DOCUMENT RESUME

ED 409 184 SE 060 345

AUTHOR	O'Neill, D. Kevin
TITLE	Bluffing Their Way into Science: Analyzing Students' Appropriation of the Research Article Genre.
PUB DATE	Apr 97
NOTE	22p.; Paper presented at the Annual Meeting of the American Educational Research Association (Chicago, IL, April, 1997).
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Communication (Thought Transfer); *Content Area Writing; *Discourse Modes; Educational Innovation; High School Students; Intermediate Grades; Literary Devices; Literary Genres; Middle Schools; Problem Solving; *Research Papers (Students); *Science Education; Science Process Skills; Secondary Education; Writing (Composition)
IDENTIFIERS	Middle School Students

ABSTRACT

This paper reports on research in the analysis of high school and middle school students' appropriation of the Research Article genre in science classes. The appropriation of this rhetorical form is proposed as a measure of students' understanding of adult argumentative practice in science and the effectiveness of a learning environment in supporting the development of this understanding. An important part of this research has been the development of a coding scheme to enable the comparison of genre appropriation patterns across a large number of texts from a variety of school and curricular settings. The coding scheme produces a series of numerical scores to indicate such things as students' fulfillment of the standard rhetorical moves of scientific research articles, the written personas that students project, and the ways in which they use sources and authorities to support argument. Because the analysis of genre appropriation is a relatively non-invasive way of conducting research (when compared to survey instruments, for example), this method can provide a useful tool for reformers to compare outcomes from iterations or conditions of curricular experiments aimed at developing students' understanding of adult persuasive practices in the sciences. Contains 16 references. (Author/NB)

Bluffing their way into science: Analyzing students' appropriation of the Research Article genre

> The page is no more than a score is to a Scarlatti sonata performed in a Santa Barbara living room...an archive mediating between an imagined event and a distant realization. To help people write more effectively we need to unpack the entire transaction and identify what the words are doing in the middle. (Bazerman 1988, pp. 9-10)

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Abstract

This paper will report on research in the analysis of high school and middle school students' appropriation of the Research Article genre in science classes. The appropriation of this rhetorical form is proposed as a measure of students' understanding of adult argumentative practice in science and the effectiveness of a learning environment in supporting the development of this understanding.

An important part of this research has been the development of a coding scheme to enable the comparison of genre appropriation patterns across a large number of texts from a variety of school and curricular settings. The coding scheme produces a series of numerical scores to indicate students' fulfillment of the standard rhetorical moves of scientific research articles, the written personas that students project, the ways in which they use sources and authorities to support argument, and so on.

Because the analysis of genre appropriation is a relatively non invasive way of conducting research (when compared to survey instruments, for example), I believe this method can provide a useful tool for reformers to compare outcomes from iterations or conditions of curricular experiments aimed at developing students' understanding of adult persuasive practices in the sciences.

Introduction: Textual genres in communities of practice

Implicit in the idea of a community are elements of stability and dynamism; continuity and change; shared interests and ongoing contention of interests. As a result of these mixtures, participants in communities of practice may find themselves arguing over similar issues again and again. Genre theorists (Miller 1984, Bazerman 1988, Swales 1990) have observed that over time, these recurring rhetorical problems may give rise to customary forms of communication. For example, because academic researchers repeatedly find themselves applying for jobs and funding, they have developed the genres of the curriculum vita, the letter of recommendation and the grant proposal, which are easily recognizable to initiates. Today, these genres have such well-wrought expectations surrounding them that they have come to form a constraint on acceptable practice in these communities. To write a curriculum vita in an uncustomary way is, therefore, to risk unemployment.

Genres are an interesting and important phenomenon because they embody the norms and values of the communities that produce and reproduce them. They give newcomers to a community a sense of its public priorities: its collective sense of what is relevant and important to its ambitions. From an individual's perspective, genres are also useful because they structure the rhetorical problems associated with contributing to a community's discourse:

> A genre is a socially recognized, repeated strategy for achieving similar goals in situations socially perceived as being similar. A genre provides a writer with a way of formulating responses in certain circumstances and a reader a way of recognizing the kind of message being transmitted.... Thus the formal features that are shared by the corpus of texts in a genre and by which we usually recognize a text's inclusion in a genre, are the linguistic/symbolic solution to a problem in social interaction. (Bazerman 1988, p. 62)

In writing as elsewhere, a well-structured problem is easier to deal with than an ill-structured one. Thus, as Bazerman points out above, a genre does some of the writer's work for her. In this way, genres represent a brand of distributed intelligence (Pea 1993) which can itself be considered one of the accomplishments of a community of practice. Genres are truly community property.

