writing have all been explored in literature. These strategies have been studied at the college level (Davis, 1991, Coles, 1991), at the high school level (Jones, 1991; Wotring, 1981), and the elementary level.

In order for the use of these activities to become a universal practice among science educators, three main issues must be addressed. First, educators must be convinced of the practical, as well as theoretical, benefits of these activities. Second, concerns to be considered while implementing these strategies should be at least identified, and to as great an extent possible, dealt with. And third, a practical model for developing effective writing to learn activities based on the theoretical research evidence must be presented. In the following sections we will explore these three issues.

Benefits of Writing to Learn Strategies

Research has indicated that there are definite benefits associated with using writing to learn strategies in the classroom. Howard (1988) pointed out that the process of writing is so critical for educators in general because students are required to generate personal responses. This assertation highlights two aspects of writing that make it beneficial and, in many cases, different from other activities used in the classroom. First, there are general benefits associated with the act of writing because the act is a process, not simply a one-time event. This process encourages and may even require that the author reflects on his or her own thoughts throughout the experience as he or she clarifies his or her ideas (Wotring, 1981: Howard, 1988). Often, this process can also allow students to work out or work through more complex problems that require higher order thinking skills, rather than just providing a single response to a simple recall question (Resnick & Klopfer, 1989). These benefits are

collaborated in other research and the rationale for the benefits can be traced back to the models put forth by Bereiter and Scardamalia and Galbraith.

The second general, beneficial aspect of writing that Howard (1988) outlined is that it is personal. Since students are reflecting on, and constructing, their own thoughts, they must take responsibility for their learning (Wotring, 1988). They are required in a sense to both "ask and answer their own thoughts" as they write (Wotring, 1988). This-self questioning allows students to connect the new knowledge with which they are dealing to preexisting knowledge and their current understanding in order to construct their own, personal meaning in their head - even as they communicate that idea on paper to someone else (Voss, 1988). Again, these benefits associated with the personal nature of writing are direct results of aspects of the previously mentioned theoretical models of the writing process. Another positive consequence of the personal nature of writing may be greater long term retention. This has been indicated in studies showing students using writing to learn strategies doing better than control groups not using the strategies on delayed post-test assessments (Wotring & Tierney, 1989). Greater retention also seems to be a result of allowing students to use more expressive, more personal styles of writing in these kinds of activities (Nieswandt & Stork, 1995). When instructors allow students to move away from the informational/ transactional writing to more expressive or even poetic writing, even more benefits of the personal nature of writing may be realized (Moore, 1994).

Writing to learn may also allow for educational practitioners to bring assessment practices and learning outcomes more in line with their own philosophical and theoretical beliefs about education. Teaching based on inquiry methods and focusing on conceptual change has markedly increased in recent years (Monhardt, 1996; Andre, 1997). Research, however, indicates that as these "new" teaching practices have increased in popularity, there has been no corresponding change in assessment practices to match the pedagological change. Students are not asked in assessment situations to deal with or to manipulate the implications of their new knowledge or to determine how it relates to a different problem. The result is that student achievement on standardized, recall type tests is still significantly better than on written assessments and essays (Monhardt, 1996). Rivard (1994) reports on a similar phenomenon when he comments that even though students are being asked to do more writing in the classroom, they are not necessarily being involved in writing activities

that are enhancing their learning. By incorporating writing activities in which students are allowed to use their own personal language in assessment roles as well as in clarification and exploration activities, teachers may gain better alignment between the theoretical ideas driving the way they teach and the goals of their assessment practices. These types of assessments may also lead to greater achievement by all students, not just a select few (Stanton, 1987; Wills, 1993).

Other benefits of writing to learn activities are not directly associated with student learning outcomes, but are related to student attitudes and views of science. Studies at both the high school and college level have shown improved student attitude about science when courses involve writing activities (Kuhn & Aguirre, 1987; Liss & Hanson, 1993). One significant population that has traditionally had a more negative attitude about science is females, especially in specific scientific disciplines like chemistry and physics (Andre, 1997). Incorporating writing activities may be one way to not only make science more appealing to females (Coley, 1989, Connolly & Vilardi, 1989; Smail, 1987), but to also close the gender gap in achievement (Connolly & Vilardi, 1989).

Concerns Relating to Writing to Learn in Science

Although much research has focused on benefits and positive aspects of writing to learn, there have been concerns raised about the practice in the literature. One area of concern deals with the research methods used to study this area. Some researchers are concerned that many studies dealing with this practice have been poorly designed and not clearly or well-reported (Rivard, 1994, Monhardt, 1996). One often repeated criticism is that many of the studies are done in isolation (Langer, 1984; Langer & Applebee, 1987) rather than in authentic classroom settings (Rivard, 1994). In addition, many studies are performed on very small groups(Rust, 1987, 1989; Newel, 1984, 1986) or for a relatively short time (Hayes, 1987). Neither of these would be characteristic of most normal school settings. Also, many studies have focused on college level situations rather than secondary or elementary schools (Rivard, 1994). Finally, some literature expresses a fear that research in this area has not been completely objective. For example, Rivard (1994) points out that some researchers seem to predetermine that writing to learn is effective, but they do not necessarily support this claim with researched-backed specifics of how and why it is effective.

Concerns also exist about the writing process itself and some drawbacks associated with it in the classroom. Some researchers feel that writing has only demonstrated benefits to specific students with particular strengths and attitudes (Anderson, 1993; Fulwiler, 1987; Wells, 1993). Certain studies have indicated a general lack of student enthusiasm for writing (Anderson, 1993; Davis, et al., 1991; Halsor, Faul-Halsor, & Hearman, 1991), a marked difficulty for some students when asked to write reflectively, (Fellows, 1994; Keys & Simmons, 1995), and an unwillingness to do writing activities unless specifically required to do so (Trombulak & Sheldon, 1989). A final inhibiting factor for some students in relation to writing activities is time. Shifting from writing as a mostly summary process to writing reflectively is a gradual process (Coles, 1991). Considerable time may be needed for some students to grow comfortable with using writing as a tool to reflect on what they have learned or seen in the classroom, and many students may get frustrated or bored with the process before that goal is accomplished (Coles, 1991).

Time is also a practical constraint for some teachers implementing writing to learn activities. Many teachers are caught between a belief that students will not value an assignment unless they grade it and a realization that grading of writing activities takes considerably more time than grading other types of daily work and assessments (Jones, 1991). In addition, students crave teacher feedback throughout the process of writing, this feedback means increased time demands placed on the teacher (Wotring & Tierney, Monhardt, 1996). The result of this perception of a time problem with writing activities may lead some teachers to move away from using writing to learn techniques. Even if teachers remain committed to using writing to learn activities, these time constraints may result in teachers focusing on more readily noticeable aspects of writing such as grammar and sentence structure in their feedback or assessment of student work. This sends mixed signals to the students about the intent of their writing and the importance of the content (Beiersdorfer, 1991). The time issue combined with traditionally little or no consideration of writing activities as a part of the science curriculum in teacher preparation or teacher training courses (Holliday, Yore, & Alvermann , 1994) have resulted in many secondary science teachers remaining unconvinced that writing can help their students learn science (Prain & Hand, 1996) or simply unwilling to attempt these types of activities in their classrooms.

A Practical Model for Developing Writing to Learn Activities in Science

Research findings indicating that different kinds of writing lead to different kinds of learning (Schumacher & Nash, 1991) has manifested itself in the formation of research-based, practical models for developing writing to learn activities in the classroom. These models are built on the emerging theoretical perspectives mentioned earlier. They are an attempt to provide educators with an efficient way to develop effective writing to learn activities that will allow students to gain the cognitive and epistimological benefits mentioned earlier, and negate many of the concerns associated with these types of activities. One such model is a writing to learn model put forth by Prain and Hand (1996).

Many factors have been considered in the development of this model, but three factors stand out as critical features of any writing task that will truly lead to better learning. First, the particular writing task must place specific demands on the writer (learner). Second, the writer must be encouraged or enabled to gain a metacognitive understanding of strategies that would be effective for their writing. Third, the overall learning environment must be set up such that conceptual growth and understanding is valued over factual knowledge (Prain & Hand, 1996; Rivard, 1994). Each of these factors must be understood and taken into account by educators when developing effective writing to learn activities.

In relation to demands placed on students, research indicates that writing tasks leading to the greatest learning are characterized by students elaborating on ideas, reprocessing ideas, and hypothesizing and interpreting (Schumacher & Nash, 1991; Resnick & Klopfer, 1989; Sutton, 1992). The demands should also be such that students are required to use new concepts and ideas, not simply restate or reuse previously learned information that is already well-understood (Langer & Applebee, 1987).

