DOCUMENT RESUME

ED 455 119 SE 065 090

AUTHOR	Seabury, Debra L.
TITLE	The Write Connection: Implication of Research on the Design of Writing Activities for Teaching Elementary Science.
PUB DATE	2001-00-00
NOTE	62p.
PUB TYPE	Reports - Research (143)
EDRS PRICE	MF01/PC03 Plus Postage.
DESCRIPTORS	Constructivism (Learning); Elementary Education; *Integrated Curriculum; *Science Instruction; Science Process Skills; *Teaching Methods; *Writing (Composition)

ABSTRACT

This inquiry examines the relationship between the science and writing processes and the implications of that relationship for classroom instruction in the upper elementary grades. Drawing on historical research from constructivism and experiential learning theory, as well as current thought on knowledge and learning process, this study builds a rationale for integrating writing and science. A model of the science writing interaction shows parallels and intersections of the two processes and illustrates the transformational interdependence of knowledge and discourse in constructing meaning and deepening understanding. Benchmarks in science literacy form the basis for three practical applications of the science writing connection for the upper elementary classroom: a research template, a newspaper report, and a persuasive poster. (Contains 47 references.) (Author/ASK)

Running head: THE WRITE CONNECTION

The Write Connection: Implications of Research on the Design of Writing Activities for Teaching Elementary Science

Debra L. Seabury
Western Washington University

Abstract

This inquiry examines the relationship between the science and writing processes and the implications of that relationship for classroom instruction in the upper elementary grades. Drawing on historical research from constructivism and experiential learning theory, as well as current thought on knowledge and learning process, this study builds a rationale for integrating writing and science.

A model of the science writing interaction shows parallels and intersections of the two processes and illustrates the transformational interdependence of knowledge and discourse in constructing meaning and deepening understanding. Benchmarks in science literacy form the basis for three practical applications of the science writing connection for the upper elementary classroom: a research template, a newspaper report, and a persuasive poster.

Table of Contents

"I can never remember things
I didn't understand in the first place."

--Amy Tan, The Joy Luck Club

The Write Connection: Implications of Research on the Design of Writing Activities for Teaching Elementary Science

The seeds for this inquiry were sown four years ago when Pearson Publishing first approached Simon and Schuster about purchasing Prentice Hall's Business and Professional books division. I doubt that the boardroom moguls factored me into the equation as they struck a deal that sent my educational titles to a new corporate home. When my editor telephoned with an invitation to revise and reissue Earth Smart (Seabury, 1994) for Pearson's upcoming catalog, I was delighted at the idea of giving an under-marketed work a boost--but revise what? And why?

While most of the interdisciplinary activities in the book were still valid and timely, the writing component had become dated. As a writer and educator I had followed the instructional trends toward writing process, writers workshop, and writing to learn. At best, the writing activities in my book were prompts and story starters (see appendix A). Further, these activities' limited creative writing focus tied to science process and content by only the thinnest of threads, not exactly what the proponents of integrated writing across the curriculum had in mind.

Statement of Purpose

This inquiry examines past and present literature to discern what types of writing activities lend themselves to science, what the critical components of writing to learn in science are, and what adaptations are suggested for teaching upper elementary learners. This study does not specifically consider the needs of primary or secondary science students nor does it address writing to learn in other content areas such as social studies or math, although the findings may, in some cases, apply to those students and subject areas as well. The goal of this inquiry is to find a better way to integrate science and writing in order to facilitate deeper understanding in both disciplines.

Research Questions

Connecting science and writing raises questions and issue in both disciplines. However, for the purpose of this study, it was necessary to limit my focus to research that offered practical applications for integrating science and writing in the upper elementary classroom. This focus concentrated my research on one primary question and three secondary questions.

Primary question.

What is the relationship between the writing process and the science process?

Secondary questions.

What are the implications of recent research for the integration of writing and science instruction in the upper elementary classroom?

Which specific writing genres best support the science process?

What instructional adaptations, if any, should be made in order to teach elementary students to write authentically in the science genres?

Definition of Terms

Four specialized terms are used throughout the following discussion of science and writing integration. Although the meaning of at least one of these terms, "science literacy," has stirred some recent controversy (Shamos, 1996), I have attempted to stay with the current majority of thought. All of the following terms are defined as they are most commonly used by mainstream science and writing educators such as Carolyn Keys (2001), Larry Yore (1999), Nancie Atwell (1998) and Donald Graves (1994).

Science Process. Scientific thought is characterized by habits of mind involving logical, rational thinking and conclusions based on clear, unbroken chains of acceptable evidence (Hand, Prain, Lawrence & Yore, 1999). The science process combines prior knowledge with new data to build meaning by constructing inferences and developing conceptual knowledge structures (Bereiter & Scardamalia, 1987; Fellows, 1994).

Students engaged in the science process investigate authentic problems and think critically about outcomes in order to construct new meaning and build understanding about the world around them. Instruction in science process involves accessing students' prior knowledge, using this knowledge to engage them, providing concrete experiences to challenge and explore ideas, and facilitating opportunities for students to discuss, reflect, and incorporate new learning into what they already know (Tucknott & Yore, 1999).

Scientific Genres. Science writing includes genres in which students write for themselves as a means of building understanding. In some genres students write for others as a way of expressing that understanding to an authentic audience (Britton, 1970; Keys, 1999). Within Britton's original framework for language study across the curriculum, Carolyn Keys (1999) lists a number of genres employed for the shared purpose of exploring ideas. These expressive genres include notes, hypotheses, abstracts, descriptions, and journal entries. Keys also lists several genres intended to inform others. These transactional genres include reports, explanations, biographies, and exposition.

Scientific Literacy. Although the practicality of achieving science literacy for all has come under some scrutiny (Shamos, 1996), most science educators agree that scientific literacy is a worthy educational goal (Fellows, 1994; Hand, Prain, Lawrence & Yore, 1999; Hand, Prain & Vaughan, 1999; Hand & Vaughan, 1996; Keys,1994, 1999; Rivard, 1994; Yates, 1983). Holliday, Yore and Alverman (1994) suggest, "Scientific literacy involves the location and comprehension of scientific information, the adoption of a contemporary view of science, the development of informed conceptions, opinions, and beliefs, and the ability to communicate these ideas and persuade others of their veracity" [italics added] (p. 878). Functional science literacy is demonstrated in the "utilization of scientific knowledge for the benefit of individuals, the common good, or social progress" (Hurd, 1998, p. 411).

Writing process. The process of writing involves "having something to say, someone to say it to, and a knowledge of standard ways of getting language down on paper" (Phenix, 1990, p. 11). Through this process writers select, organize, and develop ideas that they express in effective language and logical sequence (Atwell, 1990; Calkins, 1991; Calkins, 1994; Graves, 1994; Murray, 1985).

This writing process is rarely complete at the end of the first draft but evolves through a purposeful chain of "successive rewritings and rethinkings that mold an act of writing into the best possible form" (Zinsser, 1988, p. 16). Writing is a recursive act that progresses in a spiraling curve along which a writer constructs meaning and clarifies thoughts by writing, thinking, revising, and rewriting.

Significance of the Research Questions

While writing to learn may be powerful at all grade levels, introducing specific scientific genres in the upper elementary grades and middle school years may be especially important today (Baker & Saul, 1994; Hand, Prain, Lawrence, & Yore 1999; Keys, 1999; Rivard, 1994). In the middle grades children move toward writing proficiency (Atwell, 1990, 1998; Calkins, 1994; Graves, 1994; Upton, 1986), and at the same time, they develop connections between scientific content and the process of knowledge production in science (Fellows, 1994; Loranger, 1999; Keys, 1999; Keys, 2000; Tucknott & Yore, 1999; Yates, 1983). When these two processes (science and writing) are intentionally integrated, the potential for growth in each may be multiplied (Breiter & Scardamalia, 1987).