Goals of this paper

In recent years there has been an explosion of scholarly interest in the nature and variety of textual genres, and what they reveal about the discourse communities in which they are produced and reproduced. Much of this interest stems from a belief that a deeper understanding of genres would assist instruction (e.g. Cope and Kalantzis 1993, Freedman 1993, Bazerman 1988). I share this belief. In this paper I will present results from my use of the genre construct to evaluate an innovation in K-12 science teaching. At the heart of this effort has been the production of a practical instrument for analyzing students' appropriation of the scientific research article genre to the presentation of their work in science classes. This instrument synthesizes my own observations of students' written work at the high school and middle school level with scholarship about the research article genre from applied linguistics (Swales 1985) and the sociology of science (Bazerman 1988, Myers 1990). Before I discuss the development and use of this instrument, however, I would like to spend a few pages framing the research issues that it was designed to explore.

Appropriating scientific genres in the classroom

As genre theory would suggest and as researchers have previously illustrated, school and work settings develop their own unique genres of oral and written discourse (Berkenkotter and Huckin 1995, Yates and Orlikowski 1992). To deal with their recurring rhetorical problems, for instance, schools have developed the genres of the report card, the teacher's disciplinary note to parents, and the 5-paragraph theme. This is natural enough, given that the school is a community in its own right and necessarily develops its own unique norms. Nevertheless, the school's mission to help students understand, and possibly participate in communities of practice beyond the school militates against this separation of genres. Helping students learn to write in the customary genres of adult work settings — from business memos in typing class to lab reports and research articles in science classes — has been a developing part of practice in schools since the 1900s (Russell 1991). In this paper I will explore one area of teaching and learning practice in which school genres and work genres mindfully intersect: K-12 students' attempts to appropriate authentic genres of professional science.

Buffing their way into science

Under common K-12 teaching conditions (the lab report, the science fair project), student writer/researchers are called upon to do some fairly extraordinary impersonations. Despite knowing little about the histories of the disciplines, not feeling invested in their discourses or involved in their stakes, they must attempt to produce pieces of writing that imitate those of initiates:

> The student has to appropriate (or be appropriated by) a specialized discourse, and he has to do this as though he were easily and comfortably one with his audience, as though he were a member of the academy or an historian or an anthropologist or an economist; ...He must learn to speak our language. Or he must dare to speak it or to carry off the bluff, since speaking and writing will most certainly be required long before the skill is "learned." (Bartholomae 1985, p. 135)

Despite these complications, many of the students and teachers whom I have interviewed in my research seem to feel that imitating professional scientific writing in the classroom makes a lot of sense. The kinds of sense it makes to them may, however, vary considerably. To give you some impression of this, Figure 1 summarizes the responses of 12 high school students in a project-based science class to the question, "Why does your teacher have you write project reports in the particular format that he does?" I posed this question in an open-ended fashion during a series of focus groups. The responses were categorized post hoc.