Attainment of metacognitive strategies by students using writing activities requires that the students think about their own process of writing, as well as discuss and learn about others' strategies. The writing activities must allow students to recognize, develop, and assimilate into their own writing process strategies that will personally help them accomplish their rhetorical as well as content goals in their writing (Prain & Hand, 1996).

The overall learning environment is a critical factor not only in writing activities, but in the establishment of the students' conception of what is learning and how is it done. Students need to recognize that the activities, strategies, and outcomes developed through a

particular writing activity are all part of a broader epistimological ideal that learning science is about developing new relationships and connections between overriding concepts. It may be that particular writing types or audiences or purposes may be particularly well-suited to specific content areas. These matches should be actively sought by researchers and practitioners alike. The more matches that can be made, the more beneficial the overall learning environment will be.

The goal of an educator should be to focus on these three factors to create specific activities that "capture the imagination of the learner and give a target audience for whom it is necessary to clarify ideas" (Sutton, 1992, p. 89). It is also important that the writer feels the writing he or she is doing is not only meaningful, but also authentic (Pearson & Fielding, 1991). Instructors must be able to clearly state the expectations, rules, and intended product of writing for the students (Prain & Hand, 1996). Prain and Hand have developed a five component model that leads to the production of writing tasks with these three factors considered.

The topic to be written on is one component that must be considered when implementing a writing task. Foremost consideration should be given to the key conceptual ideas and how these are related to prior learning and previous topics. The instructor should consider what facts are necessary in regard to understanding the overall concepts, as well as what students should be able to do after gaining an understanding of the concepts. Ideally, these factors are brought out through the writing activity (Prain & Hand, 1996).

Another component to be considered in designing the writing activity would be the type of writing to be done. Myriad types of writing exist, including, but not limited to, journals, textbook explanations, letters, diary entries, concept maps, and posters. This is one aspect of the model that has received considerable attention in research. It is likely that particular types of writing will align more effectively with specific topics and conceptual areas (Rivard, 1994). Research continues to focus on determining what are the most effective matches between topic and type (Prain & Hand, 1996). This one component that may help negate the concern of only certain students with certain strengths and attitudes benefiting from writing to learn activities. By using a variety of writing types throughout the year or allowing students choices in which writing types are employed, more student

strengths and interests might be reached. This may also potentially increase overall student enthusiasm for these types of activities.

The method of text production is yet another component to be considered when developing effective writing to learn activities. This involves determining the tools to be used in doing the writing as well as the procedure to be used, such as groups, individuals, or redrafting. This may be directly related to the type of writing desired and could include paper and pencil production, computer production, or some alternative (Prain & Hand, 1996). This factor may be affected by what materials are readily available or the skill level of the students involved in relation to the tools available. Discussion with students in regarding this component may lead to valuable consideration by all students of the metacognitive strategies used in completing the writing (Prain & Hand, 1996).

The purpose of the writing is a component that must be clearly defined by the teacher for the students. Consideration of this component first focuses on when in the sequence of learning for the particular topic involved is the writing activity going to take place. Then, the exact goal of the writing, in terms of learning for the student, should be defined. Some possible purposes might include clarifying knowledge during a unit, exploring initial ideas about a unit, or applying recently acquired learning to a new situation (Prain & Hand, 1996). One way to deal with the concern of allowing students adequate time to become comfortable with writing (Monhardt, 1996) is to vary the purpose for writing throughout a unit or throughout the year. If students are allowed to write for less "pressure-filled" purposes than evaluation, they may have a chance to gain confidence in their writing and appreciate the benefits of the writing for their own clarification or exploration.

A final component to be considered in writing to learn activities is the audience. Research clearly indicates that if writing to learn is to be effective, the tasks involved should be authentic (Rivard, 1994). The audience factor deals most directly with this goal. Traditionally, most writing in science has been directed toward the teacher only (Monhardt, 1996). This is typically not perceived by students to be characteristic of an authentic task. Rather, it is viewed as a contrived situation which allows for evaluation. In order to make these tasks more authentic, and more valuable, the audience factor must be clearly defined and feedback must come directly from this audience if possible (Prain & Hand, 1996). Manipulation of the audience factor may also be a practical way for teachers to deal with

time constraints surrounding writing activities. The different audiences can provide the feedback, or even use standardized rubrics to provide evaluation so the teacher does not have to do this for all of the writing in his/her class.

For this model to be truly effective, researchers and practitioners alike must continue to develop effective matches among the five components involved. As the model is implemented to develop writing to learn activities, careful consideration must be given to the actual learning outcomes. Non-biased, objective assessment of these outcomes will not only improve the use of the model for teachers but will also go a long way toward answering the criticism that research in this area has been biased and based on preconceived presumptions of benefits. For example, it is probable that, much like with writing types, different audiences may be particularly helpful for specific topics. Just as probable is the fact that different audiences may be particularly helpful for different sets of students (Prain & Hand, 1996). The idea of a possible "alignment" between particular audiences and particular tasks needs to be addressed in research.

Audience in Relation to Writing Tasks

While all of the components of the previously mentioned writing to learn model are important, from a rhetorical perspective, the audience is extremely critical. And yet, the audience is one of the most understudied aspects of writing to learn activities. The rest of this literature review, and the study that follows it, will discuss the important aspect of the audience in relation to writing to learn activities. In addition, the benefits of writing to learn in general will be explored, with particular consideration given to determining if specific audiences may be more beneficial in gaining a conceptual understanding of particular biological concepts.

Good writers develop an understanding that the language they use and create is interactive. This necessitates careful consideration of the intended audience (Engler, Raphael, Anderson, Avery, & Stevens, 1991). In considering the audience, writers must also realize that if the language used in the text is completely technical, it would be meaningless for the audience because the audience would not have "everyday" language in which to "ground the technical" information in, as Chapman (1992) points out. Therefore, the goal of a good writer is to create a piece that not only puts their own personal understanding on paper, but communicates that understanding to a particular audience. In terms of writing to

learn for science, this means having students create what Howard and Barton (1986) call "meaningful writing" in which previous learning and new knowledge are connected through "authentic authoring tasks for uninformed audiences". In order for teachers to establish tasks with both realistic purposes and authentic audiences, some theoretical considerations about what role the audience plays in the creation of meaning for written communication must be addressed (Ede, 1984).

As previously mentioned, almost all writing done in science classrooms today is done for one audience: the instructor. Typically, this is so the teacher can evaluate and examine what the student has learned or demonstrated (Applebee, 1981). Researchers assert, however, that there are several drawbacks to using the instructor audience exclusively. First, students often view this type of writing as pointless, because they feel they are repeating something the instructor already understands (Monhardt, 1996). In fact, some analyses have even indicated students suffer "writers' block" because they try to anticipate what the teacher wants them to say instead of what they want to say or what they understand (Monhardt, 1996). This typically results in students feeling they have no sense of purpose. These factors result in an activity or assignment that is not characterized by the adequate mental engagement that would lead to meaningful learning (Keystone, 1993) suggested in the earlier models. Authentic audiences outside the teacher, however, would likely promote more revision and clarification on the part of the author. This is extremely beneficial in light of research which indicates that the more writing content is manipulated, the more likely it is the author will remember and understand the information (Prain & Hand, 1996).

One difficulty specific to writing is the ability of students to use different "syntactic complexity". This is the use of different languages for different target groups, and it develops at a much later stage in writing development than it does in oral development (Cazden, 1970; Shatz & Gelman, 1973.) One early study (Smith & Swan, 1977) showed that college students were much more likely to manipulate their syntax and word structure for younger or older groups than 6th graders were. This is a gradual and natural process , but since it does not take place as readily for students in relation to writing, it is critical that teachers not only explicitly point out the authentic audience they are using for writing activities, but also allow students to discuss, explore, and determine important characteristics of the audience (Piaget, 1932). In order to do this, teachers must have an

understanding of the possible ways students can develop an audience in writing. Two competing theories have been advanced in the literature to answer this question (Ede & Lundsford, 1984).

