DOCUMENT RESUME

ED 428 973	SE 062 373
AUTHOR	Tucknott, Joan M.; Yore, Larry D.
TITLE	The Effects of Writing Activities on Grade 4 Children's Understanding of Simple Machines, Inventions, and Inventors.
PUB DATE	1999-03-00
NOTE	35p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (Boston, MA, March 28-31, 1999).
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	Comprehension; *Constructivism (Learning); Foreign Countries; Grade 4; Intermediate Grades; Inventions; Physics; Science Instruction; *Writing Exercises; *Writing Skills; Writing Strategies
IDENTIFIERS	Conceptual Change; *Simple Machines

ABSTRACT

This paper explores the effects of infusing writing-to-learn strategies into an inquiry-oriented science unit on simple machines, inventions and inventors. This study used an intact group pretest and posttest design to capture the ecological validity of a classroom of grade 4 students and teacher. The design incorporated quantitative research methods of structured interviews of target students. Students' science understanding and writing skills were documented further with daily teacher reflections and students writing samples. This hybrid research design was selected to provide richness and depth to any conceptual changes detected and to identify potential relationships between writing tasks and science achievement within the limitations of a nonrandom intact group. Student performance on the pretest indicated minimum prior knowledge of simple machines, inventions, and inventors. Students correctly answered 37.3% of the recall items, 9.5% of the understanding items, and 25.3% of all items. Performance on the posttest demonstrated a marked improvement: students correctly answered 75.6% of recall items, 60% of understanding items, and 69.2% of all items. A correlated t-test showed that there was a significant difference between pretest and posttest means. (CCM)

The Effects of Writing Activities on Grade 4 Children's Understanding of Simple Machines, Inventions, and Inventors

Joan M. Tucknott
School District #61
Victoria, B.C. V0S 1M0 Canada

Larry D. Yore
University of Victoria
Victoria, B.C. V8W 3N4 Canada

Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Boston, MA, March 27-31, 1999.

The Effects of Writing Activities on Grade 4 Children's Understanding of Simple Machines, Inventions, and Inventors

Introduction

Current education reforms (AAAS, 1990, 1993; NCTE/IRA, 1996; NRC, 1996) promote contemporary literacy for all students that goes beyond the 3 R's and emphasizes instruction that goes beyond rote memorization and mindless activities. Science literacy for all involves improving students' habits-of-mind, critical thinking, and ability to construct understanding; increasing their understanding of the big ideas in science; and facilitating their communications to inform and persuade others to take informed action (Ford, Yore & Anthony, 1997). Constructivist science instruction involves accessing students' prior knowledge, using these ideas to engage the students, providing concrete experiences that challenge and explore their ideas, and facilitating discourse opportunities to discuss alternative interpretations, reflect on this learning, and consolidate these new ideas into their knowledge networks. Face-to-face communications and communicating-at-a-distance are both an end and a means to science literacy in a constructivist classroom. Talking science has received much emphasis (Lemke, 1990), but students also need to be able to read for understanding, evaluate the credibility of information sources, and produce a wide variety of written discourse (NRC, 1996, p. 36). Benchmarks for Science Literacy (AAAS, 1993) identified the following habits of mind (values and attitudes; communications skills; and critical-response skills) for students to reach by the end of grade 5:

- Keep records of their investigations and observations and do not change the records later.
- Offer reasons for their findings and consider reasons suggested by others.
- 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, 296 & 299).

The critical question facing generalist elementary school teachers is "How can they help their students become members of a language community and better communicators, leading to improved science understanding?" This case study explored the influences of writing-to-learn science tasks on students' conceptual achievement.

Background

Much of writing in science utilizes a knowledge-telling model of writing to evaluate students' understanding. Students systematically select a topic, recall understanding, draft a product, and produce a "good" (final) copy, which involves converting knowledge from long-term memory into written words essentially unaltered. Writing to learn more closely approximates a knowledge-transforming approach in which knowledge is actively reworked to improve understanding – "reflected upon, revised, organized, and more richly interconnected" (Scardamalia & Bereiter, 1986, p. 16). The knowledge-transforming model (Bereiter & Scardamalia, 1987) clarifies the role of conceptual knowledge about the nature of science and the target topics, the metacognitive knowledge (awareness) about and management (executive control) of written science discourse, and science writing strategies influence on the science writing process (Figure 1). Keys (1999, p. 120) believes that "the dynamic relationship between the content space and the rhetorical space in the knowledge-transforming model illuminates why writing is such a critical part of science learning".

[Insert Figure 1 about here]

Unfortunately, the attributes of an expert science writer are not completely documented and need to become a priority in the writing-to-learn science research agenda (Yore, in press). Prior knowledge about the scientific enterprise and science topic (the big ideas of science) would include recognition that science is inquiry while technology is design, how scientists use evidence, warrants and claims to formulate inference chains, the relationships among science, technology, society and the environment, understanding of unifying concepts of science and knowledge of specific concepts. Metacognitive awareness of written science discourse includes declarative, procedural, and conditional knowledge about the rules of the scientific/ mathematical symbol system, grammar, punctuation, spelling, audience, genre, and visual adjuncts. Executive control would involve deliberate self-regulation, setting purpose, strategic planning, generating ideas, organizing ideas, evaluating ideas, translating ideas into text, monitoring effects, reflecting, revising, and assessing internal consistency (Ferrari, Bouffard & Rainville, 1998). Science writing strategies include effective use of the dual nature of science language (English and mathematics), data displays, visual adjuncts, metaphors, and scientific terminology, and the alignment of genre, purpose, language, and audience. Utilizing the knowledge-transforming model as an operational framework would encourage science educators to establish conditions for discovery (Galbraith, 1992) and to get students spending more time setting purpose, specifying audience, thinking, negotiating, strategic planning, reacting, reflecting, and revising (Holliday, Yore & Alvermann, 1994).

This new writing-to-learn rhetoric is compatible with constructivist perspectives of science learning and illustrates that the symbol system used to communicate within a language community plays a critical role in constructing meaning. Connolly (1989) emphasized:

> Writing-to-learn is not, most importantly, about 'grammar across the curriculum' nor about 'making spelling count' in the biology paper. It is not a program to reinforce Standard English usage in all classes. Nor is it about ... mastering the formal conventions of scientific, social scientific, or business writing. It is about the value of writing 'to enable the discovery of knowledge'. (p. 5)

However, writing-to-learn science tasks do provide authentic opportunities to develop scientific vocabulary, grammar, spelling, punctuation, patterns of argumentation, and technical genre utilized in the science writing. Writing-to-learn science and technical writing have much in common; and effective instruction can utilize authentic technical writing tasks to promote science learning, reflection, and practical technical writing. But the "idea is to learn to think in writing primarily for your own edification and then the eyes of others. This approach will enable you to use writing to become more intelligent to yourself – to find your meaning – as well as to communicate effectively with others"(Howard & Barton, 1986, p. 14).

Explicit instruction embedded in the authentic context of scientific inquiry designed to clarify language as a symbol system; what writing is; the purpose-specific nature of scientific genre; the author's responsibilities to the audience; the interactive, constructive and generative nature of science language; the relationship between evidence, warrants, and claims; and what, how, when, and why to use specific writing strategies should be provided as an integral part of science courses (Hand, Prain, Lawrence & Yore, in press). The embedded instruction needs to convert the metacognitive awareness into action to improve self-regulation (planning actions, generating ideas, translating ideas into text, checking and revising text) and actual writing performance (Hayes & Flower, 1986; Sawyer, Graham & Harris, 1992). Surveys of teachers and analyses of school writing tasks reveal teachers were unfamiliar with many genres and a dominant classroom use of narrative and factual recounting (Wray & Lewis, 1997). Gallagher, Knapp, and Noble (1993) and Keys (1999) suggested the need for explicit instruction in a full range of genre (Table 1).