In addition, there appears to be a pressing need for new ways to teach science in the upper elementary grades, where specialists are rare and science phobia is common among classroom teachers (Baker & Saul, 1994; Bereiter & Scardamalia, 1987; Gaskins & Guthrie, 1994; Yore, Hand, Prain & Vaughan, 1999). Generally, elementary teacher preparation programs emphasize reading and writing, so quite naturally, teachers produced by those programs are often more comfortable teaching language arts rather than science. However when science is integrated with writing, teachers' confidence in their ability to teach science grows, as does their enthusiasm for teaching science content (Baker & Saul, 1994; Upton, 1986).

Further impetus to integrate science and writing instruction comes from the growing emphasis on accountability. High stakes, state-mandated assessment and evaluation have affected the way many teachers incorporate writing into content area instruction (Friedman, 2000). Such standardized tests require students to write to open-ended prompts and develop expository responses to key questions, both of which require analysis, synthesis and evaluation of what students have learned about a content-related topic.

Finally, time pressures point to the need for a more integrated curriculum. Writing to learn is an efficient teaching method, engaging students in both the means and the ends of education (Upton, 1986). Frequently, elementary teachers lament that there is simply not enough time to teach science, but when science is integrated with writing, more time can devoted to science instruction (Baker & Saul, 1994). However, when taught in conjunction with science or any other content area, writing activities must surpass the "look it up in the encyclopedia" report. Whether science related or not, writing tasks must be authentic, meaningful and tailored to the student's zone of proximal development (Calkins, 1994; Fletcher, 1993; Graves, 1994; Harvey & Harwayne, 1998; Vygotsky, 1994).

Before examining specific activities integrating science and writing in upper elementary classrooms, it is important to understand some of the research that applies to each discipline and how the two disciplines complement one another. A thorough understanding of research will enable educators to make wise choices when selecting integrated instructional practices and programs.

Review of Literature

The scientific process, as it is commonly accepted among science educators today, has its foundations in constructivism and experiential learning. The basis for scientific habits of mind such as logic and critical thinking, as well as conclusions based on acceptable evidence, can traced their beginnings to historical research into constructivist learning theory.

Historical Perspective. Understanding plus remembering equals constructivist learning (Dewey, 1938; Kolb, 1984). Constructivists and experiential learning supporters, John Dewey and David Kolb, would applaud Amy Tan's (1989) sentiment from her best selling novel, The Joy Luck Club, "I can never remember things I didn't understand in the first place"(p. 19). Specifically, Dewey and Kolb suggest that understanding constructed from the learner's experience is critical to learning and remembering.

Many sources offer definitions of experiential or constructivist learning. Kolb (1984) asserts, "Learning is the process whereby knowledge is created through the transformation of experience" (p. 38). Jackson and MacIsaac (1994) expand Kolb's definition when they suggest, "Experiential learning does not represent a theory of learning per se. Rather, it is a broad perspective on learning that focuses on authentic learning experiences as the necessary basis for meaningful skill acquisition and human development" (p. 21). This definition points to the broad nature of experiential learning theory. Kolb frames education's most basic purpose as promoting authentic, reality-based, and meaningful learning.

Further, Kolb (1984) discusses four critical aspects for effective experiential or constructivist learning. First is an emphasis on the process as opposed to the content or outcomes. Second, he asserts that knowledge is a recursive transformation process, continuously created and recreated, not an independent entity to be acquired or transmitted on a one-time-only basis. Third is his suggestion that learning transforms experience both in its objective and subjective forms. Finally, Kolb suggests that learners need to develop metacognition; that to fully understand learning, the learner must construct some understanding of the nature of knowledge.

Experiential or constructivist education is learning by doing in authentic situations where the outcome really matters. Experiential learning happens when learners are actively involved with real life questions that hold real life consequences. Further, the observable evidence of experiential learning is manifested in genuine changes within the learner--his or her beliefs, attitudes, knowledge, and/or skills (Dewey, 1938; Jackson & MacIsaac, 1994; Kolb, 1984; Kraft & Sakofs, 1988; Lewis & Williams, 1994).

Current Thought. In 1985, The American Association for the Advancement of Science (AAAS) issued a report declaring, "Science literacy consists of a knowledge of certain important scientific facts, concepts, and theories; the exercise of scientific habits of mind; and an understanding of the nature of science, its connections to mathematics and technology, its impact on individuals and its role in society" (as cited in Nelson, 1999, p. 15). Further, the AAAS, the National Science Teachers Association, and the National Academy of Sciences have joined forces in voicing commitment to basic science literacy as the first priority of science education in the twenty-first century (Nelson).

If science literacy is to be a priority in the upper elementary classroom, teachers must find ways to integrate more science instruction into a curriculum already dominated by reading and writing (Baker & Saul 1994; Gaskins & Guthrie, 1994; Rivard, 1994). Fortunately, Kolb's (1984) experiential learning model supports the suggestion that science and writing, both based in experience and process, are natural partners in learning.

Specifically, Kolb's (1984) paradigm suggests four components that are critical to experiential learning: concrete experience, reflective observation, abstract conceptualization, and active experimentation. It is in the reflective observation and abstract conceptualization components that writing and science interweave. The act of putting thoughts down on paper helps students sort and clarify their ideas, and in responding to authentic questions, learners gain understanding while they construct knowledge and strengthen their writing skills (Atwell, 1990; Bereiter & Scardamalia, 1987; Calkins, 1994; Graves, 1994; Hand, Prain, Lawrence & Yore, 1999; Harvey & Harwayne, 1998; Tchudi, 1983; Upton, 1986; Zinsser, 1988).

Science knowledge is fluid, subject to change as new evidence becomes available. In part, it is the temporary nature of science knowledge that shapes science process. Scientists invent imagined models and theories to explain how the world works and then test their thinking against reality (Hand, Prain, Lawrence & Yore, 1999). At the point where reality conflicts with theory more imagining and inventing is needed in the cycle of learning and revision. The writing process functions on a parallel path. Writers invent and draft as they imagine how meaning might be transformed into text and then test by rereading, rethinking, and revising in a recursive process (Atwell, 1990; Calkins, 1991; Calkins, 1994; Graves, 1994; Murray, 1985; Phenix, 1990).

Writing does not begin with listing topics or outlining possible directions. The writing process begins with thinking (Atwell, 1990; Calkins, 1986; Graves, 1994). Writers imagine and invent, think and rethink as they form fresh meanings and connections. Donald Murray (1985) asserts that "writing is not superficial to the intellectual life but central to it; writing is one of the most disciplined ways of making meaning and one of the most effective methods we can use to monitor our own thinking" (p.3).

When the science and writing processes are combined in the construction of meaning each recursive process supports and complements the other. Further, holistic integration of the separate processes is more than the sum of the parts. The interaction of the science and writing processes builds deeper understanding than either process builds in isolation. A model of this critical interaction was developed a quarter of a century ago by Bereiter and Scardamalia.

Model of Science Writing Interaction. Bereiter and Scardamalia (1987) suggest a theoretical framework for writing with the intended purpose of knowledge-transformation; that is writing to deepen the writer's understanding of a subject. Keys (1999) expanded the framework to reflect the habits of mind characteristic of the science process (see Fig. 1).