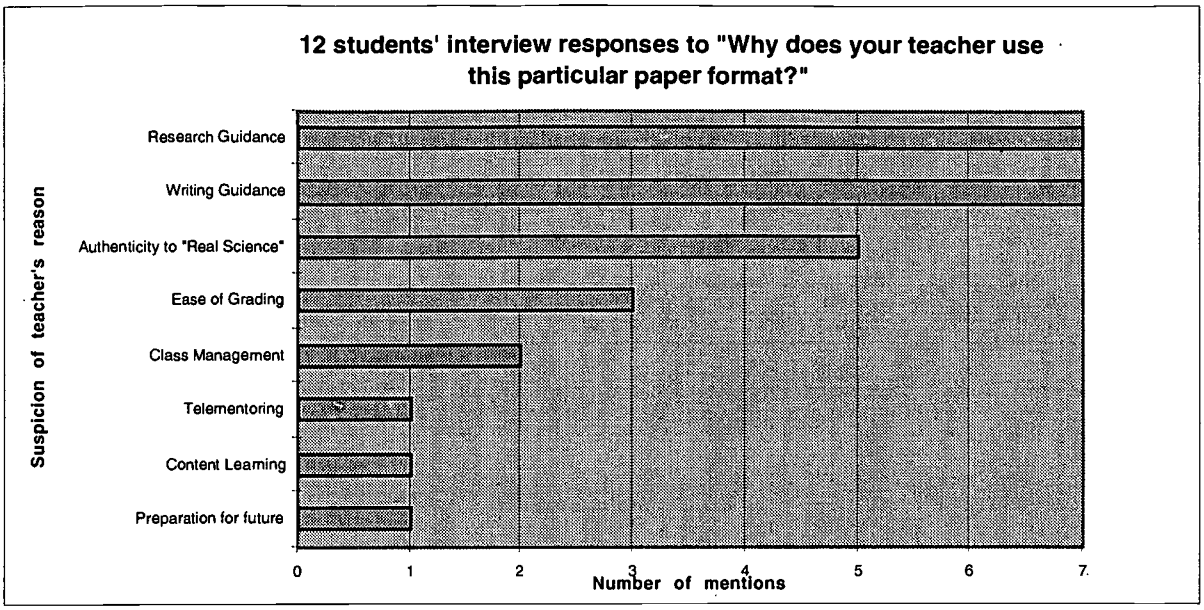

Figure 1: Students' impressions of the purposes of imitating scientific genres

It is important to mention that the activity in this particular class, which I will discuss at greater length later, was largely structured around the production of a scientific research paper in a quasi-professional format. Thus, there may have been considerably stronger integration of the writing and research tasks in this setting than in many others. Some indication of this is provided by the fact that an equal number of students cited guidance *in their research* as a reason for writing in an authentic genre as mentioned guidance in their *writing*. This suggests that the students saw and appreciated the interconnectedness of these two processes in the classroom environment.

There is not, however, a clear consensus among these students about their teacher's reasons for having them write in this genre. While perhaps of less salience to them than guidance in research and writing, the 12 students mentioned a variety of other reasons for their teacher's insistence on an authentically-formatted report. Five students suggested that part of the purpose of writing in an authentic scientific genre was to help them accurately play the role of scientists in the class. In this conception, the genre is an important prop in a collective game of academic make-believe. What may be most surprising is that so few students felt the format of the report was chosen for pragmatic reasons such as helping the teacher to grade the paper (by making the absence of valued elements more obvious), or helping him manage the class by communicating expectations more clearly.

These data aside, one may ask whether it is really *necessary* for students to imitate genres of professional science in order to appreciate or understand science. Does it even help? The answer to both questions can be yes or no, I believe, depending on whether you are personally more concerned with science "content" (past findings and theories) or science "process". To show you how I arrive at my own answer, I'll ask to you to imagine how you might have students write up a chemistry lab that bears *no* similarity to the way that a professional scientist would write it. Take your time. Likewise, can you to think of a way to have students report on a lengthy research project in science that looks *nothing* like the way that professional scientists do it? The idea is, I think, absurd.

I would argue that imitation of professional practice is implicit in the very notion of teaching science. Even if you are not convinced of this, I hope to make it clear from the examples I will explore below that for at least a century, educators have found it difficult to avoid the imitative impulse. They continue to find it difficult. The question for education researchers is what purposes this imitation is intended to serve, and how well it actually serves them.

How K-12 students encounter scientific genres

Students come under a variety of influences in the acquisition of scientific genre knowledge. With regard to traditional resources, these influences include textbooks, encyclopedias, the style guides that may be prepared by a school or school board, and handouts or class displays used by teachers. Most important, however, are the pieces of scientific writing that students are asked to produce themselves. These include the presentation boards that students involved in science fairs are commonly asked to prepare (which usually have a strict prescribed format), and the lab reports that they may be asked to prepare after a hands-on lab.

Sutton (1989) provides a comparison of guidelines provided to students for writing up labs as far back as 1898:

> Looking into the origins of this pattern of writing...it is very interesting to see the variation in the flexibility allowed, and in how much emphasis is placed on the preliminary statement of ideas. One extreme may be represented by C.B. Owen of Stowe School in his *Methods for Science Masters* (1956). He offered the mnemonic: High Powered Motors Often Crash, to trigger recall of the need for Heading, Picture, Method, Observations and Conclusion....MacNair (1904) suggested: 'The Object Aimed At', 'What Was Done', 'What Was Seen' and 'What the Result Proved'....A.G. Hughes (1933) advocated the headings 'Purpose', 'Apparatus', 'Observation', 'Inference'.... He stressed the importance of discussion before practical work to clarify its purpose.... (Sutton 1989, p. 139)