[Insert Table 1 about here]

Narrative involves the temporal, sequenced discourse found in diaries, journals, learning logs, and conversations. Narratives (document recollections, interpretations, and emotions) are far more personal and informal than most scientific writings. **Description** involves personal, commonsense and technical descriptions, informational and scientific reports, and definitions.

Frequently, descriptions will be structured by time-series of events, scientifically established classification systems or taxonomies, or accepted reporting pattern of information (5 Ws). **Explanation** involves sequencing events in cause-effect relationships. Explanations attempt to link established ideas or models with observed effects by using logical connectives of "if this, then this". **Instruction** involves ordering a sequence of procedures to specify a manual, experiment, recipe, or direction. Instructions can effectively utilize a series of steps in which the sequence is established by tested science and safety. **Argumentation** involves logical ordering of propositions to persuade someone in an essay, discussion, debate, report, or review. Arguments attempt to establish the boundaries and conditions of the issue and then to systematically discredit, destroy or support components of the issue, to clearly disconfirm or support the basic premises, or to establish alternative interpretations.

Each genre is flexible, and the writer must control the form to address the function or purpose. No lengthy piece of text uses a single genre (Anthony, Johnson & Yore, 1996). Analysis of effective writing illustrates microstructures embedded within the macro-structure. In argumentation a writer might start with a descriptive passage to engage the reader, later use an explanation passage to illustrate a critical cause-effect relationship, and in closing may use an instruction passage much the way a judge clarifies the issues, critical evidence, and the charge to a jury.

Prain and Hand (1996a, 1996b, 1999) provided a framework of five separate but inter-related components to guide improved writing practices within science classrooms: writing type, writing purpose, audience or readership, topic structure including conceptual clusters, and method of text production including how drafts are produced, both in terms of technologies used as well as variations between individual and collaborative authorship. The framework is intended as both a theoretical model to examine writing-to-learn strategies within science classrooms and as a pragmatic pedagogical model to assist teachers in the implementation of these strategies.

This writing-to-learn science framework nicely reflects elementary teachers' willingness to expand their language arts program across the curriculum and to use a variety of non-traditional writing tasks (Baker, 1996). Contemporary approaches in language arts involve establishing a language community in the classroom that addresses a wider variety of authentic speaking, listening, reading, and writing tasks (NCTE/IRA, 1996; Rowell, 1997). Linton (1997) and DiBiase (1998) utilized inquiry letters to seek relevant information to supplement classroom investigations. Letters designed to request information from experts require students to venture into different language communities. Information technology makes these approaches much more time efficient and effective.

Nesbit and Rogers (1997) described how cooperative learning approaches could be used to improve the print-based language arts in science. The use of culminating writing activities for inquiry-oriented science units can encourage students to reflect, integrate, elaborate, and consolidate on their science understandings developed during verbal interactions in the cooperative groups (Anthony, Johnson & Yore, 1997).

Peer-review, structured templates, and jigsaw writing activities have effectively enhanced students' science understanding and metacognition of science writing. Wray and Lewis (1997) developed a series of factual writing templates to support young writers in their early attempts to use factual genre. They viewed writing as a social process and the textual product as a social artifact. The use of teacher scaffolding and structured frames allowed students to develop discourse knowledge about the specific genre. Keys, Hand, Prain, and Sommers (1998) used as series of writing-to-learn activities and structured templates infused in an inquiry-based science unit to promote students' understanding of the epistemic canons of evidence, warrants, and claims in a science laboratory report and scientific argument. This science writing heuristic extended the use of Vee-diagrams and negotiated understanding to improve student science achievement and understanding of science as inquiry. Shelley (1998) described the use of prewriting activities and writing tasks to improve science understanding and to enhance compare-contrast thinking. She states "prewriting activities, particularly those including visual aids, focus writing so that students can successfully compare and contrast information" (p. 38). Breger (1995) used an approach called inquiry papers and a variety of publications to encourage middle school students to learn about science or science related topics. Students created reading logs in which they wrote down what they predicted they would be reading about, based on the title, pictures, graphs, and other clues and key pieces of information that could be used to verify their predictions. They used these ideas to create a summary consisting of the main idea with supporting details of "Who? What? Where? When? Why?" Students then reorganized (transform) the summary or key ideas in a visual way, such as a flow chart, concept map, chart, diagrams, to show how the ideas are connected. In these cases, the inquiry and the structured tasks are sequenced to require students to process, transform and internalize information, not just copy textual materials.

Rillero, Zambo, Cleland, and Ryan (1996) used "Write Now" during lesson introductions as integrative, reflective, writing-to-learn science tasks. They found open-ended questions requiring students to think about concepts learned the day before helped students consolidate the concepts being studied and provided informal assessment of the students' understanding. The best questions allowed for a diversity of responses and individual creativity, could be answered in about five minutes, and encouraged students to explain, compare, contrast, and evaluate. Sharing responses provided another discourse opportunity to support knowledge construction and to foster deeper conceptual understanding as students hear a variety of viewpoints about the questions.

MacPherson (1992) investigated the use of writing to develop the student's understanding of the language of science. Strategies were developed to help students express their understandings in their own words. The first strategies she modeled were webbing and sentence explanations. Webbing consisted of key words needed to explain science terms connected in a graphic array, and sentence explanations consisted of expressing their understanding in complete sentences. These tasks were most effective when used together;

webbing focusing on identifying important ideas, while sentence explanations provide a way to integrate the ideas into a causal relationship. Discussion prior to writing proved critical to achieve clear writing.

Mann and Volet (1996) investigated note-taking and its effect on writing summaries. They found that explicit instruction combined with group discussion, teacher modeling and group activities produced the most comprehensive notes. They also found a lack of transfer from writing good notes to writing a quality summary. The lack of transfer may be explained by the fact that the students were given explicit instruction in writing notes but were not given explicit instruction in writing summaries. Note-taking and summary writing are not simple reciprocals (Hare, 1992; Rosaen, 1989). Note-taking involves analysis and evaluation – identifying key words, main ideas and supporting information, the deletion of trivia and redundant elements, and recording in point form the essence of the overall message. Summary writing involves synthesis – generating a concise series of topic sentences and supportive sentences containing important details and applications while retaining the original author's voice.

Harrison (1991) used two-column frames with Grade 9 science students to help them think critically about science. The frames (problem-solution, theory-evidence, likes-dislikes, question-answer) were used to help students organize science information from a variety of sources, such as newspapers, videos, library books, magazines, filmstrips, and texts. The four frames provided variety and stimulated reading, thinking, and writing. Armbruster (1991) also advocated the use of frames designed for specific structure of the text (genre). Her frames were a visual representation of the organization of important content in a text, such as the main ideas of a text and the relationships connecting those ideas. Frames can have different forms (charts, tables, semantic maps, matrices, or diagrams) and can be used in different stages of reading, writing and learning. Armbruster claimed that without this type of structure students have difficulty taking notes because, as novices, they do not know which information is important. Once students have selected important information using the frames as a guide, they can consolidate their learning by summarizing their topic of research (Spence, Yore, & Williams, in press).

Rosaen (1989) investigated students' responses to creating drawings that illustrated their writing. She found that they tended to elaborate beyond the focus questions used to guide their writing when they illustrated their research reports. Students' drawings not only illustrated details they had written about, but expressed information or feelings the writers were not capable of putting into words. Students needed less teacher support and were more self-regulated at using drawing as a tool for learning. Students had more responsibility for deciding what to draw and for deciding whether the drawing was sufficient.

