The Alberta Journal of Educational Research *Vol. 56, No. 2, Summer 2010, 196-217*

Perry D. Klein

and

Boba Samuels
University of Western Ontario

Learning About Plate Tectonics Through Argument-Writing

In a quasi-experimental study (N=60), grade 7/8 teachers students were taught to write arguments in content-area subjects. After instruction, students drew on document portfolios to write on a new topic: "Do the continents drift?" In a MANCOVA, students who participated in argument instruction scored significantly higher than a control class on the combination of dependent variables. A stepwise discriminant analysis indicated that instruction most strongly affected argument genre knowledge, which in turn accounted for variance in the other dependent variables. The features of argument texts that were most strongly associated with science learning were: the number of argument moves, the number of science propositions taken up from source documents, text length, and text coherence. These results support a constructivist model of writing to learn in which students use genre knowledge to select information from source documents and construct genre-specific relationships among ideas.

Une étude quasiexpérimentale (N=60), des élèves en 7e/8e ont appris à écrire des arguments dans des matières à contenu. Après avoir reçu des instructions, les élèves ont puisé dans des portfolios de documents pour rédiger un texte sur un nouveau sujet: Les continents dérivent-ils? Dans une analyse MANCOVA de la combinaison des variables dépendantes, les performances des élèves ayant participé à un cours sur l'argumentation étaient significativement meilleures que celles d'un groupe témoin. Une analyse discriminante pas à pas a indiqué que l'instruction a eu le plus d'impact sur les arguments constitués de connaissances disciplinaires, ce qui a entraîné la variance dans les autres variables dépendantes. Les éléments suivants des textes argumentatifs étaient le plus étroitement associés à l'apprentissage des sciences : le nombre d'arguments, le nombre de propositions scientifiques puisées des documents sources, la longueur du texte, et la cohérence textuelle. Ces résultats appuient un modèle constructiviste de l'apprentissage par la rédaction selon lequel les élèves s'appuient sur des connaissances disciplinaires pour sélectionner de l'information de documents sources et construire des rapports spécifiques à la discipline entre les idées.

The National Council of Teachers of English (n.d.) has stated, "Writing fosters learning in all disciplines. It is a tool for thinking, which makes it integral to every subject at every scholastic level" (compare *The National Writing Project*, 2005). However, the effects of writing on learning, although generally positive, continue to be inconsistent (compare Bangert-Drowns, Hurley, & Wilkinson,

Perry Klein is an associate professor in the Faculty of Education. His research concerns writing education and the role of writing in content-area learning. He teaches courses in educational psychology and literacy.
Boba Samuels is a doctoral candidate in the Faculty of Education. Her research interests include students' academic writing development, writing across the curriculum, and transdisciplinary research.

2004; Tynjälä, 2001; Wallace, Hand, & Prain, 2004). One of the most heavily researched hypotheses about writing to learn is that composing in genres that require elaborative reasoning such as argumentation contributes to learning (Klein, 1999). Most results support this hypothesis; writing arguments, reflective science reports, metacognitive journal entries, and analogies promotes conceptual understanding (Bangert-Drowns et al.; Klein, Piacente-Cimini, & Williams, 2007; Wallace et al.). However, these activities assume that students are able to write texts of the required types. In fact, students vary widely in their genre writing abilities (Crammond, 1998; Persky, Daane, & Jin, 2003).

In this study, we investigated the effects of teaching argument-writing to students on their ability to use writing as a tool for learning. In the introductory section of this article, a theory of writing to learn is briefly outlined; then the roles played by instruction, genre knowledge, text structure, and source content are elaborated, and the implications of this theory for the characteristics of students' argument texts are outlined. Based on this theory, three hypotheses are proposed.

Overview of a Theory of Writing to Learn

This study was informed by cognitive theories that treat writing as a problem-solving process (Bereiter & Scardamalia, 1987; Flower & Hayes, 1980; Hayes, 1996; Spivey, 1997; see Alamargot & Chanquoy, 2001, for a review). Briefly, it is theorized that when writers are called on to compose a text such as an argument, they activate a scheme that represents an appropriate text structure. To create this structure, they set rhetorical subgoals representing discursive moves appropriate to the genre; for example, in the case of argumentation, this includes presenting evidence. To fulfill these subgoals, they select information from sources such as existing texts. They transform this information, drawing inferences, making decisions, and constructing new relationships appropriate to the genre. For example, to provide evidence for a claim, a writer may select information from a source text and consider whether it supports the claim. If it does, then the writer has constructed a new claim-evidence relationship. If the information does not support the claim, the writer may change the claim. This would comprise an instance of material-appropriate processing that would be expected to contribute to learning (Hamilton, 2004; McDaniel & Einstein, 1989).

Argument Education and Writing to Learn

Argument texts differ markedly between writers with less knowledge or experience, and those with more (Crammond, 1998; Felton & Kuhn, 2001; Golder & Coirier, 1994; Knudson, 1994); and generally, analytical genres such as argumentation appear to be less familiar to students than other genres such as narrative (Schleppegrell, 2008). This suggests that to use argumentation as a tool for learning, students may require instruction. There are two common approaches to teaching genres such as argumentation. One is based on the notion that writing is grounded in explicit knowledge about text structure. Typical teaching activities have included explaining argument concepts, modeling argumentation, and scaffolding writers using templates and other prompts. In this approach, students usually learn about argumentation in the context of writing about topics of common knowledge and interest rather than substantive disciplinary knowledge. There is considerable evidence that this

approach is effective for teaching argumentation (Englert, Raphael, Anderson, Anthony, & Stevens, 1991; Graham, 2006; Kuhn & Udell, 2003). The second approach is based on the view that implicit or situated knowledge underpins genre writing (Freedman, 1993; Freedman & Medway, 1994). It has led to instruction that focuses on context: Students read authentic texts, analyze rhetorical situations, and engage in writing for purposes important to them. In this approach, students frequently learn about argumentation as a function of engaging in writing about specific topics (Coe, 2002; Purcell-Gates, Duke & Martineau, 2007). A third approach is to combine the first two methods; students are explicitly taught about genre and immediately apply this knowledge to writing about substantive topics (Pang, 2002; Zohar & Nemet, 2002). This third approach was used in the present study. Researchers and teachers drew on the *First Steps Writing Resource* (Raison, Rivalland, & Derewianka, 1994), which combines explicit and contextual instruction; more on this below. The first hypothesis was that students who participate in argument instruction would subsequently learn more than a control group during an argument-writing activity in science and improve on other writing-related variables such as text quality.

Elaboration of the Theory: The Roles of Genre Knowledge, Text Structure, and Source Content

It was proposed that students use knowledge about text genre to inform their writing (Hayes, 1996). This proposal is based on the fact that writing skill and experience are associated with declarative knowledge about genre (Lin, Monroe, & Troia, 2007; Wright & Rosenberg, 1993). However, as noted above, some authors have proposed instead that genre writing is guided partly or fully by implicit or situated knowledge (Bereiter & Scardamalia, 1987; Freedman, 1993). In fact, few studies have directly investigated the effect of genre knowledge on writing, and none have done so in the context of writing to learn. Therefore, our second hypothesis was that the relationship between instruction and writing would be mediated by students' argument genre knowledge; that is, instruction would increase argument genre knowledge, which in turn would increase other writing-related variables such as learning during writing and text quality.