The Audience-Invoked Theory

One theory of how students should consider their audience has been called the "audience-invoked" theory (Ede & Lundsford, 1984). Supporters of this theory assert that it is dangerous to put too much emphasis on the audience when writing. They posit that writers must always conceive of the audience on their own. Since writers must always fictionalize their audience according to this theory, the writers' goal in relation to the audience is to provide cues throughout the writing that will "invoke" the response from the reader that the writer desires (Long, 1980; Walter & Ong, 1975). In fact, these theorists go as far as saying that not only does the writer have to fictionalize his or her audience, but that the reader also has to fictionalize his or herself "into" the role the writer intended for them (Ong, 1975). Proponents of this concept encourage students to prepare for writing tasks by looking at other, finished writing and determining what type of cues have been placed in the reading by the author in an attempt to promote the "appropriate" response from the reader (Ede & Lundsford, 1984).

Several criticisms have been offered in response to the audience-invoked outlook. First, it is argued that this is too simplistic a view of the audience. The argument that while speech communication has an "authentic" audience, written communication does not, is oversimplifying the entire writing process (Ede & Lundsford, 1984). Secondly, the audience invoked idea does not take into account how different subject matters may impact and be impacted by their audiences. Different subjects or topics may prove to be easier or more difficult for a particular author to construct a written composition for. In addition, different subject matter may prove to be easier or more difficult for the reader to adopt his or her appropriate or intended role. This fact is virtually ignored in the audience-invoked hypothesis when stating that all audiences are simply fictionalized (Ede & Lundsford, 1984). These criticisms have been partly responsible for the conception of a competing theory of audience.

The Audience-Addressed Theory

The competing literary theory in regard to the audience has been called the audience-addressed theory (Ede & Lundsford, 1984). This theory promotes the central role of the audience in all writing and even asserts that the very first concern in writing should be considering what are the characteristics of the audience and how can the writing help guide the reader's comprehension of the stated material (Mitchell & Taylor, 1979). Supporters of this theory admit that in some cases the audience must be fictionalized, but even in these cases, they assert, the conception of the audience should be "as close as possible to as many readers in the real world" (Pfister & Petrik, 1980). These theorists feel that the beliefs, attitudes, and expectations of the audience will ultimately determine whether or not the ideas intended by the author are conveyed. In order to prepare for this condition, the audience must be considered up front and in detail. Practitioners of this theory encourage students to participate in "real world" writing in which they write to authentic audiences (Ede & Lundsford, 1984; Mitchell & Taylor, 1979).

The audience-addressed theory is not without its share of criticism. Many argue that this theory takes too much power for developing the motivation and determining the evaluation of the written work away from the writer and places it in the hands of the audience. Others worry that by concentrating too much on the audience and what can be done to influence, persuade, and guide that audience to a particular outcome (intended by the author), ethical and moral standards of writing may be lost (Ede & Lundsford, 1984). Finally, Wall (1982) points out that this theory seems to ignore the fact that the writer will at times actually take on the role of reader of his or her own text. In this case, the audience may not be some "other" group of people.

A Compromise Theory

This criticism by Wall may be of the most importance to educators interested in writing to learn strategies. The internal dialogue discussed by Wall, in which the writer reads his or her composition as he or she is writing it in order to self-evaluate and self-critique, is exactly the dynamic process of interaction discussed by Bereiter and Scardamalia, and Galbraith in their models (Bereiter & Scardamalia, 1987; Galbraith, 1999). Since it is this interaction that leads science students to a clarification or revision of their ideas while they write about science, it would be incongruent for proponents of writing to learn strategies to

accept the audience-addressed viewpoint. However, given the preference of practitioners of writing to learn strategies (and constructivist educators in general) for authentic audiences for students (Prain & Hand, 1996), the audience-invoked theory does not provide a good fit, either. A compromise position put forth by Ede and Lundsford (1984) provides a better conception of an audience that fits with research and emerging theoretical and practical models in writing to learn in the sciences.

This compromise position takes aspects of the two previously mentioned audience theories and connects them. This approach asserts that writing is really an integration of both reading and writing. Therefore, while the audience, its structure, and its characteristics must be considered when writing, the author must also use their personal language to "give body to their own conceptions" or ideas to the reader (Ede & Lundsford, 1984). Part of the reason the author must not simply rely on their preconceived notions of the audience in constructing their paper is that the audiences reading their paper may "shift." In a sense, the author, while taking into account ideas about his or her audience, must work to convince *anyone* who reads his/her paper that he/she completely understands the material and is presenting quality information. This is facilitated by the internal dialogue Wall mentioned and is exactly the type of dynamic, write, revise, rewrite procedure that science educators believe will lead to better scientific understanding (Bereiter & Scardamalia, 1987; Galbraith, 1999; Klein, 1999).

The compromise position recognizes that writing is indeed a two-faceted endeavor. The first involves the writer clarifying his/her own thoughts and connections. This involves the author reading, rereading, and revising his/her own paper. The second area is the communication aspect in which the information is clearly and accurately conveyed to an audience outside the author. If the audience is invoked, the second aspect of writing (communication) is not entirely accounted for. If the audience is addressed, the first aspect (clarification by the author assuming readership) is not entirely accounted for. For complete scientific learning to take place through writing, both aspects of writing must be adequately involved. The compromise position on audience conception allows for this combination and is the theory that fits best with writing to learn strategies.

Summary

Writing can be a valuable tool for helping to develop, clarify, and evaluate student conceptual understandings in science. In order for these goals to be accomplished, however, the theoretical background of writing to learn needs to be addressed and involved in the implementation of these types of activities. In order for this implementation to be valuable, it must be widespread, and if it is to become widespread, educators need to be convinced of its value.

In order to convince educators that writing to learn activities can be valuable pedagogical tools in their classrooms, several factors must be considered. First, research must continue to show in unbiased but practical classroom situations that writing to learn activities do truly promote and lead to better, deeper, and more long-lasting student learning. Second, the model(s) used to develop writing to learn activities must be continually developed and revised to make sure they are effective, efficient, and practical for classroom use and student learning. The continued revision of these models would include further research into what are the best matches between specific topics, and the methods of text production, the type of writing, the purposes, or the audiences used in writing about these topics.

The rest of this thesis will be an attempt to combine the research presented in this literature review with actual data from a classroom study to move toward the two conditions for teacher adoption of these activities mentioned in the previous paragraph. First, whether or not writing to learn activities do make a significant positive difference in the understanding of two biology topics will be explored. Then, a discussion on the effects of using different audiences in the writing tasks for these topics will be undertaken to begin to explore the question of appropriate "matches" between components in the writing to learn model.

CHAPTER 3. JOURNAL ARTICLE

Introduction

Research on writing to learn in science has gained momentum during the last decade (Holiday, Yore, & Alvermann, 1994). Unfortunately, the connections between writing activities and science achievement are not well understood. Science educators and researchers agree that the goal of writing to learn activities is the creation of learning situations and environments in school settings that allow for meaningful writing, the encouragement of critical thinking and the evolution of conceptual understanding (Holiday, Yore, & Alvermann, 1994). Research is currently focused on establishing the theoretical underpinnings of why writing facilitates this type of learning and what happens cognitively that leads to increased learning. As this research base grows, one new area of discussion is how science education practitioners can design meaningful writing activities and what the characteristics of these activities should be. In particular, the value of writing to different audiences has not been fully researched. This research project was designed to explore whether or not writing to learn activities facilitate student conceptual understanding in a biology classroom setting and if writing to different audiences is an important component in the writing process.

Literature Review

Although writing is typically considered the interaction of the processes of the author polishing his or her own ideas and the author attempting to communicate those ideas (Howard & Barton, 1986; Bereiter & Scardamalia, 1987; Galbraith, 1999), writing in science classrooms has been traditionally focused on the communication aspect of writing. This communication is generally to the teacher and used for evaluative purposes (Monhardt, 1996). Writing to learn strategies, conversely, use writing as a tool to facilitate conceptual change in the author as a result of writing (Holiday, Yore, & Alvermann, 1994).

Emerging Views on Writing to Learn

Bereiter and Scardamalia (1987) and Galbraith (1999) have attempted to explain why writing allows for conceptual change by discussing the cognitive actions involved. For these researchers, writing involves the interaction of two different knowledge spaces: the content knowledge space and the rhetorical knowledge space. In a science writing task, a student's science content knowledge would be interacting with the rhetorical knowledge. As the

student makes conceptual connections and writes them down, the student's linguistic or rhetorical understandings shape the writing. This then leads to further writing that would again involve both processes. As the writing continues, the interaction between these two knowledge spaces leads to feedback among the cognitive pathways and connections involved and eventually manipulates those connections. At the conclusion of the writing, the connections would be changed and learning would have taken place (Bereiter & Scardamalia,1987; Galbraith, 1999). Klein (1999) offers a total of four hypotheses to describe the writing process. While not all four match the findings of Bereiter and Scardamalia (1987) and Galbraith (1999), two of his hypotheses overlap significantly with the earlier findings. These reiterate the importance of dynamic cognitive interactions between rhetorical knowledge and content knowledge shaping new learning (Klein, 1999).