Moline (1995) believed that drawing provides valuable knowledge-transformation opportunities. He suggested that literacy is more than communicating with words because many informational texts also include important visual elements, such as diagrams, graphs, maps, and tables. Visual literacy is necessary in everyday life to follow instructions, fill-in forms, apply for work, choose consumer goods, and plan vacations. All of these communication tasks combine verbal and visual information to make meaning. Moline (1995) recommended drawing strategies to:

- integrate literacy with other curriculum areas, such as science and technology, human society, and personal development
- motivate students who are judged to be "non-writers" and "non-readers"
- develop initiative and independence in learning, especially in the areas of research and writing
- give support and confidence to those students whose strengths lie in visual perception
- develop thinking skills, such as selecting and combining strategies, to solve problems and to initiate new solutions to writing tasks
- combine verbal and visual literacy to make an integrated text. (p. 4)

He further suggested that drawing required the transformation of information. He found that labeled diagrams could serve as glossaries that are more powerful than vocabulary lists and that words supported by pictures help students define or explain the meanings of ideas. Flow diagrams serve as a word bank to focus on key concepts, provide students with a language resource when writing, and show the relationship and sequence of steps in a process.

Collectively, the research and teaching literature suggested using a variety of writing-to-learn tasks that emphasize science as a connected body of knowledge, inquiry as a dynamic, recursive process that reveals causal relationships, and expository text as involving English, mathematics symbols, and visual adjuncts. The literature supported using structured experiences to promote webbing; diagrams, charts, flow charts, and time lines; and extended text or paragraphs of connected explanatory sentences. The following principles should guide the development of writing-to-learn tasks in science (Tchudi & Huerta, 1983):

- Keep science content central in the writing process
- Help students structure and synthesize their knowledge
- Provide a real audience for student writers that will value, question, and provide supportive criticism
- Spend time prewriting, collecting information from various sources (concrete experiences, print materials, experts, electronic data banks, visuals, etc.), sharpening focus, and strategic planning
- Provide on-going teacher support, guidance, and explicit instruction
- Encourage revisions and redrafts based on supportive criticism to address conceptual questions and clarify understandings
- Clarify the differences between revising and editing (format, spelling, mechanics, grammar)

Method

This case study used an intact group pretest and posttest design to capture the ecological validity of a classroom of Grade 4 students and teacher (Tucknott, 1997). The design incorporated quantitative research methods of pretest and posttest science content measures and qualitative research methods of structured interviews of target students. The students' science understanding and writing skills were documented further with daily teacher reflections and student writing samples. This hybrid research design was selected to provide richness and depth to any conceptual changes detected and to identify potential relationships between writing tasks and science achievement within the limitations of a non-random intact group.

The Simple Machines unit recommended by the Ministry of Education's Integrated Resource Package, Science K-7 (1995) was taught incorporating relevant writing-to-learn activities embedded in guided inquiry lessons. The science unit was developed around the knowledge and science applications outcomes provided in the curriculum guide. The lessons provided a balance of hands-on/minds-on activities in an interactive-constructivist setting (Shymansky, et al., 1997). The activities included classifying simple machines, making models of simple machines, and manipulating simple machines. These activities required applications of science processes, skills, and writing-to-learn science tasks. Writing-to-learn science activities included answering open-ended questions, note-taking and summarizing, explanatory paragraph writing, drawing diagrams and labeling with sentence explanations.

The unit was taught over a six-week period using invention as an integrative theme. The effects were measured by administering a posttest that assessed the same concepts as in the pretest but with differently worded questions. Differences in gain scores were statistically compared. Qualitative data were collected through daily teacher reflections that provided on-going information about the teaching and learning process. Individual student writing samples were collected and criteria for evaluating these samples were determined by the teacher-researcher. Structured interviews of target students were conducted and analyzed to gain insight into the students' conceptual understandings and opinions about the writing-to-learn activities' influence on their understanding of science concepts.

The purpose of the study was to explore the effects of infusing writing-to-learn strategies into an inquiry-oriented science unit on simple machines, inventions and inventors. The following question framed the study:

Does incorporating writing-to-learn strategies into a unit on simple machines, inventions, and investors influence students' recall and conceptual understanding of science?

It was anticipated that the students would adopt many of the writing strategies taught and be able to demonstrate improved recall and understanding of science. As well, because students with higher writing abilities generally possess and use some or all of these strategies in their writing already, it was further hypothesized that the greatest gains would be evident in the scores of the lower writing ability students.

Instrument

A comprehensive test bank was constructed following the design of questions in the Forces and Motion unit test from *Journeys in Science* (Shymansky, Romance & Yore, 1988). A total of 80 questions was developed incorporating the concepts of machines and inventions. A 40-item pretest and posttest were developed from the questions in the test bank. Each test was composed of 32 short-answer and multiple-choice questions designed to test lower-level recall and comprehension and 8 questions requiring paragraph answers with diagrams and labeling designed to test a higher-level understanding of science concepts of simple machines, inventions, and inventors. Questions in the two tests were similar and covered the same concepts, but the pretest items were reworded in the posttest. One point was given for each short-answer and multiple-choice question and three points for each paragraph and diagram question for a total of 56 points. The open-ended questions were scored as one point for each correct answer and two points for describing, explaining, or completing diagrams. The pretest was not marked until after the posttest was given in order to avoid any influence on the teacher-researcher.

Setting and Sample

The research took place in a Grade 4 public elementary school classroom in an urban, middle-class neighborhood. Thirty students were in the self-contained classroom; 26

participated in the study, of which there were 14 girls and 12 boys. Four boys in the class also participated in classroom activities throughout the unit but did not take the pretest. Three of the boys were absent for the pretest and the fourth boy did not take the pretest because it was felt that it would be too stressful for him to complete.

The children were of the expected age distribution for a Grade 4 class. Within this group there were wide variations in academic ability and social behaviors. Although there were five high-level readers in the class, there were no students who displayed a high level of writing ability. All the students performed better at reading than writing tasks. This assessment was based on language arts achievement in previous grades and on the teacher-researcher's appraisal of their current reading and writing abilities. Students' previous writing experience mainly consisted of weekly journal writing and occasional creative writing. Daily writing activities mainly required students to complete fill-in-the blank questions. Sentence answers rarely required students to reflect on their answer or to provide an explanation or rationale for their answer. None of the students had previously studied simple machines, inventions, or inventors.

Four students were selected for interviews, two girls and two boys. Students were selected to represent a range of abilities, high academic ability to low academic ability, high verbal communication skills to low verbal communication skills, high motivation to low motivation, and high drawing ability to low drawing ability. The first girl had high academic ability and enjoyed drawing. She tended to take longer than average time to complete assignments because she was a perfectionist. She was also very quiet and did not participate in oral discussion very much. The second girl had low academic skills and was approximately six months behind her expected grade level in reading and comprehension skills. She was more confident in oral discussion and quite comfortable answering questions in the interviews. The first boy had average academic skills but was highly motivated to do well and always put in his best effort; therefore he received high marks in most work. He was very verbal and answered questions in the interviews as completely as he could. He was, however, low in artistic ability and found drawing difficult. The second boy had high academic ability but was low in verbal communication skills. He tended to answer questions in interviews as briefly as he could and, although he made good academic achievement, he was not motivated to extend his learning beyond what was required.