The theory outlined above also proposes that text structure plays an important role in learning. The purpose of an argument text is persuasion (of the reader) or deliberation (for the writer). Argument texts comprise rhetorical moves that serve this goal; these rhetorical moves comprise the structure of the text (Crammond, 1998; Golder & Coirier, 1994). The Toulmin (2003) model of argumentation represents text structure, and it has been widely adopted in writing and content-area education because it focuses on informal reasoning to a probable conclusion (Driver, Newton, & Osborne, 2000; McNeill, Lizotte, Krajcik, & Marx, 2006). According to this model, an argument includes a *claim*, which is the assertion the merit of which the writer is trying to establish. The claim is supported by appeal to facts, which comprise *data* (Toulmin's term; often also called *evidence*). The step from the data to the claim is justified by a general statement referred to as the *warrant*. This scheme was originally developed to understand jurisprudential reasoning (Toulmin); educational researchers have adopted it with some variations. For example, Crammond also

included the *alternative solution*, a possible answer other than the claim being advanced by the arguer; and *countered rebuttal*, the arguer's recognition but not acceptance of the force of the rebuttal (Golder & Coirier, 1994; Knudson, 1994; Kuhn & Udell, 2003).

This theory of writing to learn also implies that the content of a text plays a role in the writer's learning. Most cognitive theories of writing have focused on the writers' previous knowledge as a source of text content (Bereiter & Scardamalia, 1987; Galbraith, 1999). However, in disciplinary writing, students also make use of external sources of information such as observations, experiments, and existing texts (Klein, Boman, & Prince, 2007). More generally, intertextuality is a fundamental characteristic of writing (Bazerman, 2004; Spivey, 1997). Spivey has shown that students compose new informational texts by transforming information from sources appropriately to the genre in which the student is composing. Students select propositions that are relevant to their text. They connect these so that the reader can follow a line of reasoning through this text. And they *organize* their text by grouping related ideas, sequencing them, and structuring them hierarchically (Segev-Miller, 2007). Source texts provide students with grounds for inferences beyond their own prior knowledge and so can be expected to contribute to learning during writing.

Characteristics of Good Argument Texts

Earlier research has shown that the characteristics of written texts are indicative of the cognitive processes that generated them (Sanders & Schilperoord, 2006). The theory of writing to learn outlined above implies that texts that contribute to learning should have several specific characteristics, including variety of argument moves and substantive source content. In addition, linguists have identified lexical and syntactic characteristics of academic writing (Christie, 1998; Macken-Horarik, 2002; Saddler, 2007; Schleppegrell, 2008). The third hypothesis, then, was that during argument-writing in science, the number of argument move types and content propositions from sources would predict content-area learning during writing; other characteristics were also investigated in a more exploratory way. It should be noted that an understanding of the text features associated with learning is important for both instruction and assessment. Calfee and Grietz Miller (2007) have recently argued that a goal of writing should be content-area learning. However, they point out that many current assessment rubrics are inadequate for such writing because they lack empirical validation, omit the role of content, and are not specific to the genre in which students are composing. Mindful of Calfee and Greitz Miller's critique, in this project, the characterization of good argumentation was created empirically based on the text features that were associated with learning during writing and holistic text quality; they were not prescribed in advance using a rubric. This is the first study that has used learning during writing as a criterion for identifying text characteristics worthy of evaluation.

The Present Study: Argument-Writing in Science

In this study, we proposed to assess the effect of argument instruction on writing to learn in content-area subjects, in this case, science. Earlier research has shown that argument-writing allows students to reason critically about

scientific issues and theories (Bell & Linn, 2000; Driver et al., 2000; McNeill et al., 2006). However, only a few studies have directly investigated the effects of argumentation on conceptual learning (Bell & Linn; Nussbaum & Sinatra, 2003; Zohar & Nemet, 2002). This has led to calls for further research on this topic (Duschl & Osborne, 2002; Schwarz, Neuman, Gil, & Ilya 2003). This report focuses on a series of posttest activities in which students wrote about plate tectonics, a highly appropriate topic for scientific argumentation. For centuries, advocates of continental drift pointed to several kinds of evidence that the continents had moved; critics objected to the lack of a plausible mechanism to explain this proposed movement. Continental drift remained controversial until the 1950s, when it was succeeded by plate tectonics. The recent date of this controversy, and the parallels between historical issues and students' own doubts and misconceptions, make this an appropriate topic for argumentation (Driver et al.; Gobert & Clement, 1999; Marques & Thompson, 1997).

To review, the hypotheses addressed in this study were:

1. Argument instruction would increase students' science learning during writing, and performance on other dependent variables (argument genre knowledge, number of argument move types, number of source propositions, text quality).
2. Any effects of argument instruction on science learning and other dependent variables would be mediated by argument genre knowledge; that is, argument instruction would directly increase argument genre knowledge, which would in turn contribute to science learning and other writing measures.
3. Characteristics of students' argument texts, including number of argument move types, and science propositions from sources would predict science learning and text quality.

Method

Overview of the Research Design

For an overview of the research design, see Table 1. First, three classes completed pretest assessments of writing and argument genre knowledge. Then two teachers provided their classes with genre education focused on argumentation, and a third class served as a control group. Next, all three classes completed a pretest of science knowledge about plate tectonics. They then received a portfolio containing a variety of documents concerning the continental drift controversy, and wrote on the question "Do you believe that the continents move?" Later, students completed a science posttest on their understanding of plate tectonics.

Participants

The 60 participants included 27 grade 7 and 33 grade 8 students in three split-grade classes in a school that served a lower-middle-class neighborhood in a medium-sized Canadian city. All three teachers had 10 or more years of experience. Two classes were randomly assigned to the instructional group and the third class to the control group. The students had completed provincially mandated writing assessments when they were in grade 6. Of the grade 8 students, 61% had scored at or above the expected standard; of the grade 7 students, 56% had done so. By comparison, 54% of students across the province

Table 1
Research Design

	Instructional Classes	*Control Class*
October	Pretest of argument genre knowledge Pretest writing sample	
November-April	Argument genre education and writing activities	Regular language arts program
	Unit of study: The Earth's Crust	
May	Posttest of argument genre knowledge Pretest of science knowledge Writing to learn activity: Do the continents drift?	
June	Posttest of science knowledge	

scored at the expected standard, indicating that this sample was approximately average in writing skill.

Initial Assessments

Initial assessments took place in October of the school year; their purpose was to estimate students' writing skills and knowledge before instruction. Several of the following measures required scoring. Two research assistants completed all the writing evaluations, test scoring, and coding; one was a university writing tutor and doctoral student familiar with the *First Steps* instructional approach, but naïve to the condition of the participants; the other rater was a teacher and graduate student naïve to the instructional approach and the condition of the participants.

Pretest argument genre knowledge. The purpose of this survey was to assess students' declarative knowledge about argumentation before instruction. To orient students to the task, the following definition was provided: "A written argument is sometimes called persuasive writing, opinion writing, or exposition. Its purpose is to persuade the reader. One example of a written argument is, 'Why it is Important to Recycle Paper.'" Students then answered a series of brief questions about written arguments, for example, "What do you think makes the difference between a good argument and a poor one?" The maximum possible score was 10 points; interrater reliability was r=.86; inter-item reliability was a=.70. Differences were resolved by a third rater.