By focusing on the potential of these cognitive aspects of the writing process, new, more meaningful writing to learn tasks can be created. These tasks would ideally show connections between old and new information, use authentic and uninformed audiences, promote the manipulation and evolution of conceptual ideas in the author, and focus on metacognition (Prain & Hand, 1996; Santa & Havens, 1991). The demands of these tasks on the writer would have to be clearly defined by the instructor in order to effectively promote increased student learning. If widespread use of these activities is to be accomplished, science instructors must first be convinced of the benefits of employing these techniques and then be presented with a guide for designing effective tasks of this type.

The implementation of writing to learn tasks has demonstrated many benefits in the science classroom. Writing tasks are helpful because they encourage (and in many cases require) students to take responsibility for their own learning (Wotring, 1988). The process nature of writing also necessitates continual clarification of conceptual ideas by the writer (Howard, 1988, Bereiter & Scardamalia, 1987, Galbraith, 1999) which may then lead to longer term retention of concepts (Wotring & Tierney, 1989). If students are allowed to use their own language in writing, and not required to use "proper terminology," success in regard to achieving conceptual understanding is often gained by a wider range of students through these writing to learn activities (Stanton, 1987; Wills, 1993). Other benefits not directly associated with increased performance include improved student attitudes (Kuhn & Aguirre, 1987; Liss & Hanson, 1993), improved performance by females in the sciences (

Connolly & Vilardi, 1989), and the ability of instructors to match their philosophical beliefs about learning with the assessment practices they use.

A Model for Developing Writing to Learn Activities in the Classroom

Implementation of writing to learn activities can be facilitated by using a model designed by Prain and Hand (1996). This model aids in the production of writing tasks that have three critical components of effective writing activities. First, the model allows for writing activities that put specific, clearly defined demands on the writer. Secondly, the writer is encouraged and given the opportunity to gain a metacognitive awareness of the strategies that are helpful to himself or herself or other writers through these activities. Thirdly, the overall learning environment is taken into account in relation to the writing tasks so that a learning situation where conceptual growth is more important than factual knowledge is achieved (Prain & Hand, 1996).

The Prain and Hand writing to learn model has five components to be considered in any writing activity. These five components all impact each other and allow for any of a number of varied writing tasks. One component is the topic to be written about, and this must be clearly pointed out to the student. The type or style of writing to be done is another component that must also be clarified. Often, the type of writing may be a reflection of a third component to be considered: the purpose of the writing. The writing can take place for any number of purposes, dependent, to a large extent, on the timing of the activity within the unit of study. The method of text production is another component to be considered. Finally, the intended audience for the writer must be determined and specifically considered by the author (Prain & Hand, 1996).

If this writing model is to be used to truly develop effective writing to learn tasks, not only is it imperative that all five components be well understood, but research must also be undertaken to determine the "best fit" between the five contributing components. One component that is particularly important from a rhetorical point of view is the audience.

Audience

Audience is a critical component of all good writing. Good writers develop an understanding that the language they use and create is interactive and that this must be taken into account by analyzing their audience (Engler, Raphael, Anderson, Avery & Stevens,

1991). Different methods of accomplishing this audience analysis have been offered in research literature (Ede & Lundsford, 1989).

Long (1980), among others, promotes a theory of audience analysis called the "audience-invoked theory" (Ede & Lundsford, 1984) . This viewpoint posits that there is too much emphasis placed on determining the characteristics of the audience in most writing. Rather, authors should concentrate on placing cues throughout the writing that will lead the reader to the understanding and interpretation of the text that the writer intended. Promoters of this view feel that students should look through existing texts to find cues other authors have used to promote the acquisition, by their audience, of the concepts presented in the writing. The writers should then work to use similar cues in their own writing. In addition, in this situation, the readers are required to "fictionalize" what their role, as audience, should be in order to gain the proper interpretation of the text (Ede & Lundsford, 1984).

An opposing view of audience conception is offered by Mitchell and Taylor, (Ede & Lundsford, 1984). Possessors of this view, called the "audience-addressed view", assert that the beliefs, attitudes, and expectations of the audience, not cues placed by the author, will ultimately determine whether or not the correct intent of the writing is communicated (Ede & Lundsford, 1984; Mitchell & Taylor). The audience is thought to play the central role in written composition and writers are encouraged to consider the audience prior to doing any writing. Proponents of this theory encourage "real world" writing in which students have authentic audiences, outside the classroom to which they are writing (Ede & Lundsford, 1984; Mitchell & Taylor, 1979).

The aforementioned positions on audience have each received criticism. The audience invoked idea is often labeled too simplistic, while the audience addressed viewpoint is accused of neglecting "internal dialogue" in which the writer self-assesses their reading (Ede & Lundsford, 1984; Wall, 1982). Writing to learn in the sciences is dependent upon this inner discourse as a means to clarify learning (Galbraith, 1999; Bereiter & Scardamalia, 1987), as well as communication to authentic audiences. Therefore, in relation to writing in science, a more useful position on the audience is a compromise position in which the author does consider the characteristics of the audience, but at the same time realizes that the audience reading the work may change and therefore puts cues in the writing to aid the reader in gaining the concepts the writer intended (Ede & Lundsford, 1984). This allows

writers to write to shifting audiences who might share overall or general characteristics that must be considered, but have individually unique traits that would slightly alter their position as audience. If one asserts that all students have differing prior knowledge coming into exposure to any concept (Andre, 1997), this supposition in relation to shifting audiences seems necessary.

If educators take this compromise position, their dilemma becomes determining which authentic audience types are most useful in promoting student learning. Current research in this area has shown that writing to authentic audiences younger than the writer may be beneficial as it promotes better clarification by the author. This may be due to the necessity of the author translating their conceptual ideas into an explanation using language that is appropriate to a younger audience. This appropriate language will likely not include many of the technical terms used in the author's initial learning of the material (Yang, Hand & Bruxvoort, 2002).

Research Design

Overview

The intent of this study was to explore in an authentic classroom setting and in a quantitative way the effects of using writing to learn activities within a science classroom. If the use of writing to learn strategies is to become widespread among teachers and practical for teachers, they must be shown to have demonstrated positive effects in these authentic classroom settings. In addition, information about the most effective audiences for students to write to is needed. Matches between different audience types and different science concepts must be researched and tested. This particular study was designed to both determine if positive effects were a result of using writing to learn activities, and explore effective matches between audience types and science concepts. It was based on the following research questions:

1. Does using writing to learn strategies and activities improve student conceptual understanding of science concepts?

2. Does the particular audience that a student writes to have an effect on the conceptual understanding gained by that student?

The Study

This quantitative study used a quasi-experimental, pre/post test design. Four pre-existing biology classes with the author as the instructor were used as the four independent treatment groups in the study. Two other pre-existing biology courses covering identical conceptual material were used as control groups, one for each stage of the two stage study. Students involved in the study were year 9 and year 10 students attending a public high school of approximately 1600 total students in Iowa. The study took place near the end of a year long general biology course in which all students were working towards completion of course work in biology based on the same district curriculum.

The study had a two stage design involving two separate units that were a normal component of this year long general biology course. The first unit was comprised of ten fifty minute lessons that dealt with the human nervous system with these major concepts identified as the focal point of instruction and assessment:

1. The nervous system coordinates all systems in order to maintain a homeostatic condition in the human body.

2. The different parts of the nervous systems have separate, specific jobs but all function together to help with this coordination.

3. The nervous and endocrine systems often work together using feedback systems.

The second unit of study involved ten fifty minute lessons dealing with the human circulatory and respiratory systems. The main ideas guiding this unit were:

1. The circulatory and respiratory systems must function together in order to provide the human body with the ability to make energy.

2. The circulatory system is a transport system for many items, including nutrients, oxygen, and waste.

3. The oxygen transported by your circulatory system must be gathered in by your respiratory system.

The first stage of the study consisted of all four treatment groups involved in identical writing to learn activities and a control group that did no writing activity. Instruction dealing with the nervous system was given to all students through discussion, lab activities, and individual assignments. At the completion of the unit, the treatment groups all wrote an explanation about how the nervous system helped maintain homeostasis in

humans. All groups wrote to the instructor as their audience. The students received feedback about their rough drafts from the instructor, and then prepared final drafts that were assessed by the instructor. The audience, purpose, type of writing, topic, and method of text production were all discussed by the entire class at the outset of the activity. Upon completion of the writing task, the students took a post test over the concepts covered. The control class did paper and pencil, end of the chapter questions as a means of review for the end of the unit post test. The purpose of stage one was first to compare performance on the post test between "writers" and "non-writers", and second to provide all students in the treatment groups with a writing experience so that in the second stage differences in the writing experiences themselves could be disregarded as a contributing factor to achievement.