The unit was taught by a teacher with ten years experience in elementary education. The teacher had limited science experience and background, which consisted of high school level biology and chemistry courses and university level general science and science educational methodology courses. She was currently enrolled in a Master of Education graduate program in which she had taken courses in curriculum, instruction, field-based research, reading and writing to learn, and integrated studies. Previous science units taught were teacher developed or derived from textbooks. Forces and Motion, which included many of the same activities as in the Simple Machines unit, was previously taught using Journeys in Science Grade 5 (Beugger & Yore, 1989).

Instructional Unit

The Simple Machines, Inventions, and Inventors unit was designed to teach the six basic types of simple machines and the inventing process. Objectives for the unit involved conceptual outcomes, science processes, skills, and science attitudes.

Learners will be able to (Ministry of Education, 1995):

- manipulate simple machines to determine their characteristics and uses
- compare the uses of simple machines today with those in the past
- operate simple machines to demonstrate their usefulness in everyday life
- become aware of the factors that influence the need for inventions
- develop an awareness of change in the various aspects of our world and the response of scientists and inventors to change
- become aware of achievements of Canadian and U.S. inventors
- become aware of the process of inventing and seek solutions to problems using inventive thinking

- predict the results of an experiment
- perform an experiment by following a procedure
- use appropriate tools to assist in observation
- construct simple definitions based on their experiment
- demonstrate an ability to recognize a valid interpretation of their results
- present their interpretation of the results from an experiment
- use a variety of media to present information
- demonstrate responsible action when using the scientific information and skills they have developed.

Each guided inquiry lesson utilized a pre-experience, experience, post-experience, and evaluation organization (Beugger & Yore, 1989). The pre-experience phase attempted to engage students' prior knowledge, motivate, and establish problem focus. The experience phase challenged students' prior knowledge or provided a direct exploration of the concept under investigation, such as concrete experiments, demonstrations, and building models of machines. The post-experience phase allowed students to clarify, consolidate, and apply their understandings of the ideas; this included student notes and writing tasks. The evaluation phase provided a snap-shot of students' learning using a variety of assessments: observation of individual and group work, oral discussion, daily assignments in notebooks, answers to questions of the day, and writing activities. Some lessons were completed in a single block of time, while other lessons are completed on specific days.

Typical Components of a Lesson

Pre-experience:

Question of the Day. A typical lesson on simple machines and inventions began with students answering a question of the day in their science notebook. These questions were intended to capture students' imaginations and raise their thinking to higher levels (Rillero, et al., 1996). The questions focused on concepts already explored in class, were open-ended to allow students to express their individuality, and were designed so they could be answered thoughtfully in about five minutes. Answering these questions encouraged students to explain, compare, contrast, and evaluate. After allowing five minutes of writing time, volunteers shared their answers with the class and a class discussion followed.

Overhead Transparencies. Transparencies from *Weird and Wacky Inventions* (Murphy, 1978) were shown of past inventions that were both practical and amusing. These were intended to motivate students, draw upon their prior knowledge, and create an awareness of inventions. Students were given four possible uses of the invention, and they voted for the one they thought was the inventor's intended use.

Readings. Approximately half a chapter was read from the book *Everything You Want to Know About Inventions* (Wyatt, 1987). The book followed 8 themes: inventing, how inventions happen, wearable inventions, edible inventions, around-the-house inventions, inventions that made a big difference, fun and games, and the inventive mind. The objectives of the readings were to create student motivation for inventing and to create an awareness of the process and development of inventions.

Experience:

Teacher Demonstrations and Hands-On Activities. Generally, a teacher demonstration preceded student activities. Demonstrations introduced a topic, posed a problem to investigate, modeled procedures for experimenting, or showed how to make a model. Limited equipment was available; therefore, the teacher would demonstrate the experience with one set of equipment and call on volunteers to assist. As well, when the list of equipment required was large, it was impracticable to provide more than one set of equipment. For example, complex fixed pulley systems and moveable clothesline systems were set up. Although a hands-on activity for all students was desired for each lesson, it was not always possible. Lack of equipment and space for hands-on activities are typical limitations in elementary schools.

The simple machines lessons included a hands-on activity that typically consisted of manipulating and constructing the six basic simple machines. Students made models of first class levers, wheels and axles, pulleys, inclined planes, a screw, and a wedge.

Post-experience:

Discussions, Notes, and Writing Activities. Large group discussion followed the completion of a hands-on activity. Then students recorded their results in the form of charts, notes, and diagrams. Handouts provided students with a guide to construct a model and a framework to answer questions and record observations. Additional worksheet activities supplemented and reinforced the lessons.

Writing activities were chosen for their potential to enhance students' comprehension of simple machines, inventions, or inventors and were included in each lesson. Four larger writing activities were completed as individual lessons during both language arts and science times: an invention/inventor project, explanatory paragraphs, an invention patent, and a Rube Goldberg drawing.

Writing activities required transforming a short form of writing into a longer one. For example, for the invention/inventors project, note-taking was introduced, fact sheets were used to record information in point form, and then students used the information collected to summarize the development of the invention/inventor. They also completed a poster with labeled pictures and diagrams. For the explanatory paragraph writing activity, students first practiced labeling diagrams with three or four words. Next, students invented and drew a clothing invention, then elaborated the diagrams with sentence explanations. After this technique was familiar, students made a drawing of a machine invention, labeled it, and completed the drawing with a sentence explanation. Finally, students used this information to help write explanatory paragraphs on how the machine worked. The invention patent project required selecting important information and designing a patent certificate that included this information. The Rube Goldberg activity required students to sequence the machine's operation, label the parts, describe the invention with sentence explanations, and explain how the machine worked with paragraph explanations.

Evaluation:

Students' progress was monitored daily by observing their activities and daily practice assignments. "Write-Now" questions provided ongoing assessment of the students' understanding of previously learned concepts. Writing activities were assessed based on criteria developed by the teacher. Notebooks were collected regularly and evaluated for student understanding and checked for completion.

Students were assigned marks based on progress in the following areas: locating sources for invention/inventor project, writing descriptive paragraphs, writing summaries of inventors/inventions, completed posters, notebooks, questions of the day, group participation, oral participation, and posttests.

Timeline, Data Collection, and Data Analysis

The unit was taught by the researcher over a six-week period starting in mid January. Table 2 provides an overview of concepts covered, experiences, writing activities, and products.

[Insert Table 2 About Here]

Activities providing relevant concrete experiences were incorporated into each lesson; and activities were organized for students to work individually, in pairs, in small groups, and large groups to maximize opportunities for hands-on experience and peer interactions. Each writing activity was completed using both language arts and science times before a new simple machine was introduced.

The pretest was administered the first day when a 60-minute science time block was available. No time limit was given for the test and students took between 40 and 60 minutes to complete the test. The test was not marked until after the posttest to avoid any bias on the part of the researcher/teacher. Lessons were taught in approximately four 45-minute time periods per week for science, and two 60-minute time periods per week for language arts. Teaching time was approximately 5 hours per week for a total of 30 hours.

The posttest was administered during the last day of the data collection period in mid March. No time limit for the test was given, and most students completed the test within 60 minutes.

All written work was collected and examined regularly as ongoing assessment. Samples of student writing were read to the class on a regular basis. Students showed their finished posters and summaries on an inventor/invention to their parents during the curriculum fair in mid February.

Results

Pretest and posttest results were analyzed to explore test reliability and to provide descriptive statistics. Posttests were examined for evidence of conceptual change. Interviews of four purposefully selected target students took place twice during the study, after the invention/inventor project and after the posttest. The interview results were analyzed to confirm students' conceptual understanding and clarify how writing activities benefited students.