Pretest text quality. To assess students' general level of writing skill consistently across classrooms, a writing sample was collected. Students composed a brief narrative about "What is the most interesting thing that you have done this year?" All ratings of students' data were completed independently by two raters; one was an elementary school teacher participating in graduate study in literacy education, and the other was a university writing tutor participating in graduate study in educational psychology. Both raters presented a holistic rating based on the question "How good is this text?" Interrater reliability was r=.81.

Instructional Resource and Professional Development

An important instructional resource for this project was the *First Steps Writing Resource* (Raison et al., 1994), a document that was developed in Western

Australia. It can be considered to take a balanced approach to literacy, combining holistic aspects (authentic literacy experiences, reading and writing whole texts, curriculum integration) with skills-based aspects (explicit teaching of text features and writing strategies). *First Steps* was designed as a resource for teachers rather than a prescriptive program: It includes examples of teaching and learning activities, but does not mandate a sequence of lessons. It focuses on six genres or forms that are common in educational settings: narratives, recounts, procedures, reports, explanations, and expositions (arguments). For each form, the document provides an overview of its purpose, contexts in which it is typically used, components that are required and optional, grammar, and lexis. For argumentation, these include: staged components (thesis, arguments, arguments against, and conclusion); and distinctive linguistic features such as participants (subjects and objects) that represent abstract concepts, timeless verbs that express abstract relationships (e.g., *implies*), and linking words (e.g., *therefore*).

First Steps recommends a scaffolding approach, which begins with teacher support and moves students toward independence. Throughout the grades, students are *familiarized* with various text genres through experiences such as teacher read-alouds. Students engage in more focused study through *discovery*, a problem-solving approach to learning about genre through analysis of model texts. For example, students may read several arguments, rank their quality, and state reasons for their decisions. In *modeled writing* the teacher composes in front of the class while thinking aloud. In *shared writing* the teacher and students write collaboratively. This is followed by *guided writing* in which students compose with the support of a peer, the teacher, or an external prompt such as a graphic organizer. These experiences prepare students for *independent construction* and subsequent presentation to an audience.

The teachers of the two instructional classes participated in two full days of professional development in the *First Steps Writing Component* (Raison & Rivalland, 1994; Raison et al., 1994). After this, a four-month implementation period began. The teachers were asked to lead an average of one lesson per week focused on argumentation, explanation, and/or report writing, and one writing activity per week applying these genres in the content areas. The teachers met with the research team every second week to discuss possible writing topics based on upcoming units of study, interpret students' writing samples, and discuss questions that arose during teaching. They were more interested in argumentation than in the other two genres because it is emphasized in provincial curriculum guidelines, so this report focuses on this genre. Generally, the teachers introduced material about genre writing during language arts class. The initial plan was to apply genre writing in science classes that focused on *Biomes and Ecosystems, and Lakes, Rivers and Streams*, and in history classes on *Confederation*. However, the teachers more often assigned informational writing activities during other class times, including language arts periods.

The teachers differed in the extent to which they implemented informational and content-area writing activities. One, Teacher A, adopted a *high implementation* approach with respect to informational genre. This teacher emphasized content-area reading and writing and employed several guided and independent writing activities. Argument-writing was assigned most often to

discuss current events. For example, during the project, the city introduced a bylaw that required dangerous breeds of dogs to be muzzled. This issue captured the students' interest, and they wrote lively arguments on it. The teacher of the second instructional class is referred to as Teacher B. Teacher B was strongly interested in English literature and before this project had extensively used modeled writing and independent writing in the classroom. However, Teacher B assigned writing most frequently in the imaginative and personal genres, particularly personal responses to novels. This class did little informational or content-area writing. When argumentation tasks were assigned, they were not typical of this genre. For example, when students were reading *The Giver* (Lowry, 1993), they wrote pieces on "their utopia." The teacher considered this to be argument-writing, but the students treated it as imaginative writing; all of them described their personal visions of utopia, but none wrote arguments for these visions. This class is characterized as *low implementation* with respect to argumentation. Teacher C, of the control class, taught language arts with an emphasis on the writing process. Students did some persuasive writing, but this was not focused on the content areas.

May Assessments

After approximately five months of instruction (November to April), there was a one-month pause during which students completed a unit of study on the Earth's crust. They then completed the final assessments.

Argument genre knowledge. The argument genre knowledge assessment as described in the pretests above was repeated.

Writing to learn sequence. The purpose of this sequence of activities was to evaluate the students' ability to use writing as a tool for learning. It included a pretest of science knowledge about plate tectonics; an argument-writing activity; and two weeks later a posttest of science knowledge about plate tectonics. Note that this was a transfer activity in the sense that students had not previously written argument texts on this topic. This sequence is described below in greater detail.

Pretest of science knowledge. The purpose of this was to assess students' prerequisite and prior knowledge of plate tectonics before the writing activity. Students were asked to identify the continents (5 x 1 pt); identify the major layers of the earth (4 x 1 pt.); complete six short-answer factual questions about geophysics concepts (6 x 1 pt); and answer a short essay question on the whether the continents moved (3 pts). Students were also asked to write a short explanation on how the continents *could* move, so that they could demonstrate any understanding that they had of plate tectonics, without necessarily agreeing with the theory (4 pts). Interrater reliability for total pretest science knowledge was r=.91.

Multiple-source argument-writing activity. This writing-to-learn task was similar to Webquests and other multiple-source constructivist writing activities (Dodge, 2001; Wiley & Voss, 1999). Each student received a folder with this question overleaf:

> This is a portfolio, or collection of papers. Its purpose is to help you make a decision. Early in the 20th century, Alfred Wegener proposed a theory called "Continental Drift." This is the idea that the continents were once joined together, then split apart and slowly moved to the places that we see them

Table 2
Description of Source Documents

Title	*Summary of Content*
A Jigsaw Puzzle: Can you Fit the Continents Together?	A map of the continents. Students are asked to cut out the continents and test whether they could be fitted together.
Two Opinions	Presents students with conflicting opinions concerning continental drift. The left side, titled "Alfred Wegener: Continents Drift!" summarizes Wegener's theory. The right side, titled "Sir Harold Jeffreys: The Continents Do Not Drift" summarizes Jeffreys' criticisms of continental drift and briefly introduces his "shrinking earth" theory.
Fossil Map: Prehistoric Reptiles that Match	A map of the world showing mesosaurus and cynognathus fossils in both South America and Africa.
A Warm Climate Fossil in a Cold Climate	Glossopteris information: Brief descriptive text, fossil illustration, drawing, map of distribution in Antarctica.
How Could the Continents Move? A Modern Theory	Outlines "sea floor spreading," satellite photo map of mid-Atlantic trench; brief explanatory text; cross-sectional diagram of Earth with magma flow in mantle and extrusion at mid-Atlantic trench.
Consequences of Continental Drift?	Updates "continental drift" to "plate tectonics." Brief explanations of possible role of plates in mountain building, volcanoes, and earthquakes.

today. Other scientists disagreed. Is continental drift theory true? This portfolio will not tell you. Instead, it has ideas and information that will help you to make your own decision.

The portfolio included six brief documents that students could draw on to construct an argument (see Table 2). They included brief summaries of both Alfred Wegener's pro-continental drift position and Harold Jeffreys' anti-continental drift position, as well as sources of possible evidence. The documents were intentionally brief and disparate with respect to topic and genre, so that students were required to construct their own arguments rather than simply paraphrase the sources.