The second stage of the study again involved the four treatment groups doing a writing activity and a control group doing no writing. In this stage, however, the treatment groups all wrote to different audiences. All five groups received similar instruction on the topic of the coordination of the circulatory and respiratory systems. Consistent lab work , individual homework, and discussions were undertaken to insure similar time on task for all groups. At the completion of the unit of study, each treatment group again wrote an explanation, this time about the coordination of the circulatory and respiratory systems. Treatment groups were randomly assigned audiences to write to. The first period treatment group wrote their explanation to a group of 3rd and 4th grade students. Second period wrote to their parents, 5th period wrote to an English class of year 9 and year 10 students, and 6th period wrote to the instructor. The control group that did not write did end of the chapter review questions to wrap up their study of the unit. All groups were administered a post test, and results of the post test were analyzed to determine if there were significant differences between the treatments groups as a whole and the control group, and to see if there were significant differences among the writing groups, based on the audience written to. Table 1 summarizes the overall study design.

Pretest and Post-Test

In both stages of the study design, students were administered identical pre and post tests. The tests were divided into two main sections, a recall section consisting of multiple choice or true false questions, and a conceptual section consisting of short answer questions. The nervous system assessment consisted of thirteen multiple choice questions and three

Table 1 - Overall Study Design

Stage One-Nervous System

Control	Period 1 Pretest	Period 2 Pretest	Period 5 Pretest	Period 6 Pretest
Discussion	Discussion	Discussion	Discussion	Discussion
Lab Work	Lab Work	Lab Work	Lab Work	Lab Work
Text Problems	Text Problems	Text Problems	Text Problems	Text Problems
Chapter Review Questions	Written Explanation for Teacher	Written Explanation for Teacher	Written Explanation for Teacher	Written Explanation for Teacher
Post test	Post test	Post test	Post test	Post test

Stage Two-Circulatory / Respiratory

Control	Period 1 Pretest	Period 2 Pretest	Period 5 Pretest	Period 6 Pretest
Discussion	Discussion	Discussion	Discussion	Discussion
Lab Work	Lab Work	Lab Work	Lab Work	Lab Work
Text Problems	Text Problems	Text Problems	Text Problems	Text Problems
Chapter Review Questions	Written Explanation for 3rd/4th graders	Written Explanation for Parents	Written Explanation for H.S. English	Written Explanation for Teacher
Post test	Post test	Post test	Post test	Post test

short answer, conceptual questions. The three short answer conceptual questions were as follows:

1. Compare the effects of the sympathetic and parasympathetic divisions of the autonomic nervous system.

2. Explain to your grandparent how the cells of the human body are similar to individuals in a society who work together to accomplish shared goals.

3. Based on the process of feedback inhibition, explain to your seventh grade cousin how your body maintains a relatively stable internal temperature.

Univariate analysis of variance was used on five different areas to assess differences between the treatment group as a whole and the control groups. Post test means for the multiple choice section (POST MC), conceptual short answer question one (POST SA1), conceptual short answer question two (POST SA 2), conceptual short answer question three (POST SA3), and total score (POST TOT) were compared. In addition, improvement scores in all five of these areas from pre test to post test for the treatment groups were recorded to note trends, but were not statistically analyzed.

The pre and post tests for the second stage consisted of twenty multiple choice questions, four true false questions, and three conceptual short answer questions. The conceptual short answer questions were as follows:

1. Describe to your uncle how the blood vessels in the circulatory system are like highways in a transportation system.

2. Explain to your 5th grade sister how the circulatory system and the respiratory system are dependent upon each other and what would happen if one was damaged.

3. Describe the pathway of a drop of blood going to your brain as it travels from your heart and back.

Again, univariate analysis was applied to post test scores for the control group and the treatment group as a whole. These comparisons were done on six post test areas in this stage, including multiple choice (POST MC), true-false (POST TF), conceptual short answer one (POST SA1), conceptual short answer two (POST SA2), conceptual short answer three (POST SA3), and total score (POST TOT). In addition, multiple comparisons between the four treatment classes using Tukey HSD tests were used to analyze for significant differences from groups writing to different audiences.

These tests were prepared by the instructor as a normal assessment to go with the concepts covered in the two units. Recall questions were taken from the Prentice Hall Biology Test Bank and the Advanced Placement Biology Test Bank. The conceptual questions were created by the instructor, in consultation with colleagues on staff. Test were analyzed for internal consistency. All exams were graded by the instructor, and random conceptual questions were graded by a science colleague in order to assure inter-rater reliability.

Student Grades

Students' overall grade in General Biology were known for each student going into the discussion of the two topics involved. This "baseline" grade for each student was used as a covariate to correct for differences of ability going into the study.

Results

Reliability and Validity

The Cronbach's alpha test was used to determine internal consistency for both the nervous system post test (n=149, alpha=.80) and the circulatory / respiratory post test (n=124, alpha=.69). Inter-rater reliability was 70% or higher on all conceptual questions for both tests.

Nervous System Results

I. Treatment vs. Control Group: Several one-way analysis of covariance were used to compare the mean differences between the control group and the treatment group for each of the components of the nervous system post test. Student general biology grades at the inception of the study (baseline grades) served as a covariate for analysis of covariance. In all areas of the post test, the treatment group did significantly better than the control group: POST MC ($F= 49.2$ $p = .0001$ MS=191.3), POST SA1 ($F= 139.8$ $p = .0001$ MS = 533.1), POST SA2 ($F = 51.4$ $p=.0001$ MS=313.2), POST SA3 ($F =188.7$ $p = .0001$ MS=409.5), and POST TOT ($F = 322.1$ $p =.0001$ MS=126.658). Table 2 shows individual means and individual standard deviations for each group.

Table 2 Nervous System Results

Individual Means and Standard Deviations

Question	Period 1		Period 2		Period 5		Period 6		Control	
	M	SD	M	SD	M	SD	M	SD	M	SD
Multiple Choice	65.5	15.9	63.2	15.7	59.7	15.9	62.4	13.0	44.2	15.8
Short Answer 1	63.7	27.2	60.9	18.6	57.9	30.4	57.9	27.4	9.0	16.9
Short Answer 2	40.2	21.0	34.2	16.5	48.2	23.0	46.4	18.9	18.9	9.9
Short Answer 3	68.1	26.8	69.6	19.9	73.1	25.8	76.4	21.8	20.0	15.0
Overall Total	59.8	16.2	57.1	11.2	58.9	16.4	60.2	13.3	21.3	7.1

Multiple comparisons were also done between the control group and each individual class making up the treatment groups. In addition, all treatment classes were compared to each other. Significant differences were noted only for each treatment group compared to the control group. No significant differences were noted between any two classes within the treatment group. Table 3 summarizes this data.

Circulatory / Respiratory Systems

I.Treatment vs. Control Group: Univariate analysis of variance was again used to determine if there were significant differences between the control group and the treatment groups as a whole for the different components of the circulatory / respiratory post test. Baseline grades of the students again served as a covariate. Significant differences were noted for conceptual short answer question one ($F=3.9$, $p=.005$, $MS=372.8$), conceptual short answer question two ($F=9.475$, $p=.0001$, $MS=205.3$). and post test total score ($F=7.136$, $p=.0001$, $MS=258.2$). No significant differences were noted for multiple choice ($F=1.957$, $p=.106$, $MS=233.7$) and true false ($F=2.150$, $p=.079$, $MS=456.8$). Conceptual short answer question three was the only conceptual question not significantly different ($F=2.4$, $p=.055$, $MS=450.7$). Means and standard deviations are summarized in Table 4.