Test Reliability and Validity

Students' responses to the pretest and posttest items were analyzed using a Cronbach Alpha approach to determine the degree each item was consistent with the total test. These analyses revealed acceptable indices of internal consistency. The internal consistency of the instruments used in this study were as follows: Pretest test items 1-32, $\alpha = 0.67$; items 33-40, $\alpha = 0.62$; total items 1-40, $\alpha = 0.69$. Posttest items 1-32, $\alpha = 0.79$; items 33-40, $\alpha = 0.77$; and total items 1-40, $\alpha = 0.85$. The validity and reliability of the pretest and posttest were verified by analysis of the development procedure of test items, expert judgments, and internal consistency. Item analyses revealed that only 2 out of the 40 questions had suspect difficulties.

Pretest-Posttest Results

Students' performance on the pretest indicated minimum prior knowledge about simple machines, inventions, and inventors. Students correctly answered 37.3% of the recall items, 9.5% of the understanding items, and 25.3% of all items. Their performance on the posttest demonstrated marked improvement. Students correctly answered 75.6% of the recall items, 60% of the understanding items, and 69.2% of all items. Descriptive statistics for the pretest and posttest are shown in Table 3. Means and standard deviations have been provided for part 1 of the test, items 1-32; part 2 of the test, items 33-40; and total test items, 1-40.

[Insert Table 3 About Here}

Correlated t-tests were used to determine if the gains between mean pretest scores and mean posttest scores were significant. The differences between the pretest means and posttest means for part 1, part 2, and total test were significant. Gains of 12.27 points in part 1, 12.27 points in part 2, and 24.54 points in the total test were achieved. Students made a 38.3% improvement between pretest and posttest for part 1 questions, and a 51% improvement between pretest and posttest for part 2 questions. Higher percentage achievement gains were made on the open-ended questions.

The range for a total achievement (maximum score = 56) on the pretest was 5 to 23, and the range for total achievement (maximum score = 56) on the posttest was 22 to 52. It was expected that the biggest gains would be from lower-level ability students rather than higher-level ability students. The first five students who made the most significant gains between the pretest and posttest total achievement scores and the first five students who made the least gains were examined. Contrary to what was predicted, the greatest gains were made by the higher-level ability students and the least gains by the lower-level ability students.

The data were then inspected to see if there were any gender differences between highest and lowest gains. The lowest gains were made mostly by girls and the highest gains were made mostly by boys. Next, gains for both boys and girls were inspected according to ability level.

The lowest gains by girls were made by the lowest ability students, and the highest gains by girls were made by the highest ability students. Likewise, the lowest gains by boys were made by the lowest ability students; and the highest gains by boys were made by the highest ability students. Seven out of 8 students receiving the lowest marks on the pretest were girls. However, 5 of the 7 girls made dramatic gains on the posttest.

Interview Results

Students were interviewed after completion of the invention/inventor project and after the posttest. The first interview posed questions to confirm students' conceptual understanding of simple machines and to clarify how writing activities benefited them. They were asked questions that required them to explain examples of how simple machines work and apply their knowledge to new situations. They were also asked questions about constructing their knowledge and how they used the activities to help them. Students had a limited understanding of how machines work, and it was difficult for them to give clear explanations. It was found that students used a recursive approach in their writing activities and used their notes to guide their paragraph writing. Most students indicated that it was helpful to have note guides and instructions on summary writing.

Questions asked in the second interviews were designed to detect explanations for wrong or incomplete answers on the posttest, determine which writing activities they found easiest or hardest, and which activities were most helpful in studying for the posttest. Students were also asked to define science vocabulary words that were significant in their lessons and appeared in the posttest. It was found that some questions on the posttest were answered incorrectly, but when questioned, students had some understanding of the concept. Students found completing diagram questions the easiest and sentence explanations the hardest. The majority indicated that they mostly studied the fact sheet on definitions of simple machines, given by the teacher to prepare for the test. All students showed a limited understanding of the science vocabulary and were only able to define approximately half of the terminology.

Students were successful in completing longer writing activities, such as paragraph explanations and paragraph summaries. Drawing and labeling diagram activities were the easiest activities for the students and appeared to aid in the development of their writing. The most successful writing activity appeared to be the explanatory paragraph on how a wheel and axle works. The least successful was the activity requiring them to design a patent application.

Discussion

It appears that the six weeks of schooling including an instructional strategy of incorporating writing activities into the science unit on simple machines, inventions, and investors was successful. It is unlikely that the entire gains measured could be accounted for by confounding factors not controlled by the one group pretest/posttest design. This study provided qualified support for the hypothesis that writing activities enhance students' conceptual understanding of science. Students made a 38% gain on the recall part of the test and 51% gain on the high-level comprehension part of the test. It appears that writing activities helped students to explain their answers and to construct meaningful understanding.

Contrary to what was expected, the biggest gains were made by higher-level ability students. This would suggest that higher-level ability students assumed to already possess good general writing skills benefited from the explicit science and writing instruction to achieve more knowledge. It does not suggest that lower-level ability students did not gain from the writing experiences. Importantly, most of the students who achieved the lowest scores on the pretest made considerable gains on the posttest.

In general, the lower ability students for both boys and girls made the lowest gains, and the higher ability students for both boys and girls made the highest gains. This result suggests the need to provide more explicit instruction in writing over an extended period to allow the lower ability students to develop these skills. It was also expected that girls in this grade would have better writing skills and be able to verbalize science concepts easier than boys. The findings suggest that this was not the case; the boys in this class appeared to benefit from writing in science more than the girls.

After examining students' writing and after conducting student interviews for their opinion about the helpfulness of writing activities, similar inferences were made. Most of the students found the easiest writing activities were drawing and labeling diagrams and the hardest activity was writing sentence explanations. They used labeled diagrams to study for the posttest and to aid in writing sentences and paragraph descriptions. All students were able to label diagrams and expand these labels into sentence explanations. All interviewed students indicated that they used the diagrams in varying degrees to help write paragraph descriptions on how their machine worked. Some students used a recursive writing process that added information to their diagrams or compositions; the paragraph was elaborated and the diagrams were checked to see if they had included all-important operations in the paragraph. The best paragraph descriptions were on the wheel and axle. This activity followed after making a model, answering guided questions, and drawing and labeling diagrams. It was found that the more related activities they engaged in before writing paragraphs, the more likely they were able to write good paragraphs. Since this was the only activity in which they made a model before writing how it worked, it is likely that the hands-on activity contributed to their writing success.

All the students expressed difficulty in explaining how a machine works in a sentence answer on the posttest. Moreover, answers to "questions of the day" reflected their tendency to answer with only surface explanations. When questioned during interviews for further explanations, it was discovered that they generally had sufficient understanding of the concepts but were quite often limited in expressing their knowledge. For example, one student when asked what she thought was the most important invention answered, "the radio because you never know when it is going to snow." One could infer that she also meant that the radio is an important medium in which to report the weather. Students in the interviews were also asked to define science terms used in the questions on the test. Each student was only able to answer approximately half of the definitions. This would imply that their ability to answer questions was limited by their technical vocabulary. Most students also indicated that when studying for the posttest they found the definitions on the simple machines handout very helpful in explaining the six kinds of simple machines and attempted to memorize these explanations. This suggests that their preferred learning style was to be told; but in an interactive-constructive mode of instruction, more time spent on developing students' own explanations of each type of simple machine and how it works was deemed necessary.