Postest of science knowledge. The purpose of this was to assess what students had learned while writing about continental drift; it was designed to be more challenging than the pretest, so the scores of the pretest and posttest cannot be directly compared. Nine recall items required students to complete cloze questions about plate tectonics (9 x 1 points). Three comprehension questions required students to discuss the evidence for or against continental drift and to explain a possible mechanism of continental motion (2 x 3 pts). Three inference questions presented novel scenarios and required students to predict what would happen next and explain why it would happen (3 x 2 pts). Interrater reliability was r=.85, and inter-item reliability was .75; differences were settled by a third rater.

Analysis of Argument Text

The third hypothesis referred to the characteristics of students' texts, so these were evaluated for holistic quality and analyzed with respect to a variety of linguistic variables.

Text quality. This was a holistic measure of the rhetorical quality of students' writing. Because we intended to determine empirically the text characteristics that were associated with quality (and learning during writing), we intentionally provided no rubrics to bias the answer to this question. Instead, the two raters independently judged "How good are these texts as instances of persuasive writing?" using a 10-point scale. Interrater reliability was r=.82, p<.01; because the scale was linear and holistic, differences were resolved by averaging.

Source content propositions. The two raters independently read each essay and identified whether 48 propositions from the source documents were incorporated into each; this can be considered a measure of intertextuality with respect to content. The number of such propositions was then counted for each student text. Interrater agreement was very high, r=.94. Because this variable was continuous and the possible propositions in each text were numerous, interrater differences were resolved by averaging.

Non-source propositions. The two raters independently read each text and identified science content propositions that could not be found in, or inferred from, the portfolio sources. Because the distribution of non-source propositions was strongly positively skewed (i.e., most students included none, whereas some included several), this variable was coded dichotomously as present/absent. Interrater exact agreement was 100%.

Rhetorical coherence. The two raters independently coded each text dichotomously as rhetorically coherent or incoherent. They applied the criterion that "a rhetorically coherent paper maintains a consistent purpose throughout the text; an incoherent paper is one that is substantially contradictory, disjointed, off-topic, or off-genre." Raters showed 90% exact agreement; a third rater resolved the differences.

Viewpoints. This variable represented the number of competing claims that students discussed in their texts. Texts were coded as one-sided if they discussed the pro-continental drift position or the anti-drift position only and two-sided if they discussed both positions. Interrater agreement was 95%, and a third rater resolved the differences.

Argument moves. Texts were segmented into *T*-units, each comprising a principal clause and any other clauses subordinate to or embedded in it. Each *T*-unit was classified as representing one of seven types of argument moves adapted from Toulmin (2003) and Crammond (1998): *claim, evidence, elaboration of evidence, possible rebuttal, rebuttal evidence, countered rebuttal,* and *conclusion* (see Table 3). Explanations of possible mechanisms of continental drift did not fit into this initial scheme, so an *explanation* category was added. In addition, statements that did not provide argumentation or explanation were found, so category termed "Other" was added. For each text, the number of *T*-units comprising each argument move was counted (tokens), as well as the number of types of argument moves included in the text (argument move types). For an example of a text with argument moves coded, see the Appendix. Interrater exact agreement was 78%.

Lexical and syntactic measures. The number of words and mean characters per word were electronically counted for each text. Texts were segmented into clauses and *T*-units by hand, and these were counted. From these values, the

Table 3
Definitions of Rhetorical Moves

Rhetorical Move	*Definition*
Claim	Main contentious assertion; what the writer wants to persuade the reader of; usually the main idea of the piece, for example, "I agree with Alfred Wegener that the continents drift!" Includes any subclaim, repetition, definition, qualification, or reservation of the claim.
Evidence	Reason to believe the author's claim, for example, "The first reason is because the same fossils can be found in South America and Africa."
Elaboration of evidence	Further discussion of evidence that has been offered or is about to be offered. Includes warrants that link evidence to claim; further descriptions of evidence; further examples of the same type of evidence; anomalies in evidence.
Possible rebuttal	Assertion contrary to writer's claim. For example, "Some scientists, like Harold Jeffreys, said that the continents were never connected." Includes alternative solutions, for example, "Sir Harold Jeffreys believed that the Earth had shrunk."
Rebuttal evidence	Reason or support for the rebuttal. For example, "There is no force that could move the continents."
Countered rebuttal	Refutation of the rebuttal or rebuttal evidence, or objections to the opposing claim. For example, "But there is a force that could move the continents—magma."
Conclusion	Reiteration of claim or summary of argument; includes rhetorical flourishes on conclusion, for example, "I hope you agree."
Explanation	A causal statement, tells how or why an event occurs. For example, "The continents could have moved because of glaciers."
Other	Any discourse that does not fit the above categories. For example, "Continental drift is a very interesting theory."

number of words per clause, clauses per *T*-unit, and words per *T*-unit were calculated.

Results

Hypothesis One: Effects of Argument Instruction.

A MANCOVA was conducted to test the hypothesis that argument instruction would increase learning during writing, and other writing measures (argument genre knowledge, argument moves types in text, science propositions from sources, argument text quality). Instruction was the independent variable. To account for students' prior writing abilities, three pretest covariates were included: pretest argument genre knowledge, pretest text quality, and pretest science knowledge (Table 4); these correlated significantly with the dependent variables (Table 5). Instruction produced a large, statistically significant effect on the combination of dependent variables, Pillai's trace=.59, $F(10, 102)=5.67$, $p<.001$, partial $\eta^2=.30$. The top half of Table 6 presents raw means by class for the dependent variables; the bottom half presents the means adjusted for pretest scores.

To interpret the MANCOVA, two kinds of follow-up analyses were carried out. The first examined univariate questions, that is, questions about in-

Table 4
Pretest (covariate) Means (Standard Deviations) By Class

Pretest Variables	*Control (n=17)*	*Class Low Implementation (n=21)*	*High Implementation n=22)*
Raw Means (SD)			
Argument Genre Knowledge	2.24 (1.97)	3.55 (1.98)	3.77 (1.76)
Text Quality	5.82 (2.16)	5.43 (2.32)	5.95 (1.74)
Science Knowledge	9.71 (3.13)	9.67 (3.14)	13.02 (1.78)

dividual dependent variables (Huberty & Morris, 1989), because several of these were of educational interest in themselves. Because conducting multiple univariate tests increases the probability of a false rejection of the null hypothesis, and the initial MANCOVA does not protect against these, the alpha level was adjusted using the Bonferroni correction to a the criterion of $p<.01$. Instruction strongly affected posttest argument genre knowledge $F(2, 54)=12.18$, $p<.001$, partial $\eta^2=.31$; instruction also affected the number of argument move types in the argument texts that students wrote, $F(2, 54)=5.76$ $p<.001$, partial $\eta^2=.18$. In addition, instruction significantly affected the number of science content propositions from source documents that students included in their texts, $F(2, 54)=6.07$, $p<.001$, partial $\eta^2=.18$; the low-implementation class scored higher on this variable than the control class or the high-implementation class. The effect of instruction on argument text quality was not significant, $F(2, 54)=0.06$, n.s., partial $\eta^2=.00$; nor was the effect of instruction on science posttest knowledge $F(2, 54)=1.04$, n.s., partial $\eta^2=.04$. Therefore, the hypothesis that

Table 5
Correlations Among Covariates and Dependent Measures

Scale	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1. Pretest Text Quality	.28*	.08	.29*	.32**	.26*	.27*	.30*
2. Pretest Argument Genre Knowledge		.34**	.54**	.24*	.33**	.30*	.46**
3. Pretest Science Knowledge			.46**	.14	.09	.33**	.42**
4. Posttest Argument Genre Knowledge				.41**	.39**	.36**	.54**
5. Argument Move Types					.31**	.28*	.16*
6. Science Content Propositions						.61**	.44**
7. Posttest Argument Text Quality							.56**
8. Posttest Science Knowledge.							