Table 3 Nervous System Multiple Comparisons

Significance in Multiple Comparisons (*** = significant at .05 level)

1) Multiple Choice

	Control	Period 1	Period 2	Period 5	Period 6
Control		***	***	***	***
Period 1	***		----	----	----
Period 2	***	----		----	----
Period 5	***	----	----		----
Period 6	***	----	----	----	

2) Short Answer 1

	Control	Period 1	Period 2	Period 5	Period 6
Control		***	***	***	***
Period 1	***		----	----	----
Period 2	***	----		----	----
Period 5	***	----	----		----
Period 6	***	----	----	----	

3) Short Answer 2

	Control	Period 1	Period 2	Period 5	Period 6
Control		***	***	***	***
Period 1	***		----	----	----
Period 2	***	----		----	----
Period 5	***	----	----		----
Period 6	***	----	----	----	

4) Short Answer 3

	Control	Period 1	Period 2	Period 5	Period 6
Control		***	***	***	***
Period 1	***		----	----	----
Period 2	***	----		----	----
Period 5	***	----	----		----
Period 6	***	----	----	----	

5) Overall Total

	Control	Period 1	Period 2	Period 5	Period 6
Control		***	***	***	***
Period 1	***		----	----	----
Period 2	***	----		----	----
Period 5	***	----	----		----
Period 6	***	----	----	---	

Table 4 Circulatory / Respiratory Results

Individual Means and Standard Deviations

Question	Period 1		Period 2		Period 5		Period 6		Control	
	M	SD	M	SD	M	SD	M	SD	M	SD
Multiple Choice	62.2	18.5	66.5	16.5	74.2	18.6	70.9	13.7	56.9	22.3
True False	63.9	33.5	76.1	24.4	84.2	20.2	77.7	21.9	53.1	22.1
Short Answer 1	54.9	23.0	60.9	21.1	55.0	20.1	47.6	19.6	27.1	19.1
Short Answer 2	69.6	17.0	70.4	17.9	63.3	7.6	61.4	14.3	33.8	23.9
Short Answer 3	39.5	21.2	44.3	24.3	54.2	23.4	44.5	25.3	20.4	23.4
Overall Total	55.4	16.3	60.3	16.3	65.6	15.2	58.9	15.2	39.8	18.2
n	27		23		30		28		16	

II. Treatment Group Comparisons: To determine if there was a difference in the groups due to baseline grades, univariate analysis was applied to all results. Multiple comparisons were then made using the Tukey test to note any significant differences between individual groups. No significant differences were noted for any of the groups writing to different audiences in their performance on the post test. For all questions where significant differences were noted, the treatment group performed significantly better than the control group, but no one treatment group was shown to perform significantly better than any other treatment group. On conceptual question three, despite the treatment groups as a whole not being significantly better than the control group, all treatment groups did perform significantly better than the control group when compared individually except treatment group one ($p=.084$). Multiple comparisons for phase two of the study are shown in Table 5.

Discussion

Analysis of the results of this particular study leads to some findings that coincide with previous research and others that may actually lead to further questions. Consideration of the results here will begin with a discussion of the question of whether writing to learn activities are beneficial in the classroom and conclude with a discussion of what particular audiences were most beneficial for these biological topics.

Table 5 Circulatory / Respiratory Treatment Groups Multiple Comparisons

Multiple Comparisons (Tukey HSD)
Significance in Multiple Comparisons (*** = significant at .05 level)

1) Multiple Choice

	Control	Period 1	Period 2	Period 5	Period 6
Control	x	-----	-----	-----	-----
Period 1	-----	x	-----	-----	-----
Period 2	-----	-----	x	-----	-----
Period 5	-----	-----	-----	x	-----
Period 6	-----	-----	-----	-----	x

2) True False

	Control	Period 1	Period 2	Period 5	Period 6
Control	x	-----	-----	-----	-----
Period 1	-----	x	-----	-----	-----
Period 2	-----	-----	x	-----	-----
Period 5	-----	-----	-----	x	-----
Period 6	-----	-----	-----	-----	x

3) Short Answer 1

	Control	Period 1	Period 2	Period 5	Period 6
Control	x	***	***	***	***
Period 1	***	x	-----	-----	-----
Period 2	***	-----	x	-----	-----
Period 5	***	-----	-----	x	-----
Period 6	***	-----	-----	-----	x

4) Short Answer 2

	Control	Period 1	Period 2	Period 5	Period 6
Control	x	***	***	***	***
Period 1	***	x	-----	-----	-----
Period 2	***	-----	x	-----	-----
Period 5	***	-----	-----	x	-----
Period 6	***	-----	-----	-----	x

5) Short Answer 3

	Control	Period 1	Period 2	Period 5	Period 6
Control	x	-----	***	***	***
Period 1	-----	x	-----	-----	-----
Period 2	***	-----	x	-----	-----
Period 5	***	-----	-----	x	-----
Period 6	***	-----	-----	-----	x

6) Overall Total

	Control	Period 1	Period 2	Period 5	Period 6
Control	x	***	***	***	***
Period 1	***	x	-----	-----	-----
Period 2	***	-----	x	-----	-----
Period 5	***	-----	-----	x	-----
Period 6	***	-----	-----	-----	x

Control vs. Treatment Groups

Results from this study support findings from recent studies that students using writing to learn activities perform statistically better than counterparts not using the strategies. On both the nervous system and the circulatory / respiratory system post tests, the treatment group had higher means than the control group on all questions. On the nervous system post test, the treatment groups means were significantly higher in all question categories and for the overall total.

The results from the circulatory / respiratory post test in relation to treatment group versus control group comparison were not as dramatic as the nervous system, but still lend credibility to the assertion that writing to learn activities aide student achievement. Statistically significant differences were observed for short answer questions one and two, and in the overall total. In all questions, treatment means were higher than control group means. The fact that the multiple choice and true false questions did not yield significantly different means would indicate that the benefit from writing activities is more dramatic for conceptual questions, as opposed to recall questions. The short answer questions represented conceptual questions, and on two out of the three questions of this type, the treatment group did significantly better. Writing to learn activities are more likely to promote knowledge transforming writing, rather than simply knowledge telling writing and this type of writing would be more beneficial for acquisition and reorganization of conceptual understanding.

Several areas of concern in relation to the overall study design must be commented on in relation to the findings comparing the performance of the treatment groups to the control groups. One potential area of bias would be the grading of the conceptual questions. The questions were scored by the instructor of the treatment groups, who was also the study designer. In order to lessen the possible impact of bias, two precautions were taken. First, a grading rubric was created that included a detailed checklist for each conceptual question. This rubric was applied to all graded conceptual questions. Further, each conceptual question was graded at the same time, but in random order to avoid the possibility of bias toward one particular class. Finally, a science colleague of the instructor randomly graded ten samples of each conceptual question on each test to determine inter-rater reliability. In this comparison, no two scores from the two graders differed by more than one point. In

addition, for all six conceptual questions, inter-rater reliability was at least 70 % or greater.

Another possible area of concern in relation to the study design is the choice of control groups used. The control groups for both stages were taught by different instructors than the treatment groups. This allows for the possibility of teacher effects causing or at least contributing to the differing outcomes in performance. However, precautions were again taken in an attempt to counteract these effects. The instructors involved met before instruction took place to discuss the concepts covered and assure that they agreed. The type of activities to be used in instruction were also matched up so that the only marked difference in instruction would be the writing task at the end of the unit for the treatment groups. Importantly, the time on task was also equalized in order to insure that the same amount of time was devoted to the material covered. While this still does not insure that there were not teacher differences, it does control for major differences that would have likely had the most impact on the study. Further, in practical research such as this study, differences in teaching methods are virtually impossible to completely control, and in many ways the use of different teachers teaching the same material with the only difference being the use or non-use of writing would be consistent with what would actually take place in many high school settings.

Another factor that helped to account for differences in the classes and the concern for teacher effects was the use of a covariate. The covariate used was the overall biology grade for the students at the beginning of the units used in this study. The student grades included all activities up to beginning of the study and were not only a measure of student performance in biology, but also a measure of overall performance. For this study, the class averages for this baseline grade all fell in a range from 74.0 % to 89.0%. Multiple comparisons between baseline grades indicated p values of .095 and higher, indicating no significant differences amongst groups due to these baseline grades.

A final area that could raise concern in regards to outcomes would be the use of pretests by the treatment groups. The rationale for their use was initially to have a quantitative measure of conceptual change and to be able to at least gauge the prior knowledge of the students in these two topics. Averages for the pretests indicated that while no group had a pretest percentage of over 31%, all groups did better on the circulatory / respiratory pretest (range = 24.67% - 30.93%) than on the nervous system pretest (range =

18.70% - 20.36%). This shows some indication of greater prior knowledge for the unit on the circulatory and respiratory system, but it also indicates that prior knowledge in both areas was low. However, the fact that the initial scores were so low and the inability to properly use them in our statistical analysis due to the lack of consistent units limited the effectiveness of these as a measure. Therefore, the pretests had usefulness as an instructional tool in determining prior knowledge, but provided little help statistically.