Science content knowledge and discourse, or writing, knowledge run parallel in the model. The

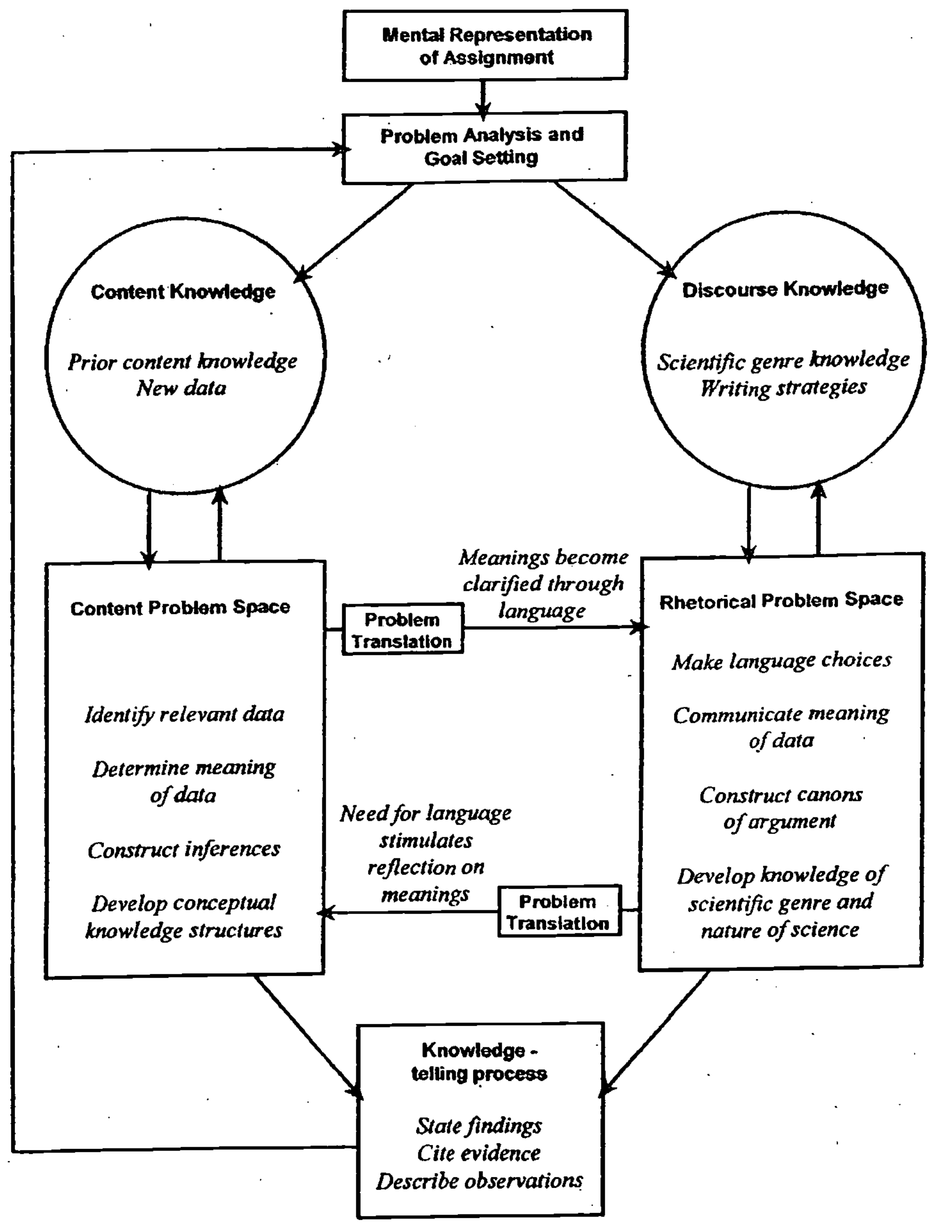


Figure 1. Bereiter and Scardamalia's (1987) knowledge-transforming model of composition with applications and reflections relevant to scientific investigation. Italics added by Carolyn Keys (1999).

interactions between content and writing connect the sides of the model. Bereiter and Scardamalia (1887) suggest that language clarifies the meaning while the need for language stimulates the learner's reflection upon the meaning. Further, Keys' (1999) additions to the model show that content problems and rhetorical problems are collaborative. The meaning of the data and determining the meaning of the data both contribute to the construction of scientific knowledge.

The dynamic relationship of interaction between content knowledge, represented on the left side of the model, and discourse knowledge, on the right, helps to clarify why writing is such a critical part of science learning. It is the very act of putting tentative thoughts down on paper in the concrete form of writing that challenges those thoughts. Taking a stance in writing demands some level of commitment even if, and perhaps especially if, that commitment is transitory.

Science writing in the upper elementary grades is much like other forms of writing. Science writers need to have knowledge of writing forms and strategies, and in this case, the scientific genres. Transformational interactions between the science process and the writing process are intrinsic in scientific genres.

Purpose, audience, and most of all meaning, define scientific writing designed to describe, explain, instruct and persuade a specific audience.

Role of Scientific Genres. Bereiter and Scardamalia's (1987) transformational view of writing to learn in science moves beyond knowledge-telling, which is traditionally used to assess recall through a written product, often a report on an assigned topic or a short essay on a constructed response test. Writing to learn is more than "grammar across the curriculum" or "making spelling count" (Connolly, 1989; Holliday, Yore & Alvermann, 1994; Tchudi, 1983; Tucknott & Yore, 1999). Emphasis is not on the writer's use of surface conventions but on his or her shaping, reshaping, and transmitting meaning.

Certainly this constructivist process involves the correct use of scientific grammar, vocabulary, syntax, and semantics, but not as ends. Surface conventions are a means to give the writing clarity and readability, to make it accessible to the chosen audience. In this way the need for correct conventions comes as an authentic outgrowth of the writer's desire to understand and to be understood.

Table 1

Genre, Purpose, Outcome and Audience
of Writing-to-Learn Science
(Adapted from Gallagher, Knapp & Noble, 1993)

Genre	Purpose	Outcome	Audience
Narrative	Recording Emotions and Ideas	Attitudes	Self and others
Description	Documentation	Basic Knowledge	Others
Explanation	Causality	Cause-effect Relationships	Others
Instruction	Directions	Procedural Knowledge	Others
Argumentation	Persuasion	Patterns of Argument	Others

Science genres, then, are grounded in content and are employed by science writers for the purpose of enhancing understanding. Further, Gallagher, Knapp and Noble (1993) suggest that the scientific genres may also be viewed in terms of audience and outcome as well as purpose (See Table 1).

Scientific genres may address a wide variety of audiences, including self and others, for a number of purposes each of which builds, transforms, or transfers understanding through writing. Scientists write for self, other scientists, students, and the general public. Each audience requires a different form, voice and focus. Students engaged in the science process often have authentic purposes for writing. Such forms might include keeping logs and journals, tracking data and procedures, making meaning of results, sharing data with colleagues or telling a public audience what they have discovered (Baker & Saul, 1994; Hand, Prain, Lawrence, & Yore 1999; Keys, 1999; Keys, 2000). Encompassing a wide range of audiences, forms and purposes, writing in the science genres is an integral part of scientific literacy.