N=60.
*$p<.05$; **$p<.01$.

argument instruction would increase learning during writing and other dependent variables was partly supported.

Hypothesis Two: The Mediating Role of Genre Knowledge

The second kind of follow-up to the MANCOVA focused on a multivariate question, that is, a question about the relationships among the dependent variables (Huberty & Morris, 1989). Recall that it was hypothesized that instruction would directly increase students' argument genre knowledge, which in turn would affect the other dependent variables (argument move types in text, science content from sources, argument text quality, posttest science knowledge). To test this hypothesis, discriminant analysis was employed. As a follow up to a MANCOVA, a discriminant analysis tests the hypothesis that the dependent variables form a function that separates the groups that comprise the independent variable, here classes. Stepwise discriminant analysis does so by entering variables into this function based on their statistical value in discriminating the classes. If as hypothesized the effect of instruction on the other four dependent variables were mediated by argument genre knowledge, then argument genre knowledge would be the variable that differs most strongly between classes, so it would be selected first into the model. Also, argument genre knowledge would account for the same variance in class membership that is accounted for by the other four dependent variables, so these four would correlate with the resulting function, but add little to discriminating the classes. When the analysis was conducted, only one significant function was generated; it accounted for a large amount of variance between the classes, Λ=.645, χ^2 (2, N=60)=24.99, p<.001; canonical correlation=.60. Consistent with hypothesis two, the only variable that contributed significantly to this function was posttest argument genre knowledge. Also consistent with hypothesis two, other variables correlated with this function and did not add to its ability to discriminate classes: science posttest r=.55; argument posttest text quality r=.33; argument content propositions r=.32; and variety of argument moves r=.24. These results support the hypothesis that argument genre knowledge mediated the effects of instruction on the other dependent variables.

Hypothesis Three: Characteristics of Texts Associated with Science Learning and Text Quality

Recall that hypothesis three was that the features of written texts, particularly variety of argument moves and science content from sources, would predict both science learning during writing and text quality. Before reading the statistics, it may be helpful to view the student argument presented in the Appendix, which was typical of good texts. The results are presented in Table 6; descriptive and correlational data about each type of rhetorical move are presented in Table 7.

Consistent with hypothesis three, the number of argument move tokens correlated significantly with science learning and text quality; however, the number of argument move types correlated poorly. This suggests that some kinds of argument moves are more effective if several instances are included. This interpretation is supported by Table 7, which shows that most students included several *T*-units of evidence and elaboration of evidence and that the frequency of both of these argument moves correlated with text quality and

Table 6
Postest (Dependent) Variables, Raw Means (Standard Deviations), and Marginal Means Adjusted for Covariates (Standard Error), By Class

Postest Variable	*Control (n=17)*	*Class Low Implementation (n=21)*	*High Implementation (n=22)*
Raw Means (SD)			
Argument Genre Knowledge	3.57 (1.81)	6.50 (1.70)	6.89 (2.40)
Argument Move Types	2.76 (1.15)	4.10 (1.09)	4.00 (1.60)
Science Content Propositions	6.15 (4.07)	10.33 (4.68)	7.52 (3.18)
Argument Text Quality	4.21 (2.55)	4.55 (1.92)	5.23 (2.08)
Posttest Science Knowledge	5.71 (3.08)	6.81 (3.35)	7.05 (2.80)
Marginal Means (SE)			
Argument Genre Knowledge	$4.11\ (.42)_a$	$6.78\ (.37)_b$	$6.20\ (.38)_b$
Argument Moves Types	$2.77\ (.32)_a$	$4.20\ (.29)_b$	$3.90\ (.30)_b$
Science Content Propositions	$6.69\ (.97)_a$	$10.63\ (.88)_b$	$6.82\ (.90)_a$
Argument Text Quality	4.56 (.53)	4.80 (.48)	4.71 (.49)
Posttest Science Knowledge	6.60 (.67)	7.26 (.61)	5.95 (.62)

Note. Means with subscripts differ significantly, $p<.01$.
Covariates appearing in the model were evaluated at the following values: Pretest Argument Genre Knowledge=3.258; Pretest Writing Sample=5.733; Pretest Science Knowledge=10.908.

science posttest knowledge. Also consistent with hypothesis three, the number of science propositions from sources correlated significantly with both text quality and learning during writing. Conversely, non-source science content was the only negative predictor of text quality. A reading of the texts indicates that non-source science content often included misconceptions about plate tectonics, for example, that the movement of the continents was caused by glaciers, waves, or asteroid impacts.

There were several other significant predictors of text quality and science learning. Text length, as measured in number of words, predicted both text quality and science learning. As the sample in the Appendix exemplifies, better texts were about one full page in length; this appeared to be the minimum necessary for writers to present the argument moves and science content associated with holistic quality and science learning (Tables 7 and 8). Coherence was also a significant predictor; approximately two thirds of the students presented rhetorically coherent texts, and this feature correlated with both text quality and science learning.

Some other variables did not correlate significantly or substantially with text quality or science learning. One example was addressing both sides of the issue; two-sided texts that were coherent were highly rated, but two-sided texts that were incoherent, for example, asserting two contradictory claims without synthesizing them in any way, received low ratings. Similarly, measures of word length and syntactic complexity were weak correlates of text quality and science learning.

Table 7
Argument Text Characteristics, Correlations with Text Quality and Posttest Science Knowledge

Characteristic	*Mean*	*SD*	*+Pct*	*Text Quality*	*Correlation‡ Science Learning*
Rhetoric					
Argument Move Tokens	7.93	3.47		.56**	.44*
Argument Move Types	3.68	1.42		.28*	.12
Rhetorically coherent			70.0	.56**	.23*
Includes two viewpoints			50.0	.14	.06
Voice (Scale 1-5)	3.23	1.12		.19	.30**
Science Content					
Source content propositions	8.12	4.30		.61**	.44**
Non-source content propositions			41.7	–.49**	.44**
Length/Lexical/Syntactic					
Number of words	149.60	59.24		.52**	.54**
Characters per word	4.58	.23		.24*	.23*
Words per clause	7.02	1.16		.34**	.23*
Words per *T*-unit	12.44	2.43		.33**	.25*
Clauses per *T*-unit	1.79	.32		.06	.05

+For dichotomous variables, the percentage of texts with a given characteristic is reported.
‡For text quality, correlation statistic is Pearson for continuous variables, η for dichotomous variables; for science learning, statistic is partial correlation between text characteristic and science posttest knowledge with science pretest knowledge accounted for.
*p<.05; **p<.01.

Discussion

We begin this section by discussing the effectiveness of instruction; next we evaluate the theory of writing to learn presented in the introduction in the light of the results. We discuss the pedagogical and methodological limitations of the study; and finally, we suggest implications for classroom teaching.