Another writing activity that showed promising results as a knowledge-transforming vehicle was note-taking. Notes were taken in point form and recorded on a fact sheet that served as a guide. The guide required students to find important information on an inventor/invention from three different sources. The facts were then used to write a 5-7 sentence summary report on their inventor/invention. Students relied on their notes to write the summary, and students interviewed stated that they could not have written the summary as easily without their notes. One student said he could have written the summary but he would not have been as selective in reporting only important information and would have written the first four facts he found in a book. Another said she found the fact sheets save time because she would not have to keep looking back in her books and she said the notes also helped her remember everything. A third student commented that he would not have had a clue what to put in the summary if he had not used the fact sheet as a guide. A 5-7 sentence summary procedure was taught and students completed a poster based on their summaries. All students were able to write good summaries following the guidelines given, with the main idea first, supporting details next, and a concluding sentence. As no one had difficulty writing these summaries, explicit instruction appeared to be beneficial in writing summaries.

In conclusion, the most effective writing activities were those that transformed one genre of writing to another: note-taking to summaries, drawing and labeling to sentence explanations, and drawing and labeling to paragraph explanations or descriptions. These tasks required revision without repetition. The least effective activity was making a patent application because it served more as a knowledge-telling device than a knowledge-transforming device.

On the basis of the findings of this study, and within the scope of the limitations of the design, certain implications for classroom practice can be drawn. The achievement gains in means score between the pretests and posttest indicate that incorporating writing strategies in a unit on simple machines, inventions, and inventors did not appear to limit students' performance. Writing activities are more successful when explicit instruction is given; therefore, care should be taken to include this step in all writing activities. There is substantial evidence that the inclusion of hands-on activities contributed to the success of writing; therefore, it is suggested that, whenever possible, hands-on tasks should be included in lessons. Since writing activities are very time-consuming, it is advisable to reduce the number of larger writing activities and provide more in-depth explicit instruction on fewer tasks. To provide students with good knowledge-transforming writing tasks, teachers must set a purpose, provide an interactive-constructive learning environment, and have an authentic audience. An effective strategy to provide sufficient time for writing is to use language arts time for reading and writing science. In order to provide the foundation students need to communicate scientifically, increased attention needs to be directed at developing science vocabulary. Identifying prior knowledge of vocabulary would be beneficial in determining the extent of instruction needed. As well, continued practice of writing in different genre for different purposes is recommended.

References

American Association for the Advancement of Science (AAAS) (1990). Science for all Americans Project 2061. New York, NY: Oxford University Press.

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

Anthony, R.J., Johnson, T.D., & Yore, L.D. (1996). Write-to-learn science strategies. Catalyst, 39(4), 10-16.

Armbruster, B.B. (1991). Framing: A technique for improving learning from science texts. In C.M. Santa & D.E. Alvermann (Eds.) Science learning: Processes and applications (pp. 104-113). Newark, DE: International Reading Association.

Baker, D.M. (1996). It's write for science: A how-to guide for improving children's science and writing skills simultaneously. Science and Children, 33(5), 24-27, 44, & 50.

Bereiter, C., & Scardamalia, M. (1987). The psychology of written composition. Hillsdale, NJ: Erlbaum.

Beugger, P., & Yore, L.D. (1990). Journeys in science, grade 5. Toronto, ON: Collier Macmillan Canada Inc.

Breger, D.C. (1995). The inquiry paper. Science Scope, 19(2), 27-32.

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, NY: Teachers College Press.

DiBiase, W.J. (1998). Writing a letter to a scientist. Science and Children, 35(6), 14-17, 66.

Ferrari, M., Bouffard, T., & Rainville, L. (1998). What makes a good writer? Differences in good and poor writers' self-regulation of writing. Instructional Science, 26, 473-488.

Ford, C., Yore, L.D., & Anthony, R.J. (1997). Reforms, visions, and standards: A cross-cultural curricular view from an elementary school perspective. Paper presented at the Annual Meeting of the National Association of Research in Science Teaching, Oak Brook, IL, March 21. [ALSO *Resources in Education (ERIC), ED405220]*

Galbraith, D. (1992). Conditions for discovery through writing. Instructional Science, 21, 45-72.

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

Hand, B., Prain, V., Lawrence, C., & Yore, L.D. (in press). A writing in science framework designed to enhance science literacy. International Journal of Science Education.

Hare, V.C. (1992). Summarizing text. In J.W. Irwin & M.A. Doyle (Eds.), Reading/writing connection: Learning from research (pp. 96-118). Newark, NJ: International Reading Association.

Harrison, S. (1991). Tools for learning science. In C.M. Santa & D.E. Alvermann (Eds.), Science learning: Processes and applications (pp. 114-122). Newark, DE: International Reading Association.

Hayes, J.R., & Flower, L.S. (1986). Writing research and the writer. American Psychologist, 41, 1106-1113.

Holliday, 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.

Howard, V.A., & Barton, J.H. (1986). Thinking on paper. New York, NY: Quill.

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., Hand, B., Prain, V., & Sommers, P. (1998). Rethinking the laboratory report: Writing to learn from investigation. Paper presented at the National Association for Research in Science Teaching, San Diego, CA, April 19-22.

Lemke, J.L. (1990). Talking science: Language, learning, and values. Norwood, NJ: Ablex

Linton, G. (1997). Letters, we get letters. Science and Children, 35(1), 25-27.

MacPherson, P. (1992). Use of writing to develop the student's understanding of the language of science: A preliminary report. Paper presented at the annual meeting of the National Science Teachers' Association, Boston, MA, March 23-27.

Mann, C., & Volet, S. (1996). Note-taking strategies for improving the quality of year 7 summaries of expository materials. Australian Journal of Language and Literacy, 19, 198-209.

Martin, J.R. (1993). Literacy in science: Learning to handle text as technology. In M.A.K. Halliday & J.R. Martin (Eds.), Writing science: Literacy and discursive power (pp. 166-202). Washington, DC: Falmer Press.

Ministry of Education (1995). Integrated resource package, science K to 7. Victoria, BC: Province of British Columbia, Ministry of Education Curriculum Branch.

Moline, S. (1995). I see what you mean: Children at work with visual information. York, ME: Stenhouse.

Murphy, J. (1978). Weird and wacky inventions. London, UK: Scholastic.

National Council of Teachers of English and International Reading Association (1996). Standards for the English language arts. Urbana, IL: National Council of Teachers of English.

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

Nesbit, C.R., & Rogers, C.A. (1997). Using cooperative learning to improve reading and writing in science. Reading and writing quarterly: Overcoming learning difficulties, 13, 53-70.

Prain, V., & Hand, B. (1999). Students' perceptions of writing for learning in secondary school science. Science Education, 83, 151-162.

Prain, V., & Hand, B. (1996a). Writing for learning in secondary science: Rethinking practices. Teaching and Teacher Education, 12, 609-626.

Prain, V., & Hand, B. (1996b). Writing for learning in the junior secondary science classroom: Issues arising from a case study. International Journal of Science Education, 18(1), 117-128.

Rillero, P., Zambo, R., Cleland, J., & Ryan, J. (1996). Write from the start: Writing to learn science. Science Scope, 9 (7), 30-32.

Rosaen, C. (1989). Writing in the content areas: Reaching its potential in the learning process. Advances in Research on Teaching, 1, 153-194.

Rowell, P.A. (1997). Learning in school science: The promises and practices of writing. Studies in Science Education, 30, 19-56.

Sawyer, R.J., Graham, S., & Harris, H.R. (1992). Direct teaching, strategy instruction, and strategy instruction with explicit self-regulation: Effects on composition skills and self-efficacy of students with learning disabilities. Journal of Educational Psychology, 84, 340-352.

Scardamalia, M., & Bereiter, C. (1986). Helping students become better writers. School Administrator, 42 (4), 16 & 26.