Science Literacy Benchmarks. Over decades, the discussion of science literacy for all Americans has sparked debate among scientists and educators. In 1993 The American Association for the Advancement of Science identified the following habits of mind as benchmarks for students to reach by the end of fifth grade:

- Keep records of their investigation and observation and do not change the records later
- Offer reasons for their findings and consider reasons for suggesting them
- Write instructions that others can follow in carrying out a procedure
- Make sketches to aid in explaining procedures or ideas
- Use numerical data in describing and comparing objects and events

- Ask "How do you know?" in appropriate situations and attempt reasonable answers when others ask them the same question
- Buttress their statements with facts found in books, articles, and databases, and identify the sources used and expect others to do the same
- Recognize when comparisons might not be fair because some conditions are not kept the same
- Seek better reasons for believing something than "Everybody knows that..." or "I just know" and discount such reasons when given by others (pp. 286-299)

Keys (1999) asserts that such higher order scientific habits of mind can and should be explicitly taught to elementary students. Explicit instruction is especially crucial for students marginalized by the traditional curriculum. Critical thinking and writing skills, which characterize literacy for empowerment, are not innate. Those who possess them have been taught, either in elite schools or elite homes. When teachers fail to teach critical thinking and writing skills to all students, those without these skills are left behind (Delpit, 1995; Finn, 1999).

Writing to learn in science has great potential in the upper elementary grades. The explicit teaching of scientific genres helps students develop critical thinking and reasoning skills. Students learn the language of science and how to construct scientific explanations. In this way, students build understanding of science through the writing process, using language as a tool to direct their intellectual power toward finding answers to authentic questions (Hand, Prain, Lawrence and Yore, 1994; Holiday, Yore & Alvermann, 1994; Loranger, 1999; Keys, 1999).

Research points to the value of integrating the writing process and the science process in general--and the value of integrating them in the upper elementary classroom in particular. Research further suggests that the next step is to move beyond theory and address the practical applications of science writing for use by classroom teachers working with real kids in real schools--and all that that entails. This real-world connection comes back to the stated purpose of this inquiry, the design of three practical science writing activities for inclusion in the revision of Earth Smart (Seabury, 1994).

Applications

Science writing, like any writing nurtured in the upper elementary classroom, requires support from the teacher. But what sort of support? And how much of it?

Following are descriptions of three supports for elementary students engaged in the science and writing processes. These three examples include the use of a template, an umbrella topic, and a gradual handing over of responsibility from the teacher to the student for both the writing and the construction of meaning. Further, the activities address a variety of audiences and include a variety of forms while enhancing the interactive relationship between the science process and the writing process.

Supporting Elementary Science Writers. Ideally teaching an integrated science writing process in the upper elementary classroom should be similar to teaching any type of writing, in that the teaching entails a gentle handing over of responsibility from teacher to the student (Atwell, 1998). The steps in this scaffolding or handing over may include, modeling, collaborative writing, guided writing, and finally, independent writing. The level of support balances at the tipping point between what a student already knows and what that student is ready to learn.

Templates to help shape science writing have been found useful with middle school students encountering new science writing forms. The use of templates shows logical promise with younger writers (Keys, Yang, Hand & Hohenshell, 2001). These templates, or prompts, scaffold students' early attempts at science writing and increase early successes as the genre becomes more familiar.

Also helpful is the overarching structure of an umbrella topic to focus study within the classroom while preserving maximum writing choice by individual students (Harvey & Harwayne, 1998). An umbrella topic such as "Water" opens wide possibilities for student exploration while keeping content focused on larger objectives. Students might experiment with evaporation, study local water quality laws, survey individuals and monitor conservation measures--all under the general umbrella topic. Possible umbrella topics can also be tailored to established grade level curriculum, and thus, enable teachers to cover mandated themes while keeping students' choices open.

The following classroom activities illustrate how these three supports, templates, umbrella topics, and the gradual shift of responsibility, work in practice. The first activity makes use of a template to focus and support student science writing. The second activity features a gradual reduction in scaffolding, handing over of responsibility for writing from the teacher to the student. The third activity utilizes an overarching umbrella topic under which students explore their own interests. The suggested activities also include a wide range of forms, purposes, and audiences.

Template. Use of a template supports the student by providing an underlying structure or organization for both the science and writing processes. The science research template (Appendix B) helps students frame their own authentic questions and pursue them in an organized way by researching, hypothesizing, testing, and reflecting.

Activity: Science research template

Audience: Self, classmates, teacher

Purpose: Record observations

Procedure: A research template can help students gather and organize information about their own questions while building their own understanding. Use of a research template can guide a wide variety of laboratory activities while supporting students' use of their critical thinking and logic. Use of the template involves giving students an explicit set of questions to help them to frame authentic questions and form the habits of mind that lead to scientific literacy.

The elementary teacher might begin by helping students generate a K-W-L chart about the large topic Water Quality; a three-column chart headed "What I Know," "What I Want to Know," and "What I Learned" (Harvey, 1998). Students, perhaps in pairs or small groups, could then select specific topics of interest from the "Want to Learn" list. Students would use the guiding questions from the research template to focus their investigation and experimentation. Later, the results could be used as a basis for the newspaper report activity to follow.

Writing process goals including taking notes, writing instructions, synthesizing and summarizing would be taught explicitly. Science process goals would be taught through exploration of students' questions and interests. Intentional teaching toward both writing and science goals could take place in whole group mini-lessons, small group lessons, or through individualized instruction.

Scaffolding. The intentional gradual handing over of responsibility supports student science writers as they explore science and construct meaning through writing. This gentle transition will often include an examination of the form or genre through professional models, modeling by the teacher while thinking aloud about the process, guided practice with attention and support from the teacher, and finally, independent practice with students almost entirely responsible for their own outcomes.

Activity: Newspaper report

Audience: School community

Purpose: To inform

Procedure: Writing a report for a class newspaper gives students a larger audience for insights gained through authentic scientific research. The student might use the results of inquiry based on the research template questions in the activity above. Suppose the student investigated water quality and found evidence that the local fresh water supply, dependent on surface water, was in danger of contamination from pesticides routinely applied to lawns--including the acres of lawn and play fields surrounding the school. A published newspaper report circulated within the school community would be authentic writing used to raise a concern that grew out of scientific research.

Process goals would certainly include the features of a newspaper report. Students would need to know what distinguishes a fact from an opinion, why brevity and objectivity are necessary, and how topics are organized and supported by details added in order of importance (Mooney, 1998). These concepts could be taught by taking actual news stories apart to discover the form and how it works. The teacher could model this analysis as well as demonstrate the report writing. Shared or collaborative writing could be the next instructional step, depending of the prior knowledge of the students. A checklist (Appendix C) to guide the process can also act as a focus for students' self-assessment.

Umbrella topic. An overarching or umbrella topic can serve to focus individual projects while supporting students' understanding of larger concepts. Umbrella topics add a dimension of structure and organization that allows the teacher to tie the work of individual students to class curriculum goals. Such overarching topics enable students to see how smaller parts contribute to the larger body of knowledge within a discipline or content area. Under the larger topic, students select their own areas of interest to pursue in depth. Ideally the composite of self-selected projects, supplemented with explicit lessons designed to fill in any content gaps, reflect the depth and breadth of the umbrella topic.

Activity: Persuasive poster

Audience: Public

Purpose: Persuade

Procedure: Science literacy involves a component of advocacy that reaches beyond understanding to action. Creating posters to persuade the public to take action for the common good based on the implications of scientific research is one way for students to move learning out of the classroom and into the community.

Several umbrella topics are suggested by science advocacy. Again borrowing from the activities described above, a teacher might choose the overarching theme of water quality. A science umbrella topic such as how human behavior influences water quality might lead to persuasive posters designed to raise public awareness on water quality issues. Under that umbrella topic a student might chose to create an informational poster asking people to limit the use of chemical pesticides on their lawns. The information and understanding gained through research and report writing would be brought to bear on persuading the public to act in the interest of all who draw fresh water from the surface water supply. Finished posters could be displayed at a local library, community hall, or other civic building.