Effects of Genre Education

The results of the MANCOVA and follow-up analyses showed that consistent with hypothesis one, argument instruction significantly contributed to students' argument genre knowledge and moderately but significantly contributed to key text characteristics: the number of types of argument moves and science propositions from sources. However, contrary to hypothesis one, instruction did not affect students' learning during argument-writing or the holistic quality of their texts. This disparity in the effects of instruction is interpreted below.

Recall that the second hypothesis was that genre knowledge would mediate the effects of instruction, that is, instruction would affect students' genre knowledge, which in turn would affect other dependent variables. This claim was supported by the discriminant analysis: Argument genre knowledge was the

Table 8
Argument Moves, Frequency by Quartiles and Correlation with Text Quality and Posttest Science Knowledge

Rhetorical Move	*Quartiles*			*Correlation*	
	25th	*Median*	*75th*	*Text quality*	*Postest science knowledge*
Claim	1.00	1.00	2.00	–.02	.18
Evidence	2.00	3.00	4.00	.39*	.22*
Elaboration of evidence	1.00	2.00	3.00	.37*	.23*
Possible rebuttal	0.00	0.00	1.00	.20	.14
Rebuttal evidence	0.00	0.00	1.00	–.02	.22*
Countered rebuttal	0.00	1.00	2.00	.18	.23*
Conclusion	0.00	1.00	1.00	.35*	.35*
Explanation	0.00	1.00	3.00	–.01	–.08
Other	0.00	0.00	1.00	–.34**	–.02

N=60.
*$p<.05$; **$p<.01$.

dependent variable most strongly affected by the intervention, and it accounted for the relationships between instruction and the other dependent variables. This pattern of results cannot demonstrate the mediating role of argument genre knowledge with certainty, because it is largely correlational. However, given that genre knowledge can only be manipulated indirectly through instruction, this is the best evidence available to date on this issue. This study extends earlier research, which has shown that high-achieving writers know more about genre than low-achieving writers (Lin, Monroe, & Troia, 2007) in three ways: It shows that genre knowledge mediates the effects of instruction; it shows that this principle extends to individual writing assignments; and it shows that this principle applies to writing to learn. Our conclusion that explicit genre knowledge contributes to writing is consistent with cognitive models of composing (Hayes, 1996; Spivey, 1997). However, it differs from the results of a study by Freedman (1993). There were several differences between these two studies: Freedman worked with young adults, whereas the present study involved elementary students; it is not clear how Freedman probed students' genre knowledge; and her study was a multiple case study with a small sample. This disparity in findings suggests the need for further research to identify the conditions under which explicit genre knowledge contributes to students' writing.

The Theory of Writing to Learn

A theory of writing to learn is outlined in the introduction (Bereiter & Scardamalia, 1987; Hayes, 1996; Spivey, 1998): these results can be used to comment on its four main components. First, it is proposed that students use argument genre knowledge to generate rhetorical subgoals. Data on subgoal setting were not collected in the present study; however, indirect support for this proposition comes from the fact that argument genre knowledge contributed to the

variety of argument genre moves in text. The role of goal-setting could be more directly investigated using recordings from think-aloud writing or student-student collaborative writing.

The second main proposition is that students use genre knowledge to select content from source documents. This is supported by the finding that on average, students included eight science propositions from the source documents, and better texts included more; and 80% of the total *T*-units in students' texts comprised argument moves. This means that students were not simply paraphrasing the sources; they were transforming source information to construct evidence and other rhetorical moves. The prevalence of source content in the students' texts is consistent with the view that intertextuality plays a critical role in content-area writing, and indeed writing in general (Bazerman, 2004; Spivey, 1997). This finding provides a useful corrective to prevailing cognitive theories, which have prioritized writers' prior knowledge over external textual and non-textual sources (Bereiter & Scardamalia, 1987; Galbraith, 1999).

The third main proposition in the theory was that students connect information to comprise argument moves. Argument moves are by definition connective; for example, a fact becomes evidence by supporting a claim. As noted, connecting was apparent in the finding that on average 80% of the *T*-units in text comprised argument moves (Table 7). The importance of connecting ideas was also supported by the fact that two thirds of the texts showed rhetorical coherence. The fact that about one third of the texts were low in coherence is characteristic of elementary writers, many of whom maintain reference to a topic only at the local, sentence-to-sentence, level (Berninger, Fuller, & Whitaker, 1996). Coherence in argument-writing is particularly challenging, because ideally it requires the integration of evidence for conflicting claims; even university writers often fail to achieve it (Flower et al., 1990; Nussbaum, & Schraw, 2006). Data have not been presented here concerning students' organizing of ideas, but most texts presented a claim at the beginning, followed by evidence, rebuttals and countered rebuttals (if these were included), and finally a conclusion (see Appendix). As a caveat to the third proposition, note that it is not contended here that construction of argument moves chronologically follows the selection of content. It could plausibly be suggested either that content could trigger ideas for rhetorical moves (e.g., "Fossils in the arctic … that shows the continents have moved!"); or a search guided by interest in a rhetorical move could guide the selection of content (e.g., "Let me try to find some proof … here's some, fossils in the arctic!). How students match rhetorical goals and relevant content from source documents is an important question for future research.

The fourth proposition in the theory was that this process (assimilating content, constructing argument moves) contributes to learning; this was the focus of the third hypothesis and the analysis of text characteristics. The role of constructing argument relations was supported by the correlation of the number of argument move tokens in text with science learning. Students who learned more science included most of the following argument moves: introduction, several pieces of evidence, several elaborations of evidence, a possible rebuttal, rebuttal evidence, a countered rebuttal, and a conclusion. This fourth proposition was also supported by the correlation between science proposi-

tions from sources and science learning. Conversely, scientific information that was not based on the sources had mixed effects on learning and text quality. On one hand, a positive role for prior knowledge was supported by the fact that students' pretest science knowledge contributed significant unique variance to the combination of dependent variable (Bell & Linn, 2000). On the other hand, science propositions in the students' texts that were not derived from the sources and presumably came from their prior beliefs correlated negatively with science learning and text quality. This reflected the fact that these prior beliefs often comprised misconceptions typical of upper elementary students (Gobert & Clement, 1999; Marques & Thompson, 1997). The strong contribution of source documents to students' writing and learning compared with the inconsistent role of their prior "knowledge" again points to the importance of intertextuality.

A Seeming Paradox

The results of this study present a seeming paradox: On one hand, the expected effect of argument instruction on science learning during writing did not occur. On the other hand, the model of writing to learn was largely supported. Yet these findings may not be as paradoxical as they appear: The model comprises several serial causal links: instruction → argument genre knowledge → argument characteristics → conceptual learning. Because the variance accounted for by each link is less than 100%, and because the links between consecutive variables are multiplicative, the strength of the relationship between the first variable (instruction) and the last variable (science learning) must be substantially smaller than any of the individual links in the chain. This is analogous to the case of elementary reading education, in which research shows that phonics instruction significantly improves decoding, and decoding significantly predicts text comprehension. However (except in kindergarten and grade 1), the knock-on effect from phonics instruction to text comprehension is small and not statistically significant (Ehri, Nunes, Stahl, & Willows, 2001).