Shelley, A.C. (1998). The write approach. Science Scope, 22(1), 36-39.

Shymansky, J.A., Romance, N. & Yore, L.D. (1988). Journeys in science, New York, NY: Macmillan.

Shymansky, J.A., Yore, L.D., Treagust, D.F., Thiele, R.B., Harrison, A., Waldrup, B.G., Stocklmayer, S.M., & Venville, G. (1997). Examining the construction process: A study of changes in level 10 students' understanding of classical mechanics. Journal of Research in Science Teaching, 34, 571-593.

Spence, D.T., Yore, L.D. & Williams, R.L. (in press). The effects of explicit science reading instruction on select grade 7 students' metacognition and comprehension of specific science text. Journal of Elementary School Science.

Tchudi, S.N., & Huerta, M.C. (1983). Teaching writing in the content areas: Middle school/junior high. Washington, DC: National Education Association.

Tucknott, J.M. (1997). The effects of writing activities in children's' understanding of science. Unpublished M.Ed. Project. Victoria, BC: University of Victoria.

Wray, D., & Lewis, M. (1997). Teaching factual writing: Purpose and structure. Australian Journal of Language and Literacy, 20, 131-139.

Wyatt, V. (1987). Inventions: An amazing investigation. Toronto: Greey de Pencier.

Yore, L.D. (in press). Enhancing science literacy for all students with embedded reading instruction and writing-to-learn activities. Journal of Deaf Studies and Deaf Education.

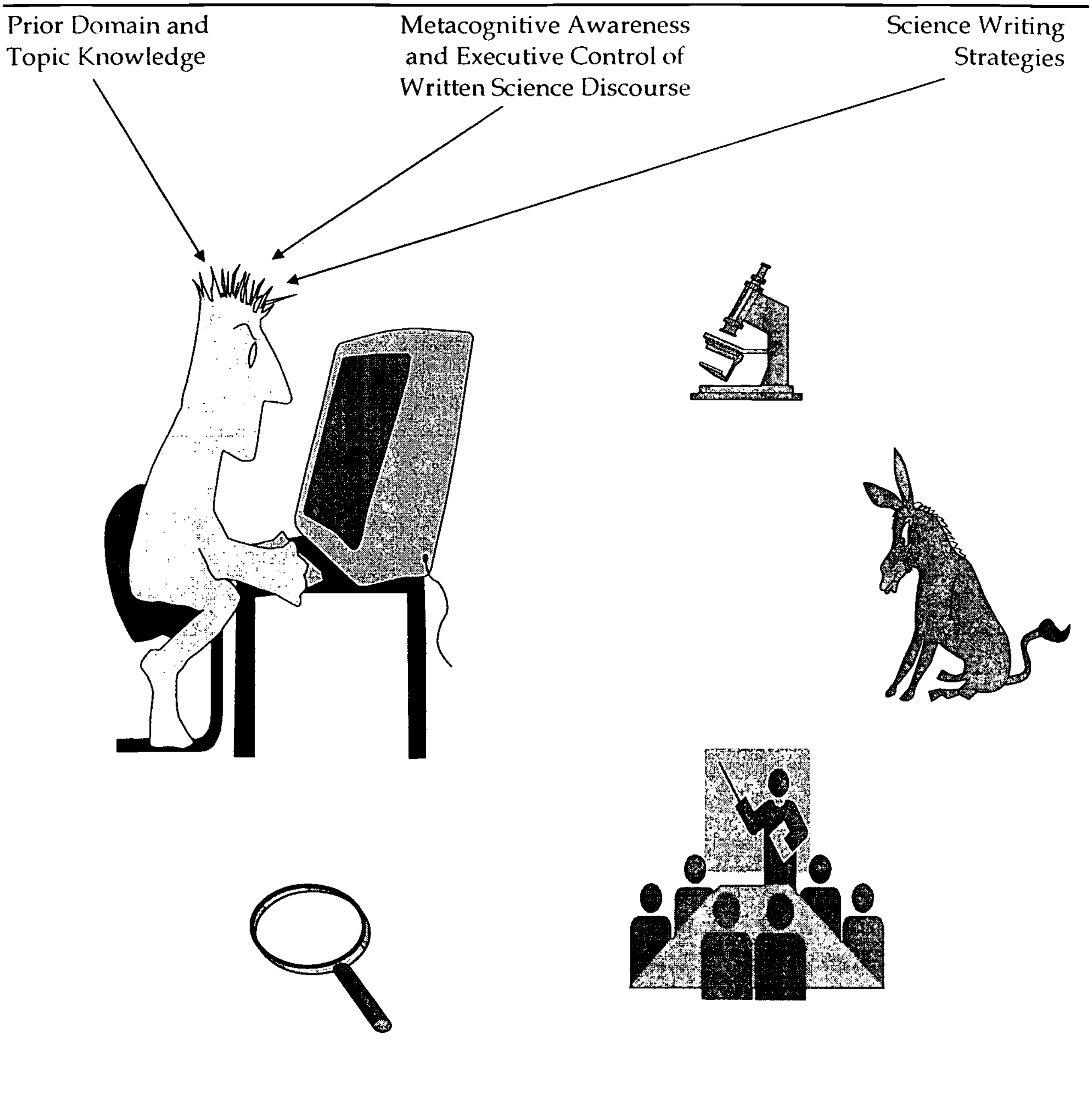

Figure 1. Knowledge-transforming model of writing (Bereiter & Scardamalia, 1987).

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 of events	Basic knowledge	Others
Explanation	Causality	Cause-effect relationships	Others
Instruction	Directions	Procedural knowledge	Others
Argumentation	Persuasion	Patterns of argument	Others

Table 2. Overview of Lessons.

Lesson	Time Periods	Concept Focus	Experience	Writing Activity	Products
1	1	Pretest			
2	2	Introduction to Inventors/ Inventions	KWL -transparencies of weird and wacky inventions -reading-history of inventions	-notes	-KWL chart
3	3-5	Work, Force, and 6 Simple Machines	-transparencies of weird and wacky inventions -demonstrations of work and force -classify samples of 6 machines -identifying exercises	-question of the day #2 -recording scientific method -drawing experiment	-model of 1st class lever
4	6-7	1st Class Lever	-transparencies of weird and wacky inventions -demonstration of 1st class levers -experiment with fulcrum distance		
5	8-10	New Clothing Inventions	-view transparencies of new inventions -draw new inventions	-labeling with three or four words -summary sentence explanations	-clothing invention drawing
6	11	Reinforcement of 6 Simple Machines	-gathering samples of six basic machines	-lists	-lists
7	12	New Simple Machine Invention	-draw simple machine parts for a pick-up machine	-labeling sentence explanations	-drawing of simple machine
8	13	Explanatory Paragraphs	-discussion of drawings -paragraph writing procedure	-writing explanatory paragraph on how machine works	-5 sentence paragraph
9	14-15	Invention/ Inventor Research	-highlighting and selecting important information	-note taking in point form	-sample notes in point form about Louis Pasteur
10	16-18	Invention/ Inventor Research Fact Taking	-reading resources for individual research	-fact recording	-fact sheets
11	19-21	Invention/ Inventor Research Summarizing	-class sample about Louis Pasteur	-writing summaries	-5 sentence summary of inventor