Results from this study indicate only positive effects on students using writing to learn strategies in their achievement, and in most cases these positive effects were statistically significant effects.

Comparison of Effects of Writing to Different Audiences

Results from the comparison of achievement of students on the circulatory respiratory system post test were also analyzed to detect any differences due to these students writing to different audiences. No strong statistical findings surfaced, but analysis did yield some important trends and ideas for consideration.

Comparison of the individual treatment groups was done for the nervous system post test and as expected, no significant differences were detected. All classes wrote to the same audience, the instructor, and no individual class achieved significantly better as a result of this writing. The second stage of the study, in which these classes did write to different audiences took place soon after this initial writing activity. The lack of any significant difference in the first stage indicated that all students entering the second stage had some experience with a writing to learn activity, but that no class was significantly better prepared for the second writing.

None of the audiences was found to lead to significantly better post test achievement in all cases, but some trends did appear in the results. The first trend of note is that the group writing to the instructor (Period 6) did not, in any case, have significantly better results than any other group. This is important because many traditional writing activities are set up with the teacher as the only audience. Some educators fear that if the students write to different audiences, student performance will suffer. This was not the case in this study. Students writing to audiences outside of the teacher all did statistically better than students who did no writing. In addition, these students writing to outside audiences did not perform statistically worse than students writing to the teacher. This trend, while not

necessarily supporting the assertion that authentic audiences are beneficial, at least shows that these audiences will not hinder student performance.

Another informative factor is highlighted when considering the results of the class writing to the 3rd / 4th grade audience. As mentioned in the literature review, some previous research has hypothesized that writing to younger audiences may be beneficial because it necessitates that the author translate their own understanding into a form more appropriate for their young audience. This translation may involve more engagement of the students cognitive networks and may promote more cognitive and conceptual growth. This particular study suggests that another factor, the type of assessment questions asked by the instructor may also be an important factor. In this study, the class writing to the 3rd / 4th grade audience was the only class to not do significantly better on a conceptual short answer question than the control group. This class performed significantly better on the first and second short answer questions than the control group, but not on the third. Short answer question one dealt with the an analogy between the circulatory and respiratory systems and the transportation system in our country. Many of the students writing to the 3rd / 4th grade audience used some sort of analogy in their papers, and therefore may have been better prepared for answering this type of question. This highlights yet another relationship that may need to be explored further as writing to learn activities become more prevalent.

It is also worth consideration that on conceptual short answer question three, the class that had the highest mean scores for this question was the class writing to their high school aged peers in an English class. This particular question asked for an application of the conceptual understanding gained in relation to the circulatory / respiratory system. In order to score well on the question, students had to not only understand the overall connections between the two systems, but also apply those connections to a particular pathway in the body. The fact that writing to same aged peers may have been beneficial for this question again suggests a possible link between particular assessment expectations and the audience written to. Research indicates that using ones "personal language" rather than "proper terminology" can be beneficial. Students writing to their peers may be more able to engage in this type of writing, leading to benefits that help with application problems. However, since the peers were not members of the actual biology class, the writers could not simply retell material, they had to process it. This processing would likely be beneficial as

well. Finally, factors of this writing experience match quite well with the compromise position of audience conception. This position asserts that students must carefully consider their audience and its characteristics when writing. But, the compromise position also notes that writers must provide for "shifting audiences" by putting cues in the writing to lead any audience to the desired understanding. One of these shifting audiences may be the writer themselves as they reread their work, and this rereading is a necessary step in the conceptual development of the writer. In the case of writing to same aged peers, the consideration of audience was facilitated by the fact that the author would be very familiar with the characteristics of the intended audience. In addition, the cues in the writing would be appropriate for high school aged students, and when these cues were reread by the author themselves, may have been easier to cognitively consider and help with new connection building.

Conclusion

Information from this particular study supports the assertation that writing to learn activities help students gain conceptual understanding of scientific topics. In doing so, it continues to affirm the necessity of researchers and educators alike studying this pedagogical tool. The results in relation to differing audiences also provide some collaboration with earlier findings. The use of authentic audiences is supported. Continued work on determining the best matches between particular scientific concepts and particular audiences for writing is needed.

New questions also arise from this work. Work needs to be done in determining the role that the feedback students receive from their authentic audience has in developing conceptual understanding. Matches between the purpose of the writing (clarification, application, looking for connections) and audiences should be explored as well. The area of determining adequate, consistent, and beneficial ways of assessing conceptual understanding gained from writing to different audiences must be addressed. Consideration of all these questions and their implications will continue to drive refinement of the writing to learn process in the future.

CHAPTER 4. GENERAL CONCLUSIONS

Introduction

The preceding two sections of this thesis were intended to first establish a theoretical background based on research for writing to learn activities, and the audience used in these writing activities in particular, and to then describe an actual study testing the ideas put forth in the the theoretical discussion. This final section will attempt to link the information from previous literature dealing with these topics to the information gathered in the study. Reasons for these links, implications of these links, and new questions pertaining to these links will be explored. This section is divided into three subsections. The first will be a discussion of the results of the research study in the relation to previous research findings in this area. The second subsection will discuss limitations of this particular study and what could be done in future research to rectify these problems. The third subsection will cover implications of this particular work, including ideas about possible future studies and a discussion of where these particular findings may lead us.

Discussion

The results of the preceding research study in conjunction with the literature reviewed leads to several important considerations for educators. Additionally, new questions and possible areas of research emerge.

The most overriding aspect of both the literature reviewed and the study undertaken is that writing to learn activities are beneficial and should be used in science classrooms. The study in this thesis is in agreement with a growing number of other studies that consistently show quantitative evidence of the benefits of this practice. This particular study showed in a very practical, authentic, classroom situation that student achievement was increased when writing to learn activities were used. Exception may be taken by some who point out that while the control groups performed substantially (and in many cases statistically significantly) lower, this may have been due to the fact that a different instructor taught the control groups. This, in fact, is a strength of this study, as this would be the exact situation in many schools. Students learning the same conceptual ideas would do so with different teachers. The combination of differing student conceptions with different teaching methods would likely lead to at least slightly different learning outcomes. But, by employing research backed writing to learn strategies, the chances of the instruction leading to greater student

achievement and greater conceptual understanding is increased. This study blends with countless others in asserting that the use of these writing to learn activities will help all students in a wide array of curricular environments.

If the practice of using writing to learn activities is to be implemented by a wide range of educators, the best methods of employing them must be determined. The second aspect of this thesis took up that task, exploring the nature of the audience to be used. Research indicates that the most beneficial pedagogical practice from a rhetorical standpoint is to conceive of the audience using a compromise position between two extremes. Teachers should facilitate an audience conception in which the student writers consider the characteristics of their audience to a great extent, but do not get so tied up in the consideration of the particular audience that they fail to account for the possibility of different audiences at some point in the future reading their work. Accounting for these "shifting audiences" involves including cues throughout the work that help the audience reach the desired understanding of the writer. This compromise position also allows for many of the factors presented in current models of writing processes. The findings of this particular study mesh well with this compromise position on audience and factors associated with the audience in writing.

One factor the results of this study apply to is that the best audience for student writers is probably not necessarily the instructor. When students write to the instructor, they often do nothing more than rephrase what the instructor has already told them. In doing so, the students are simply retelling information. This retelling does not allow them or force them to go through a cognitive revision process that is mentioned in most current research as an important aspect of writing processes that promote conceptual growth. In addition, this type of writing, while allowing students to write to an audience that is familiar to them, does not necessitate the use of many cues in their writing for the audience. In fact, many students will simply repeat terms and vocabulary they have been told and hope the instructor who reads the work will fill in any missing details. This writing situation does not facilitate maximum student conceptual growth.

If the instructor is not the most beneficial audience for student writers, the next question becomes who is. The study involved in this thesis does not overwhelmingly support one particular audience, but it does provide some insight that may help to identify

beneficial audiences and some factors that should be considered when attempting to make this determination.

One factor that should be recognized is that students often benefit from using their own language and vernacular. If students are forced to use specific terminology, the connections between topics, and the overarching concepts may be lost amidst a flurry of definitions. Audiences that allow students to use their own, natural language are typically beneficial. In this study, some benefit to writing to peers was noted. It is likely that at least contributing to this benefit was the fact that students felt more comfortable in using their own words for this group than for any of the other audiences. In addition, it was more likely that the students had a very close match between their conception of the target audience and the actual audience who read their paper, as well as an easier time of placing cues throughout the paper.