Process goals for creating a persuasive poster could target the concepts of basic design or the use of illustrations, graphs and charts. Other teaching points might include writing to a specific audience, focusing on main ideas, making clear word choices, or organizing subordinate details. The clarity of communication would be built on the clarity of science understanding, while the science understanding would be further clarified by communication. An organizer for prewriting (Appendix D) would help students plan as they focus on the features specific to the poster form.

Discussion

At the beginning of this inquiry, I posed four questions, one primary and three secondary. Each of these questions made a unique contribution to this study as they lead from historical research to current thought, and finally, to practical application.

Primary question. What is the relationship between the writing process and the science process? The science and writing processes are integrally connected in a spiraling relationship that is both parallel and interactive. Each process builds on the other in a recursive cycle that acts to construct meaning and foster deep understanding. Students who engage in science writing deepen their experiential learning of both science and writing.

Secondary questions. What are the implications of research for the integration of writing and science instruction in the upper elementary classroom? Which specific genres best support the science process? What adaptations, if any, should be made to teach elementary students to write authentically in the science genres?

Introducing integrated science and writing processes in the upper elementary grades capitalizes on students' growing proficiency in writing and their innate interest in the natural world around them. This integration of processes also enhances learning in both disciplines while making efficient use of instructional time. Also, teachers who feel unsure about their own ability to teach science content gain confidence when science is integrated with language arts.

Science genres may be viewed in terms of their purposes, outcomes, and audiences. These genres include narrative, descriptive, explanatory, persuasive and instructional writing forms. Writing in these genres helps students meet the benchmarks of basic science literacy. Further, all of these science genres can be explicitly taught in the upper elementary grades.

Certain adaptations and supports seem to increase early student success in the science genres. Templates, scaffolding with the gradual transfer of responsibility from teacher to student, and the use of umbrella topics to focus instruction all help upper elementary students as they integrate the science and writing processes.

The activities included in the preceding section are illustrative of the practical ways in which science process and writing process might be integrated in the upper elementary classroom. These sample activities are intended only as a starting point to stimulate further thoughts on implementation of a program for science and writing literacy--a new way of thinking about teaching science, not in isolation, but as a natural part of why and what students write.

Suggestions for Future Research

Most of the research on integrating science and writing has been conducted with secondary and college students. A limited amount of the published research is based on middle school students. Very few researchers have studied elementary teachers and students. And none, to my knowledge, have reached into the primary grades. Much remains to be learned about the science writing connection with these younger learners.

Based on my study of past and current research I offer the following questions for future consideration.

- Which types of writing activities best support specific science disciplines in the elementary classroom?
- Which elementary learners benefit most from which types of writing science connections?
- Does collaborative writing enhance the science process for all students?
- Do some students benefit more than others from participation in collaborative writing activities?
- Is there a correlation between writing in the content areas and improved scores on standardized tests?
- How can writing process skills be taught most effectively within the context of integrated science writing?

Conclusion

Historical and current research has shed much light on the questions I posed at the beginning of this inquiry. The cooperative connection between the science process and the writing process has been established. Nurturing of the interactive relationship between these two processes seems to be a logical and natural part of the middle grades. Further, the interactive science-writing connection has been shown to have practical implications for teachers in the upper elementary grades, both in what they teach and how they teach.

While there is nothing intrinsically wrong with my original creative writing activities in Earth Smart (Seabury, 1994), these activities do not go far enough in fostering an interactive connection between the writing process and the science process. They are fine language art activities but they fall short of connecting the writing process to the science process. The activities described in the Applications section of this project are a step forward in integrating writing and science for the enhancement of both.

Finally, perhaps the most significant result of this study may be my own metacognition, as a student and an educator. Throughout the research and writing of this project, the power of integrating writing to learn in the content areas became clearer and clearer because I was experiencing it for myself in the most meaningful way. Rewrite after rewrite, my approximations lead back to research, which in turn, lead to deeper evidence and stronger revisions in a recursive spiral intertwining processes and disciplines. Appropriately enough, my inquiry to find a stronger connection between writing and science offered an object lesson on its own topic. Writing does indeed increase understanding.

References

American Association for the Advancement of Science (AAS). (1990). Science for all Americans. New York: Oxford University Press.

American Association for the Advancement of Science (AAS). (1993). Benchmarks for science literacy. New York: Oxford University Press.

Atwell, N. (1991). Coming to know: Writing to learn in the intermediate grades. Portsmouth, New Hampshire: Heinemann.

Atwell, N. (1998). In the middle: New understandings about writing, reading, and learning. Portsmouth, New Hampshire: Heinemann.

Baker, L. & Saul, W. (1994). Considering science and language arts connections: A study of teacher cognition. Journal of Research in Science Teaching, 31, 1023-1037.

Bereiter, C. & Scardamalia, M. (1987) The psychology of written composition. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Calkins, L. M. (1991). Living between the lines. Portsmouth, New Hampshire: Heinemann.

Calkins, L. M. (1994). The art of teaching writing. Portsmouth, New Hampshire: Heinemann.

Connolly, P. (1989). Writing and the ecology of learning. In P. Connolly & t. Vilardi (Eds.), Writing to learn mathematics and science (pp. 1-14). New York: Teachers College Press.

Delpit, L. (1995). Other people's children: Cultural conflict in the classroom. New York: The New Press.

Dewey, J. (1938). Experience and education. New York: Macmillian.

Fellows, N. J. (1994). A window into thinking: Using student writing to understand conceptual change in science learning. Journal of Research in Science Teaching, 31, 985-1001.

Finn, P. J. (1999). Literacy with an attitude: Educating working-class children in their own self-interest. Albany, New York: State University of New York.

Fletcher, R. (1993). What a writer needs. Portsmouth, New Hampshire: Heinemann.

Friedman, A. A. (2000). Writing and evaluating assessments in the content area. English Journal, 90, 107-116.

Gallagher, M., Knapp, P. & Noble, G. (1993). Genre in practice. In B. Cope & M. Kalatzis (Eds.) The powers of literacy: A genre approach to teaching writing. (pp. 179-202). Pittsburgh: University of Pittsburgh Press.

Gaskins, I. W. & Guthrie, J. T. (1994). Integrating instruction of science, reading and writing: Goals, teacher development, and assessment. Journal of Research in Science Teaching, 31, 1039-1056.

Graves, D. H. (1994). A fresh look at writing. Portsmouth, New Hampshire: Heinemann.

Hand, B. & Prain, V. (1996). Writing for learning in science: A model for use within classrooms. The Australian Science Teacher's Journal,42, 23-27.

Hand, B., Prain, V., Lawrence, C. & Yore, L. (1999). A writing in science framework designed to enhance science literacy. International Journal of Science Education, 21, 1021-1035.

Harvey, S. & Harwayne, S. (1998). Nonfiction matters: Reading, writing, and research. York, Maine: Stenhouse.

Holiday, W. G., Yore, L. D. & Alvermann, D. E. (1994). The reading-science learning-writing connection: Breakthroughs, barriers, and promises. Journal of Research in Science Teaching, 31, 877-893.

Hurd, P. D. (1998). Scientific literacy: New minds for a changing world. Science Education, 82, 407-416.

Jackson, L., & MacIsaac, D. (1994). Introduction to a new approach to experiential learning. In L. Jackson, l. & R. S. Caffarella (Eds.), New directions for adult and continuing education. Experiential learning: a new approach, 62, 17-28. San Francisco: Jossey-Bass.

Keys, C. W. (1994). The development of scientific reasoning skills in conjunction with collaborative writing assignments: An interpretive study of six ninth-grade students. Journal of Research in Science Teaching, 31, 1003-1022.