Lesson	Time Periods	Concept Focus	Experience	Writing Activity	Products
12	22	2nd and 3rd Class Levers	-transparencies of weird and wacky inventions -demonstration comparison of 1st, 2nd, & 3rd class levers	-question of the day #3 -draw comparison -identify 3 kinds of levers	-drawing
13	23	Inventor/ Invention Poster	-transparencies of weird and wacky inventions -class sample poster of Louis Pasteur	-posters with headings, pictures and summaries	-individual poster of inventor/ invention
14	24	Wheel and Axle	-make model of wheel and axle	-question of the day #4 -diagrams and explanations	-model of wheel and axle -explanatory paragraph
15	25	Poster (Art time)	-planning	-layout headings, diagrams and pictures	-individual poster
16	26-27	Invention Patents	-highlighting important information -sample patent	-describe how it works -make a title	-explanatory paragraph
17	28	Current Events on New Inventions	-highlighting important facts	-describe how it works -make a title	-explanatory paragraph
18	29-30	Pulleys	-transparencies of weird and wacky inventions -demonstration of fixed and moveable pulley	-question of the day #5 -drawing, labeling diagrams -experimenting with individual pulleys	-drawing individual pulley experiments -notes
19	31	Inclined Plane	-transparencies of weird and wacky inventions -demonstrations of inclined plane	-question of the day #6 -diagrams -notes	-diagrams -notes -model
20	32	Rube Goldberg Drawings	-examine examples of Rube Goldberg cartoons	-draw own cartoon -sentence explanations	-drawings of cartoon
21	33	Rube Goldberg Drawings with Simple Machines	-examine example of balloon popping machine	-draw own balloon popping machine -sentence explanations	-drawings of balloon popping machine
22	35	Wedge & Screw	-transparencies of weird and wacky inventions -demonstrate making screw	-question of the day #8 -notes -diagrams	-drawing -model
23	36	Patent Design Contest	-examine class samples -review criteria of important information-discussion	-notes on board	-individual patent winners
24	37	Posttest			

Table 3. T-test Analysis of Pretest and Posttest Differences (n=26).

	Pretest		Posttest				
	Mean	**SD**	**Mean**	**SD**	**t**	**df**	**p-value**
Part 1	11.92	4.21	24.19	4.73	12.59	25	<.001
Part 2	2.27	2.36	14.54	5.43	12.18	25	<.001
Total	14.19	5.20	38.73	9.40	15.87	25	<.001

S062373

ERIC

U.S. Department of Education
Office of Educational Research and Improvement (OERI)
National Library of Education (NLE)
Educational Resources Information Center (ERIC)

REPRODUCTION RELEASE

(Specific Document)

I. DOCUMENT IDENTIFICATION:

Title: The effects of writing activities on grade 4 children's understanding of simple machines, inventions, and inventors.

Author(s): Tucknott, Joan M. & Yore, Larry D.

Corporate Source:

Publication Date: March 29, 1999

II. REPRODUCTION RELEASE:

In order to disseminate as widely as possible timely and significant materials of interest to the educational community, documents announced in the monthly abstract journal of the ERIC system, *Resources in Education* (RIE), are usually made available to users in microfiche, reproduced paper copy, and electronic media, and sold through the ERIC Document Reproduction Service (EDRS). Credit is given to the source of each document, and, if reproduction release is granted, one of the following notices is affixed to the document.

If permission is granted to reproduce and disseminate the identified document, please CHECK ONE of the following three options and sign at the bottom of the page.

The sample sticker shown below will be affixed to all Level 1 documents	The sample sticker shown below will be affixed to all Level 2A documents	The sample sticker shown below will be affixed to all Level 2B documents
PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL HAS BEEN GRANTED BY Sample TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 1	PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE, AND IN ELECTRONIC MEDIA FOR ERIC COLLECTION SUBSCRIBERS ONLY, HAS BEEN GRANTED BY Sample TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 2A	PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY Sample TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 2B
Level 1	Level 2A	Level 2B
[✓]	[ ]	[ ]
Check here for Level 1 release, permitting reproduction and dissemination in microfiche or other ERIC archival media (e.g., electronic) *and* paper copy.	Check here for Level 2A release, permitting reproduction and dissemination in microfiche and in electronic media for ERIC archival collection subscribers only	Check here for Level 2B release, permitting reproduction and dissemination in microfiche only

Documents will be processed as indicated provided reproduction quality permits.
If permission to reproduce is granted, but no box is checked, documents will be processed at Level 1.

I hereby grant to the Educational Resources Information Center (ERIC) nonexclusive permission to reproduce and disseminate this document as indicated above. Reproduction from the ERIC microfiche or electronic media by persons other than ERIC employees and its system contractors requires permission from the copyright holder. Exception is made for non-profit reproduction by libraries and other service agencies to satisfy information needs of educators in response to discrete inquiries.

Sign here, → please

Signature: Larry D. Yore; Joan M. Tucknott

Printed Name/Position/Title: LARRY D. YORE Professor

Organization/Address: Department of Social & Natural Science, Box 3010 Victoria BC Can V8W 3N4

Telephone: 250-721-7769

FAX: 250-472-4616

E-Mail Address: lyore@uvic.ca

Date: March 29, 1999

Share Your Ideas With Colleagues Around the World

Submit your conference papers or other documents to the world's largest education-related database, and let ERIC work for you.

The Educational Resources Information Center (ERIC) is an international resource funded by the U.S. Department of Education. The ERIC database contains over 850,000 records of conference papers, journal articles, books, reports, and non-print materials of interest to educators at all levels. Your manuscripts can be among those indexed and described in the database.

Why submit materials to ERIC?

- **Visibility.** Items included in the ERIC database are announced to educators around the world through over 2,000 organizations receiving the abstract journal, *Resources in Education* (*RIE*); through access to ERIC on CD-ROM at most academic libraries and many local libraries; and through online searches of the database via the Internet or through commercial vendors.

- **Dissemination.** If a reproduction release is provided to the ERIC system, documents included in the database are reproduced on microfiche and distributed to over 900 information centers worldwide. This allows users to preview materials on microfiche readers before purchasing paper copies or originals.

- **Retrievability.** This is probably the most important service ERIC can provide to authors in education. The bibliographic descriptions developed by the ERIC system are retrievable by electronic searching of the database. Thousands of users worldwide regularly search the ERIC database to find materials specifically suitable to a particular research agenda, topic, grade level, curriculum, or educational setting. Users who find materials by searching the ERIC database have particular needs and will likely consider obtaining and using items described in the output obtained from a structured search of the database.

- **Always "In Print."** ERIC maintains a master microfiche from which copies can be made on an "on-demand" basis. This means that documents archived by the ERIC system are constantly available and never go "out of print." Persons requesting material from the original source can always be referred to ERIC, relieving the original producer of an ongoing distribution burden when the stocks of printed copies are exhausted.

So, how do I submit materials?

- Complete and submit the *Reproduction Release* form printed on the reverse side of this page. You have two options when completing this form: If you wish to allow ERIC to make microfiche and paper copies of print materials, check the box on the left side of the page and provide the signature and contact information requested. If you want ERIC to provide only microfiche or digitized copies of print materials, check the box on the right side of the page and provide the requested signature and contact information. If you are submitting non-print items or wish ERIC to only describe and announce your materials, without providing reproductions of any type, please contact ERIC/CSMEE as indicated below and request the complete reproduction release form.

- Submit the completed release form along with two copies of the conference paper or other document being submitted. There must be a separate release form for each item submitted. Mail all materials to the attention of Niqui Beckrum at the address indicated.

For further information, contact...

Niqui Beckrum
Database Coordinator
ERIC/CSMEE
1929 Kenny Road
Columbus, OH 43210-1080

1-800-276-0462
(614) 292-6717
(614) 292-0263 (Fax)
ericse@osu.edu (e-mail)