Another factor that is important in determining the appropriate audience for writing is the goal or intent of the writing. Specific types of questions may be more easily answered by students who have written to specific audiences. For example, in the study presented here, the class writing to the 3rd / 4th graders had some benefit when answering questions asking for analogies or connections, while the classes writing to peers were better at application questions. Instructors have to consider both the topic or concept they are interested in exploring and the purpose of the writing they are assigning. Students who write to a younger audience may focus their writing on one or two overriding concepts, which would be beneficial if the purpose is to note big ideas, but may not be as helpful if the purpose is to apply these concepts to a new or novel situation.

The level of writing ability and skill may also impact the best audience to use for a particular writing activity. Research has indicated that novice writers may be more inclined to use knowledge telling writing as opposed to knowledge transforming writing. Specific audiences may be more appropriate for these different kinds of writers and writing processes. For example, a class of expert writers may not benefit as much from writing to a younger audience because the rhetorical goals for that audience would not be as demanding. A group of novice writers might get more benefit out of that situation, but may struggle if they are to write to an older audience or an audience that is perceived to be very highly

skilled. Obviously, the fact that most classes in high secondary schools will include a wide variety of skill levels, makes this consideration somewhat difficult.

This study provides evidence that student writing can be beneficial in establishing conceptual growth. To accomplish this growth, many factors need to be considered. The writing needs to be to an authentic audience that the student has carefully considered. The audience for the writing should be selected to reflect the overall purpose for the writing. Students and teachers alike must recognize the importance of explicitly discussing how the audience is to be conceived and how the writing process can benefit the writer. By pointing these factors out, more attention to the cognitive and metacognitive aspects of the writing process will be gained and greater learning will take place.

Limitations

Several factors may have limited the ability to generalize the results gathered in this particular study to all educational settings. These limitations should be considered in conjunction with the results in order to have a true understanding of exactly what these results do and do not speak to in terms of the field of science education. Control or complete elimination of these limiting factors should be the goal of future research in this area.

The most obvious limitation in this particular study was the inexperience of the researcher. This body of work represents the first attempt by this author to conceive of, conduct, and analyze an authentic, long term research study. Many factors that likely impacted the research design and the credibility of the results were recognized after the research was completed or after they had already had an impact. A more experienced researcher may have been able to anticipate these factors and their effects and deal with them before they impacted the study. In this particular case, the researcher was only able to carefully review upon completion of the project these types of factors, and note them in the discussion of the results, so that the audience reading the information may take them into consideration.

Some limitations in the study are related to the fact that the activities studied took place as a part of a normal general biology curriculum in an authentic secondary school setting. While this is desirable from the standpoint of providing sound research evidence from the exact situations that the activities will be used in, it does present some problems

with generalizing the findings and the possible existence of confounding variables, many of which may not be easily accounted for. For example, in this particular study, time of year may have impacted the study results. The units covered in this study were both in the last month of the school year. In particular, the unit for stage two of the study, the circulatory and respiratory systems, took place in the last two weeks of the school year. It is likely that student performance at least to some degree was impacted by this, although it would be difficult to account for this factor statistically. In addition, the four periods did not all meet at the same time of the school day, and the time of day may have also impacted the results. Comprehensive future research should be done throughout the school year and with different audiences being examined at all times of the school day in order to determine if the trends and results found here hold up.

Other limitations were the result of using preexisting classes for the study. Differences in general academic ability were controlled for by using grades coming into the study as a covariate in the statistical analysis, but other factors may have also impacted the study results. In general, the greater the number of subjects tested, the more confidence researchers have in their results, but in this case, class sizes limited the number of students that were tested. The type of instruction and the delivery of that instruction in the different classes may have also been a limitation resulting from using preexisting classes. It is unrealistic to assume that just because the same concepts guided instruction in all classes and the same type of discussions, lab activities, textbooks, and written assignments were used in all courses, that identical instruction was given every period of every day the study took place. This is especially true in the case of the control groups, which were identical courses to the courses for the treatment groups, but taught by different instructors. While this again lends to the "authenticity" of the study in the sense that this would be true of any actual school setting, it does at least leave open the possibility of some other factor, outside of the studied variable of writing activities, accounting for differences in student performance. Further research using more controlled settings in conjunction with authentic classroom settings may be worthwhile.

Another limitation relates to the evaluation of writing by this instructor. This instructor, like most science educators, did not receive in depth training in evaluation of writing as part of his teacher preparation. The result is that the development of a grading

rubric to adequately evaluate the writing students do both from a scientific state and a rhetorical state is difficult. Consultation with English teachers does provide some assistance in this area, but this may be a limitation of this study, and of the practice of using writing to learn in science in general. It is possible that the factors evaluated in the student writing did not necessarily promote the best clarification by the student authors. Similarly, it was difficult for this instructor to develop conceptual questions on the test over this material that linked back to the writing activity without asking for exactly the same information. This was due more to a lack of comfort in the realm of writing and rhetorical factors than in the science area.

A final limitation of this study pertains to the selection of the audiences used by the classes in the study. It was the desire of the researcher to include one audience younger than the student writers, one audience basically the same age as the writers, and one audience older than the writers. To do this, 3rd / 4th graders, high school students, and parents were selected as audiences. It is very possible that a different "younger" audience (for example 5th / 6th grade students) may have provided different results. In addition, characteristics of the particular audiences may have been unique to this particular high school. For example, the city this study took place in has both a large university and a world-reknown medical hospital. It is possible that the characteristics of the "parent" audience in this particular community do not match the characteristics of other parent audiences in other communities. Again, further comprehensive research into the effect of audiences using slightly different audiences from different geographic or even socioeconomic areas would be beneficial to see if results and trends noted in this study are consistent.

Implications

Results from this particular study have two general attributes in common with much research in this area. First, a positive connection between writing to learn activities is established, and the indication is that the practice is beneficial for science students. But second, the reasons for this positive correlation and the specific characteristics that will enhance this positive connection are not as clear from the research results. These findings lead to many new questions that need to be addressed as research continues to indicate benefits of using writing to learn activities.

One possible next step would be to explore the long term retention associated with the writing to learn activities. Studies involving post-post tests or delayed post tests may help determine if the immediate benefits of writing to learn activities, such as those suggested here, are consistent in long term retention. Additionally, particular audiences may have greater impact on long term retention, even if the impact on immediate retention is not significantly different from using other audiences.

Another area to be considered in future research would be student attitudes toward writing activities. Exploration of the effects of differing student attitudes toward writing activities could be compared to results of studies like this one to see if the different attitudes have a greater or lesser effect than different characteristics of the writing itself. Studies could then focus on determining what are the best ways to develop and foster positive student attitudes toward writing and what factors might result in negative attitudes.

Obviously, more research is needed into the area of the most appropriate and most beneficial audiences to use in these types of activities. Quantitative and qualitative research is needed to help establish the most effective audiences in general, and may also be helpful in determining the best "younger", "age-equivalent" and "older" audiences for use in these activities. Audience conception needs to be researched as well in order to determine if different student conceptions of their audience impacts their conceptual understandings differently. Additionally, more research is needed in determining the best matches between topics and audiences. For example, a topic such as ecology may be better clarified when writing to an audience of age equivalent peers than for any other audience, but the topic of biotechnology may be better matched with an audience of parents. These links need to be studied across a wide range of geographic locations, ability groups, socioeconomic situations, genders, ethnicities, and other groups as well.

Evaluation and feedback are two other factors that need to e researched more fully in relation to writing to learn activities. It is possible that the type, depth, or even organization of the feedback given from an audience may be more important than the characteristics of the audience themselves. The most appropriate methods of giving and using feedback need to be studied and determined. The same can be said of the evaluation of the writing. It would seem likely that the type of evaluation that the student author anticipates for his or her paper would impact the quality of the paper he or she produces and this may in turn impact

conceptual understanding. Ideas about different types of evaluation, including allowing the authentic audience to do some or all of the evaluating need to be explored.

Results from this particular study can be added to the growing list of research showing a positive connection between the use of writing to learn activities and student conceptual understanding in science. However, in terms of the specific characteristics of the writing to learn activities that are leading to these benefits, or likely to increase the chances for these benefits, these research results, like many before it, proves to be inconclusive. The most important implication from all of this is that science education researchers and practitioners must do two things in order to continue to reform their discipline in coming years. First, positive effects of writing to learn activities need to be continually shown and reiterated. Second, increased effort must be put forth into determining what are the best specific characteristics of these activities to promote student learning. If science educators can be convinced these activities are truly beneficial, and then shown effective, research backed ways to use them, they will have no choice but to include these activities in their curriculum. And when science educators do this, science students will benefit.

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