Keys, C. W. (1999). Revitalizing Instruction in Scientific Genres: Connecting Knowledge Production with Writing to Learn in Science. Science Education, 83, 115-130.

Keys, C. W. (2000). Investigating the thinking process of eighth grade writers during the composition of a scientific laboratory report. Journal of Research in Science Teaching, 37, 676-690.

Keys, C. W., Yang, E., Hand, B. & Hohenshell, L. (2001). Using science writing heuristic to enhance learning outcomes from laboratory activities in seventh grade science: Quantitative and qualitative aspects. Paper presented at the annual meeting of the National

Association for the Research in Science Teaching, St. Louis, MO, March.

Kolb, D. A. (1984). Experiential learning. Englewood Cliffs, New Jersey: Prentice-Hall.

Kraft, D., & Sarkofs, M. (Eds.). (1988). The theory of experiential education. Boulder, CO: Association for Experiential Education.

Lewis, L. H., & Williams, C. J. (1994). Experiential learning: Past and present. In L. Jackson, l. & R. S. Caffarella (Eds.), New directions for adult and continuing education. Experiential learning: A new approach, 62, 17-28. San Francisco: Jossey-Bass.

Loranger, A. L. (1999) The challenge of content area literacy: A middle school case study. The Clearing House, 72, 239-243.

Mooney, M. E. (1998). Text forms and features: A resource for intentional teaching. Washington State: The Office of Superintendent of Public Instruction.

Murray, D. M. (1985). A writer teaches writing. Boston: Houghton Mifflin.

Nelson, G. D. (1999). Science literacy for all in the 21st century. Educational Leadership, 57, 14-17.

Phenix, J. (1990). Teaching writing. Markham, Onterio: Pembroke Publishers.

Rivard, L. P. (1994) A review of writing to learn in science: implications for practice and research. Journal of Research in Science Teaching, 31, 969-983.

Seabury, D. L. (1994). Earth smart. West Nyak, New Jersey: The Center for Applied Research in Education.

Shamos, M. H. (1996). The myth of scientific literacy. Liberal Education, 82, 44-49.

Tan, A. (1989). The joy luck club. New York: Putnam.

Tchudi, S. N. & Tchudi, S. J. (1983) Teaching writing in the content areas: Elementary school. Washington, D. C: National Education Association.

Tucknott, J. M. & Yore, L. D. (1999, March). The effects of writing activities on grade 4 children's understanding of simple machines, inventions and inventors. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Boston, MA.

Upton, J. (1986). Write on: Improving learning through writing. Paper presented at the Annual Meeting of the National Council of Teachers of English, 76th, San Antonio, Texas, November 21-26.

Vygotsky, Lev. (1994). The development of thinking and concept formation in adolescence. In R. van der

Veer & J. Valsiner (Eds.), The Vygotsky reader. Cambridge: Blackwell.

Yates, J. M. (1983) Research implications for writing in the content areas. Washington, D. C: National Education Association.

Yore, L. D., Hand, B. & Prain, V. (1999) Writing-to-learn science: Breakthroughs, barriers, and promises. Paper presented at the International Conference of the Association for Educating Teacher in Science, Austin, TX.

Zinsser, W. (1988). Writing to learn. New York: Harper and Row.

Appendix A:

Writing Activities from Earth Smart

(Seabury, 1994)

Creative Writing

Creative writing is an important component in any interdisciplinary unit. Writing challenges students to synthesize information and integrate new ideas with what they already know and believe.

Help students to be successful in their writing by brainstorming ideas, words, facts, and observations. List these on the board or overhead. Accept everything students offer and add your own impressions as well. In writing rough drafts the important thing is to get the ideas on paper. Have students reread their writing to themselves and share them. Encourage them to refine their work. After self-editing, students should proof their work with an adult. Check for grammar, spelling, and punctuation.

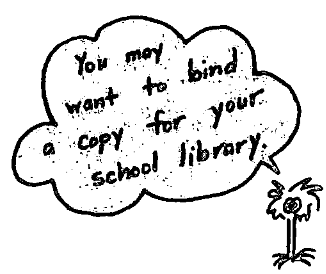
Use the reproducible student pages for final copies. Students put a great deal into their writing, so it is important that the presentation of the finished products be worthy of their efforts. Attempt to find display ideas that will let students share their writing with classmates, families, the school, and the larger community.

From the Diary of . . .

Students can move away from their own point of view by writing a diary for a plant or creature in their environment. Help students choose subjects for their diaries. Discuss diaries as a writing form. Share some famous diaries. Suggest that these writings often include feelings, opinions, and personal thoughts. Help students develop the point of view of their subjects through brainstorming. Encourage them to include comments about habitat, community, and ecology from their subjects' point of view.

Allow time for students to write entries in their diaries each day for at least a week. They may write on notebook paper or in a journal, if you use them. When diaries are complete, have students reread their entries and choose one entry that they would like to share. You may allow them to combine thoughts from two or more entries. Proofread, edit, and polish these entries.

Provide students with copies of "From the Diary of ..." Have students write their final copies of their chosen entries. Children can share their diary entries orally. Make copies of all the children's final copy entries and bind them in a book for your classroom. Original copies should be returned to the student authors.



My Green Commitment

Students can reflect on what they have learned about the environment and human behavior by writing their own personal commitments to being earth smart. Discuss pledges and oaths. Share examples such as the 4-H Pledge, the Scout Pledge, or an oath of office. You may want to share the Declaration of Independence as well. Help students see how these writings promise certain behaviors and commitments.

Brainstorm with your class things that each of us can do to help preserve the natural environment. Encourage them to reflect on what they really want to commit themselves to. Which things do they believe are most important? What will they continue to do?

Allow time to write rough drafts of students' commitments. Proofread and edit the rough drafts. Supply student sheets, "My Green Commitment," for each student's finished copy. You may want to reproduce the student sheets on pastel green or even parchment paper. Students should sign their commitments and share them with classmates. If possible, invite your principal or other dignitaries to listen in. You or your principal should sign as a witness. An official-looking stamp or seal would be a great addition. Display these commitments in a hallway or window where visitors to your school can read and enjoy them.

Animal Diamante

Use a simplified diamante or diamond-shaped poem to have students develop skills with description. This simplified form has seven lines. The form and a sample poem are shown below. You may want to collaborate on a few group poems to help students become comfortable with the form.

Brainstorming helps generate a wide variety of subject possibilities. Have each student write several poems. Students may work individually or in pairs. The students' best efforts should go on the "Animal Diamante" final form. Mount these poems on diamonds of blue and green construction paper. Punch a hole in the top corner and use a piece of brown yarn to hang for display. You may want to mount these back to back or have students make illustrations for the back sides.