Limitations

Several limitations are mentioned above. Methodologically, because the content and genre were specialized and the sample was modest in size, the generalizability of the findings is limited. A second methodological limit is that the identification of text features that contributed to learning was based on calculating multiple zero-order correlations; correlations cannot prove causation, and multiple statistical tests increase the likelihood of some false rejections of the null hypothesis. A pedagogical limitation of the study is that although the model was supported, argument instruction did not increase students' ability to use writing as a tool for learning. However, given that argument-writing typically elicits critical thinking and appears to increase learning about the specific content to which it is applied, it remains a worthwhile educational activity (Bell & Lin, 2000; McNeill et al., 2006; Zohar & Nemet, 2002).

Educational Implications

Some research on writing from sources suggests that the default strategy for students is "structure mapping," in which they use the organization of one source text as a template to organize their own writing, partly reducing composition to paraphrasing (Nash, Schumacher, & Carlson, 1993). However, our

study suggests that providing students with disparate brief documents and asking them to compose in a new genre (here argumentation) leads them to transform source materials to create a novel text. Therefore, with the limitations discussed above in mind, we tentatively suggest that teachers could consider the following practices.

- Teaching argument structure; for most students, instruction would focus on possible rebuttals, rebuttal evidence, countered rebuttals, conclusions, and warrants.
- Prompting students to consider all relevant information from sources.
- Encouraging students to check that their text is coherent, that is, that they have supported a claim throughout the text and presented a conclusion that sums up their argument.
- Assessment could be made more appropriate to specific genre by including dimensions that are often neglected in rubrics such as variety of argument components, appropriate use of source content, and global coherence (Berninger et al., 1996; Calfee & Greitz Miller, 2007).

Conclusion

In summary, this study extends empirical research on cognitive theories of writing to the practice of learning science through argumentation. Consistent with these theories, genre knowledge informs students' creation of rhetorical structure in text. At the same time, consistent with theories of intertextuality, genre structures allowed students to select relevant pieces of information from sources and build relationships among them. The result is that as students construct knowledge for readers, they also construct it for themselves.

References

Alamargot, D., & Chanquoy, L. (2001). (Eds.). Writing a text: A complex task. In G. Rijlaarsdam (Ed.), *Through the models of writing* (pp. 1-32). Dordrecht, Netherlands: Kluwer Academic.

Alamargot, D., & Chanquoy, L. (2001). (Eds.). Through the models of writing. In G. Rijlaarsdam (Series Ed.), *Studies in writing*. Dordrecht, Netherlands: Kluwer Academic.

Bangert-Drowns, R.L., Hurley, M.M., & Wilkinson, B. (2004). The effects of school-based writing-to-learn interventions on academic achievement: A meta-analysis. *Review of Educational Research, 74*, 29-58.

Bazerman, C. (2004). Intertextuality: How texts rely on other texts. In C. Bazerman & P.A. Prior (Eds.), *What writing does and how it does it: An introduction to analyzing texts and textual practices* (pp. 83-96). Mahwah, NJ: Erlbaum.

Bell, P., & Linn, M.C. (2000). Scientific arguments as learning artifacts: Designing for learning from the Web with KIE. *International Journal of Science Education, 22*, 797-817.

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

Berninger, V.W., Fuller, F., Whitaker, D. (1996). A process model of writing across the life span. *Educational Psychology Review, 8*, 193-218.

Calfee, R.C., & Greitz Miller, R. (2007). Best practices in writing assessment. In S. Graham, C.A. MacArthur, & J. Fitzgerald (Eds.), *Best practices in writing instruction* (pp. 265-286). New York: Guilford Press.

Christie, F. (1998). Learning the literacies of primary and secondary schooling. In F. Christie & R. Misson (Eds.), *Literacy and schooling* (pp. 47-73). London, New York: Routledge.

Coe, R.M. (2002). The new rhetoric of genre: Creating political briefs. In A.M. Johns (Ed.), *Genre in the classroom: Multiple perspectives* (pp. 3-13). Mahwah, NJ: Erlbaum.

Crammond, J.G. (1998). The uses and complexity of argument structures in expert and student persuasive writing. *Written Communication, 15*, 230-268.

Dodge, B. (2001). Focus: Five rules for writing a great webquest. *Learning and Leading with Technology, 28*(8), 6-9, 58.

Driver, R., Newton, P. & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*, 287-312.

Duschl, R.A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education, 38*, 39-72.

Ehri, L.C., Nunes, S., Stahl, S., & Willows, D. (2001). Systematic phonics instruction helps students learn to read. Evidence from the National Reading Panel's meta-analysis. *Review of Educational Research, 71*, 393-447.

Englert, C.S., Raphael, T.E., Anderson, L.M., Anthony, H.M., & Stevens, D.D. (1991). Making strategies and self-talk visible: Writing instruction in regular and special education classrooms. *American Educational Research Journal, 28*, 337-372.

Felton, M., & Kuhn, D. (2001). The development of argumentative discourse skills. *Discourse Processes, 32*, 135-153.

Flower, L., & Hayes, J. R. (1980). The cognition of discovery: Defining a rhetorical problem. *College Composition and Communication, 31*, 21-32.

Flower, L., Stein, V., Ackerman, J., Kantz, M.J., McCormick, K., & Peck, W.C. (1990). *Reading-to-write: Exploring a cognitive and social process*. New York: Oxford University Press.

Freedman, A. (1993). Show and tell? The role of explicit teaching in the learning of new genres. *Research in the Teaching of English, 27*, 222-251.

Freedman, A., & Medway, P. (1994). Introduction: New views of genre and their implications for education. *Learning and teaching genre* (pp. 1-22). Portsmouth, NH: Heinemann.

Galbraith, D. (1999). Writing as a knowledge-constituting process. In M. Torrance & D. Galbraith (Eds.), *Knowing what to write: Conceptual processes in text production* (pp. 139-159). Amsterdam: Amsterdam University Press.

Gobert, J.D., & Clement, J.J. (1999). Effects of student-generated diagrams versus student-generated summaries on conceptual understanding of causal and dynamic knowledge in plate tectonics. *Journal of Research in Science Teaching, 36*, 39-53.

Golder, C., & Coirier, P. (1994). Argumentative text writing: Developmental trends. *Discourse Processes, 18*, 187-210.

Graham, S. (2006). Strategy instruction and the teaching of writing: A meta-analysis. In C.A. MacArthur, S. Graham, & J. Fitzgerald (Eds.), *Handbook of writing research* (pp. 187-207). New York: Guilford Press.

Hamilton, R.J. (2004). Material appropriate processing and elaboration: The impact of balanced and complementary types of processing on learning from text. *British Journal of Educational Psychology, 74*, 221-237.

Hayes, J.R. (1996). A new framework for understanding cognition and affect in writing. In C.M. Levy & R. Ransdell (Eds.), *The science of writing* (pp. 1-27). Mahwah, NJ: Erlbaum.

Huberty, C.J., & Morris, J.D. (1989). Multivariate analysis versus multiple univariate analyses. *Psychological Bulletin, 105*, 302-308.

Klein, P.D. (1999). Reopening inquiry into cognitive processes in writing-to-learn *Educational Psychology Review, 11*, 11, 203-270.

Klein, P.D., Boman, J.S., & Prince, M.P. (2007). Developmental trends in a writing to learn task. In M. Torrance, D. Galbraith, & L. Van Waes (Eds.), *Writing and cognition: Research and application* (pp. 201-217). Amsterdam: Elsevier.

Klein, P.D., Piacente-Cimini, S., & Williams, L.A. (2007). The role of writing in learning from analogies. *Learning and Instruction, 17*, 595-611.