FORM

noun
adjective, adjective
participle, participle, participle
a sentence or phrase containing four words
participle, participle, participle
adjective, adjective
noun

SAMPLE POEM

Spinner
Tiny, inky
Watching, peering, hoping
Delicious, juicy insect dinner
Waiting, lurking, hunting
Eager, hungry
Spider

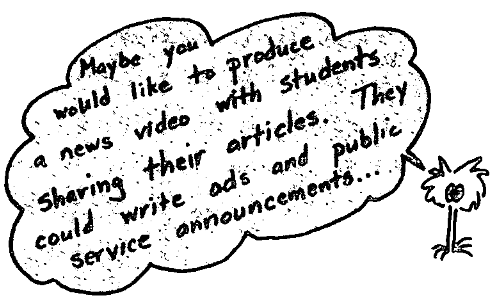
Earth Smart News

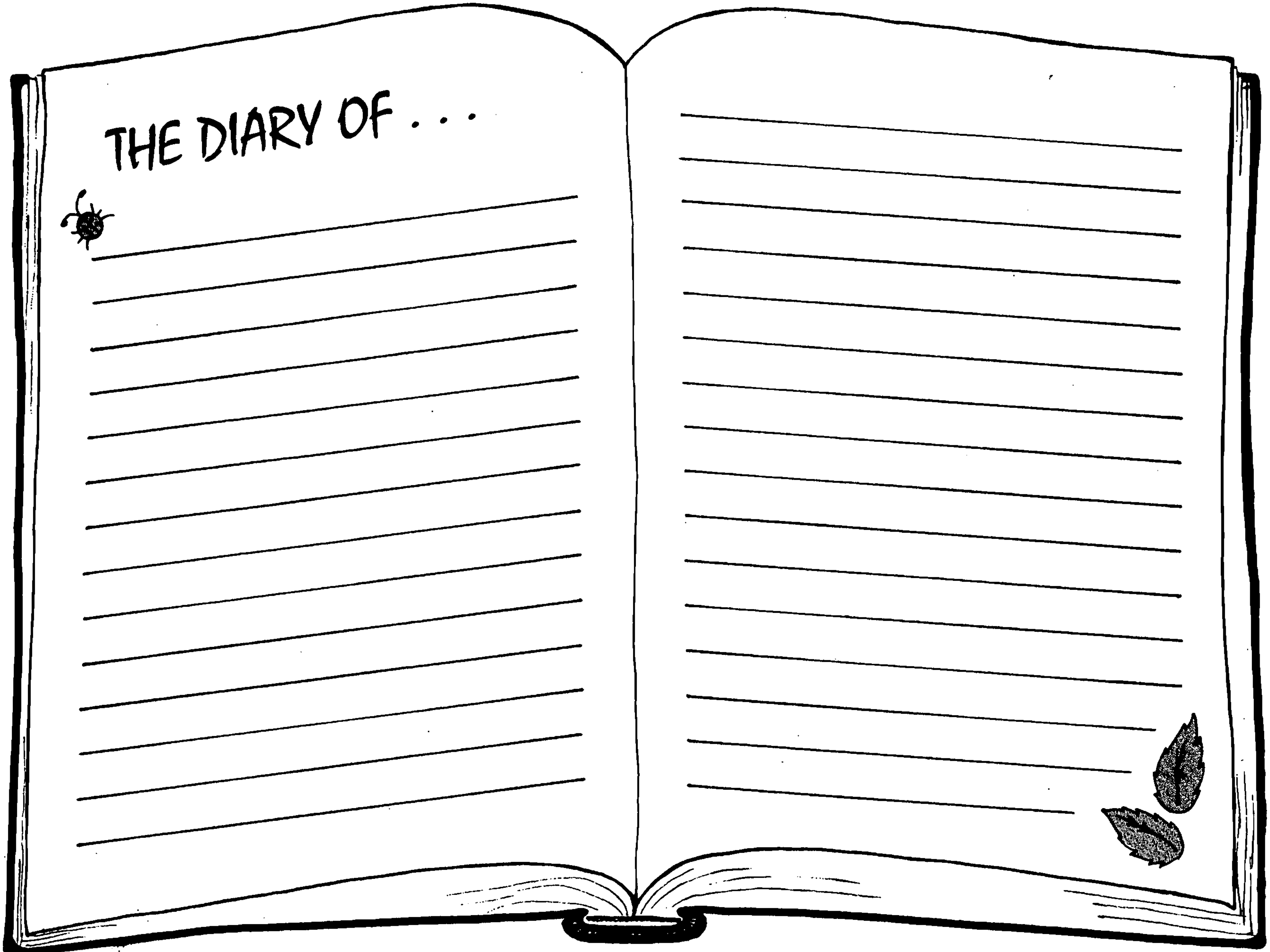
Your students can spread the word about the environment by becoming reporters for the *Earth Smart News*. Begin by having students read and discuss several short news articles. Help them notice the headlines and writing styles. Explain that they will be writing news articles for the *Earth Smart News*.

Have students choose and research environmental issues. These issues may be local, regional, national, or global. Encourage children to include details about how the issues will affect them and their families. Also address what is being done about the issues. Help them polish their articles.

Students should copy their edited articles onto the *Earth Smart News* pages. Students should add an illustration, graph, or other visual in the space provided. Each article also needs a catchy headline. Reproduce finished articles back to back and staple to make completed copies of your newspaper.

Original articles should be returned to students. Distribute copies of your newspaper to other classes who share your interest in the earth.




THE DIARY OF . . .

MY "GREEN" COMMITMENT

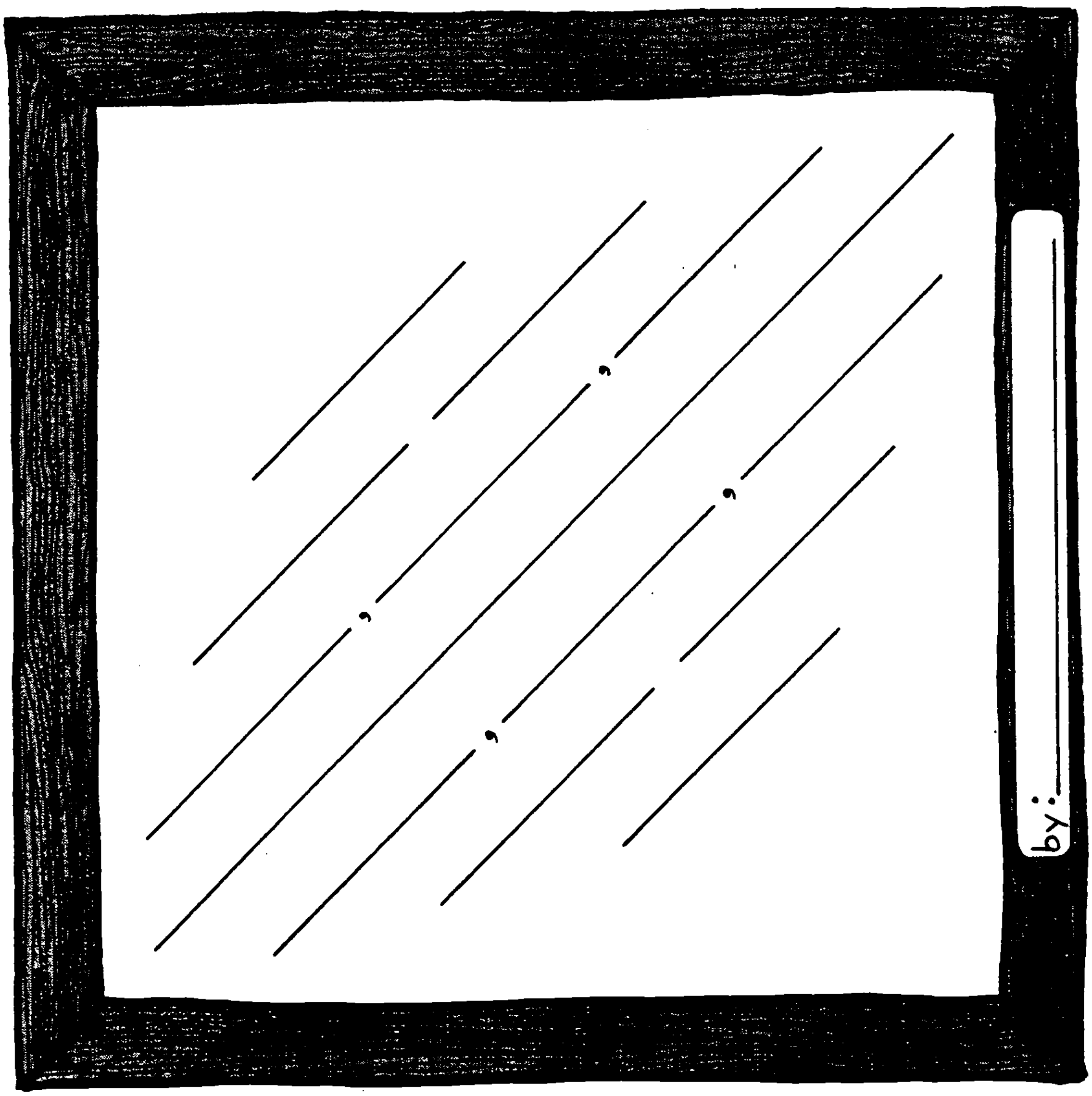
signed by: ______________________

witnessed by: ______________________

date: ______________________

ANIMAL DIAMANTE

Cut along this line for display.