Knudson, R.E. (1994). An analysis of persuasive discourse: Learning how to take a stand. *Discourse Processes, 18*, 211-230.

Kuhn, D., & Udell, W. (2003). The development of argument skills. *Child Development, 74*, 1245-1260.

Lin, S.-J.C., Monroe, B.W., & Troia, G.A. (2007). Development of writing knowledge in grades 2-8: A comparison of typically developing writers and their struggling peers. *Reading and Writing Quarterly, 23*, 207-230.

Lowry, L. (1993). *The giver*. Boston, MA: Houghton Mifflin.

Macken-Horarik, M. (2002). Something to shoot for: A systemic functional approach to teaching genre in secondary school science. In A.M. Johns (Ed.), *Genre in the classroom: Multiple perspectives* (pp. 17-42). Mahwah, NJ: Erlbaum.

Marques, L., & Thompson, D. (1997). Misconceptions and conceptual changes concerning continental drift and plate tectonics among Portuguese students aged 16-17. *Research in Science and Technological Education, 15*, 195-222.

McDaniel, M., & Einstein, G. (1989). Material appropriate processing: A contextualist approach to reading and studying strategies. *Educational Psychology Review, 1*, 113-146.

McNeill, K.L., Lizotte, D.J., Krajcik, J., & Marx, R.W. (2006). Supporting students' construction of scientific explanations by fading scaffolds in instructional materials. *Journal of the Learning Sciences, 15*, 153-191.
Nash, J.G., Schumacher, G.M., Carlson, B.W. (1993). Writing from sources: A structure mapping model. *Journal of Educational Psychology, 85*, 159-170.
National Council of Teachers of English. (n.d.). *Research based policy statements on writing*. Retrieved March 19, 2007, from: http://www.ncte.org/edpolicy/writing/research/122398.htm.
National Writing Project. (2005). *Encourage writing: Annual report of the National Writing Project*. Berkeley, CA: Author.
Nussbaum, E.M., & Schraw, G. (2006, April). *Promoting argument/counterargument integration in students' writing*. Paper presented at the annual meeting of the American Educational Research Association, San Francisco.
Nussbaum, E.M., & Sinatra, G.M. (2003). Argument and conceptual engagement. *Contemporary Educational Psychology, 28*, 384-395.
Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching, 41*, 994-1020.
Pang, T.T.T. (2002). Textual analysis and contextual awareness building: A comparison of two approaches to teaching genre. In A. M. Johns (Ed.), *Genre in the classroom: Multiple perspectives* (pp. 145-161). Mahwah, NJ: Erlbaum.
Persky, H.R., Daane, M.C., & Jin, Y. (2003). *The nation's report card: Writing, 2002, NCES 2003-529*. Washington, DC: US Department of Education, Institute of Education Sciences, National Centre for Education Statistics.
Purcell-Gates, V., Duke, N.K., & Martineau, J.A. (2007). Learning to read and write genre-specific text: Roles of authentic experience and explicit teaching. *Reading Research Quarterly, 42*, 8-45.
Raison, G., & Rivalland, J. (1994). *First steps: Writing developmental continuum*. Portsmouth, NH: Heinemann.
Raison, G., Rivalland, J., Derewianka, B., Johnson, T.D., Sloan, P., Latham, R., Kovalevs, K., Bindon, R., Annandale, K., Larsen, J., Dewsbury, A. (1994). *First steps: Writing resource*. Portsmouth, NH: Heinemann.
Saddler, B. (2007). Improving sentence construction skills through sentence-combining practice. In S. Graham, C.A. MacArthur, & J. Fitzgerald (Eds.), *Best practices in writing instruction* (pp. 163-178). New York: Guilford Press.
Sanders, T.J.M., & Schilperoord, J. (2006). Text structure as a window on the cognition of writing. In C.A. MacArthur, S. Graham, & J. Fitzgerald (Eds.), *Handbook of writing research* (pp. 386-402). New York: Guilford Press.
Schleppegrell, M J. (2008). Grammar, the sentence, and traditions of linguistic analysis. In C. Bazerman (Ed.), *Handbook of research on writing: History, society, school, individual, text* (pp. 549-564). New York: Erlbaum.
Schwarz, B.B., Neuman, Y., Gil, J., & Ilya, M. (2003). Construction of collective and individual knowledge in argumentative activity. *Journal of the Learning Sciences, 12*, 219-256.
Segev-Miller, R. (2007). Cognitive processes in discourse synthesis: The case of intertextual processing strategies. In M. Torrance, D. Galbraith, & L. Van Waes (Eds.), *Writing and cognition: Research and application* (pp. 231-250). Amsterdam: Elsevier.
Spivey, N.N. (1997). *The constructivist metaphor: Writing, reading, and the making of meaning*. San Diego, CA: Academic Press.
Toulmin, S. (2003). *The uses of argument*. Cambridge, UK: Cambridge University Press.
Tynjälä, P. (2001). Writing, learning and the development of expertise in higher education. In P. Tynjälä, L. Mason, & K. Lonka (Eds.), *Writing as a learning tool: Integrating theory and practice* (pp. 37-56). Dordrecht, Netherlands: Kluwer Academic.
Wallace, C.S., Hand, B., & Prain, V. (2004). *Writing and learning in the science classroom*. Dordrecht, Netherlands: Kluwer Academic.
Wiley, J. & Voss, J.F. (1999). Constructing arguments from multiple sources: Tasks that promote understanding and not just memory for text. *Journal of Educational Psychology, 91*, 301-311.
Wright, R.E., & Rosenberg, S. (1993). Knowledge of text coherence and expository writing: A developmental study. *Journal of Educational Psychology, 85*, 152-158.
Zohar, A., & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching, 39*, 35-62.

Appendix
Sample of Student Argument for Continental Drift, Coded for Argument Moves

Text	*Argument Move*
I believe in continental drift.	Claim
Therefore, I am agreeing with Alfred Wegener.	Claim
There are many reasons that have persuaded me to believe in continental drift.	Elaboration of evidence
The first reason that made me believe in continental drift is that in the Arctic there are fossils of plants and animals that could not possibly adapt (survive) in those temperatures.	Evidence
Therefore, the continents must have moved North or for some reason the temperature dropped dramatically in seconds, giving the animals no chance to adapt.	Elaboration of evidence
So the logical answer is that the Continent drifted North until everything froze, which proves Alfred's idea.	Elaboration of evidence
The second thing that proves Alfred's idea is the rocklayers of North America and Europe.	Evidence
If the continents used to be joined, the rocklayers would be fairly similar.	Elaboration of evidence
Alfred proved that the rocklayers of Europe and North America were identical.	Elaboration of evidence
Some people say that animals are all over the world, which is true,	Possible rebuttal
and they believe that is why fossils have been found which are the same species.	Rebuttal evidence
Well how do they think they got there?	Countered rebuttal
Did they fall from the sky?	Countered rebuttal
I believe that the continents split, giving the animals no chance to move together, so they got stuck on separate continents therefore proving Alfred's idea.	Countered rebuttal
Unless they just fell from the sky, which is highly unlikely.	Countered rebuttal
I think that continental drift is true because of these reasons, however, there are many others.	Conclusion
I hope you soon believe in continental drift.	Conclusion
It changed my perspective on the world.	Conclusion
I hope it will do the same for you.	Conclusion