★ EARTH ★ SMART ★ NEWS ★

☆ SPECIAL EDITION FOR ENVIRONMENTAL ISSUES ☆

HEADLINE:

BYLINE

Appendix B:

Science Research Template

(Adapted from Keys, 2001)

Name______________________________

Scientific Research

A. Beginning Ideas: What are my questions?

____
____
____
____
____

B. How might I find out the answers?

____
____
____
____
____

C. Tests: What will I do?

____
____
____
____
____
____

D. What might these tests tell me?

____
____
____
____
____
____

E. Observations: What did I see?

F. Claims: What can I claim?

G. Evidence: How do I know?

H. Reading: How do my ideas compare with others' ideas?

I. Reflection: How have my ideas changed?

Appendix C:

Newspaper Report

Checklist

Name_______________________

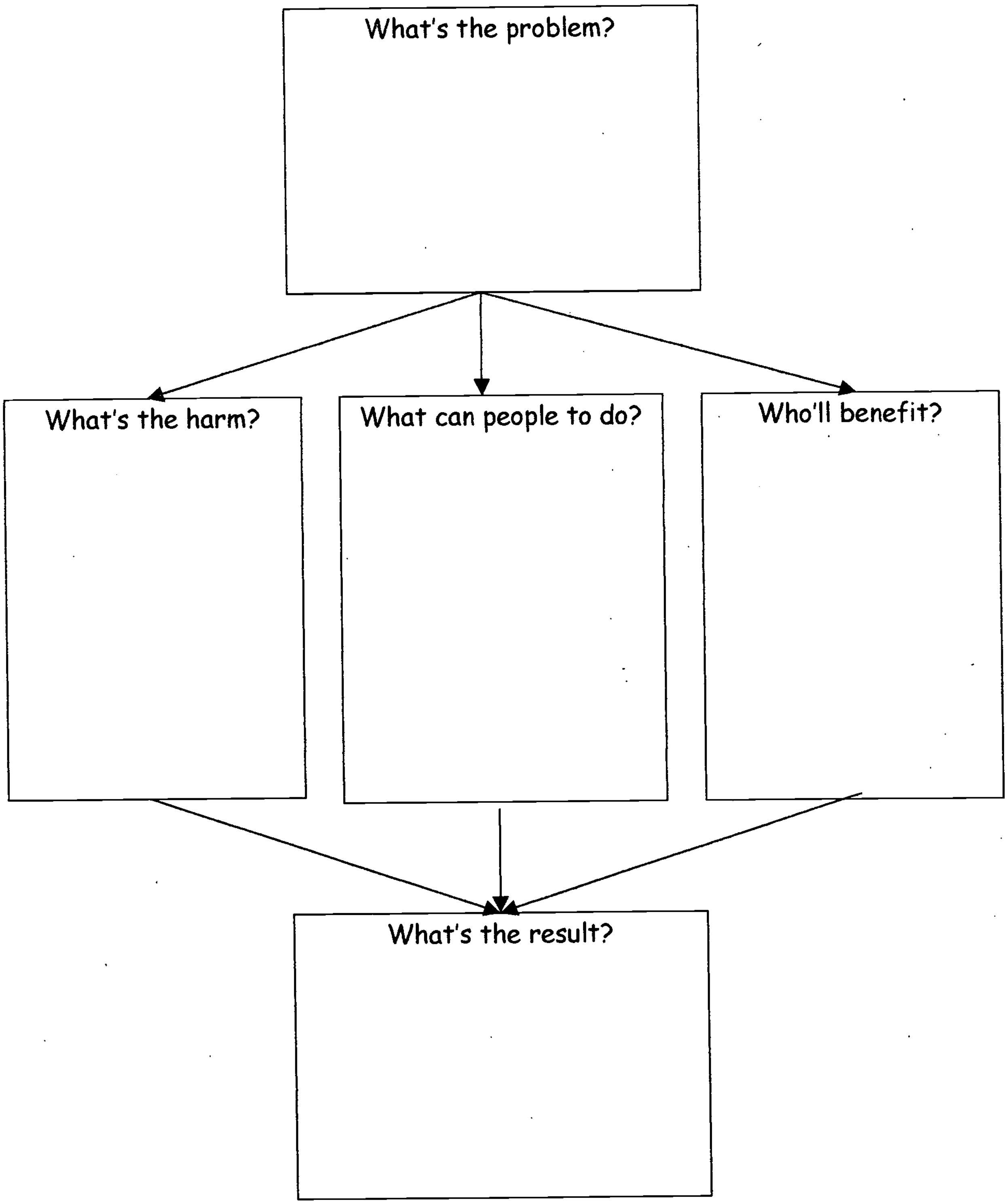
Newspaper Report Checklist

- ☐ My lead sentence includes the most important idea in my report.
- ☐ Details are included in the order of importance.
- ☐ My report provides factual record of what was done or said.
- ☐ My report is free of opinions, judgments and assumptions
- ☐ I have included information to answer:
  - Who
  - What
  - When
  - Where
  - Why
- ☐ My report includes enough background information for the reader to understand the main idea.
- ☐ My report follows standard rules of grammar, punctuation, spelling and format.

Appendix D:

Persuasive Poster Planner

Planning for Persuasion



Name: ______________________________

	E-Mail Address:	Date:

III. DOCUMENT AVAILABILITY INFORMATION (FROM NON-ERIC SOURCE):

If permission to reproduce is not granted to ERIC, *or*, if you wish ERIC to cite the availability of the document from another source, please provide the following information regarding the availability of the document. (ERIC will not announce a document unless it is publicly available, and a dependable source can be specified. Contributors should also be aware that ERIC selection criteria are significantly more stringent for documents that cannot be made available through EDRS.)

Publisher/Distributor:
Address:
Price:

IV. REFERRAL OF ERIC TO COPYRIGHT/REPRODUCTION RIGHTS HOLDER:

If the right to grant this reproduction release is held by someone other than the addressee, please provide the appropriate name and address:

Name:
Address:

V. WHERE TO SEND THIS FORM:

Send this form to the following ERIC Clearinghouse:

However, if solicited by the ERIC Facility, or if making an unsolicited contribution to ERIC, return this form (and the document being contributed) to:

ERIC Processing and Reference Facility
4483-A Forbes Boulevard
Lanham, Maryland 20706

Telephone: 301-552-4200
Toll Free: 800-799-3742
FAX: 301-552-4700
e-mail: ericfac@inet.ed.gov
WWW: http://ericfac.piccard.csc.com

EFF-088 (Rev. 2/2000)