Clearly, each of these sets of guidelines reflects different ideas about the purposes behind students' imitation of adult scientific practice. In the course of his review, Sutton characterizes two general classes of guidelines among those he observed: those that depict science as a regimen of careful recording ('Science as "Describing What Happens"'), and those that depict science as a regimen of withholding judgment until all the data are in ('Science as "Data First and Theory Later"'). Both classes of guidelines send particular messages to students about the nature of scientific practice, as indeed such guidelines do in the world of adult professional practice (Bazerman 1988, Chap. 9 discusses the messages of the APA guidelines). In effect, these guidelines emphasize different sets of rhetorical problems for authors and identify different genres through which solutions to those problems can be developed.

Lest there be any doubt, educators still develop and use a variety of guidelines for science writing. The poster shown in Figure 2 was observed in a middle school science classroom in 1996. In it you will notice some similarities to the guidelines Sutton describes above, though I might argue that this poster presents a more inclusive view of scientific practice. Unlike most of Sutton's examples, it does not focus narrowly on the act of observation, and actually encourages students to generate hypotheses *before* the outcome of an experiment is known. However, it has its own flaws. Through its illustrations, the poster actually mystifies the process of hypothesis-generation (which it pictures as a child gazing into a crystal ball), and encourages the idea that "research" is something bookish, done in the library alone. By placing Research in order after Purpose, it also obscures the possibility that the Purpose of an investigation might emerge out of *reading* something (such as a peer's research). In itself this does considerable violence to the idea of a scientific community and obscures the relationship between genres of reporting and the conduct of research. Finally, like Sutton's examples, this poster continues to give preferential place to experimental protocol in the development of scientific knowledge. In fact, a great deal of scientific practice does not involve much laboratory experimentation (for instance Astronomy, Atmospheric Science, Botany, or Ecology).

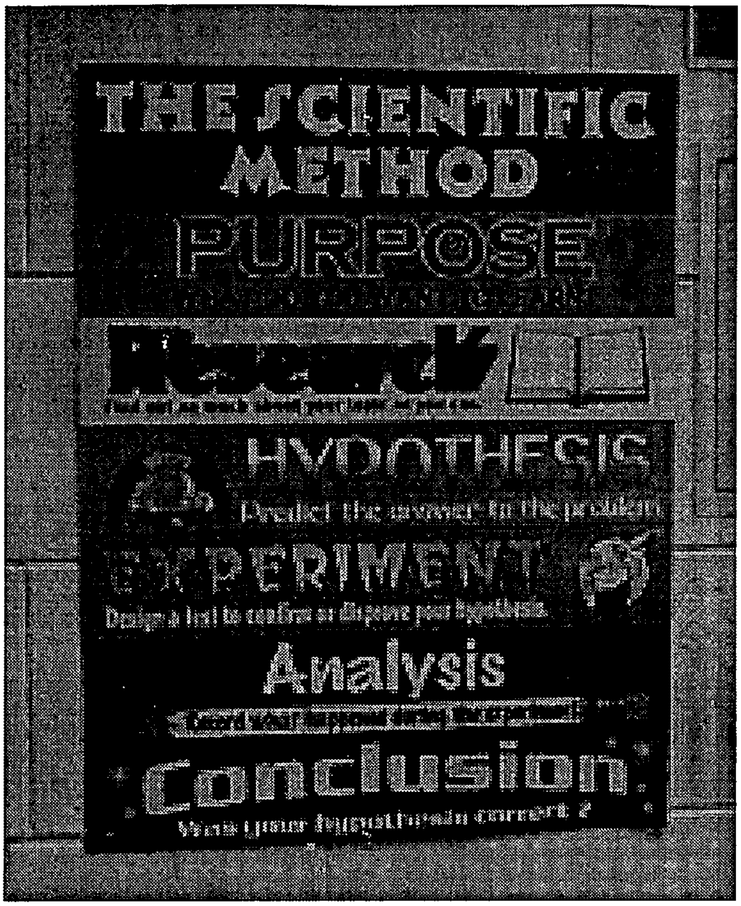

Figure 2 "Scientific Method" poster observed in a middle school science classroom

The captions to the sections read:

"Purpose: What do you want to learn?"

"Research: Find out what other people know..."

"Hypothesis: Predict the answer to the problem"

"Experiment: Design a test to confirm or disprove your hypothesis"

"Analysis: Record what happened during the experiment"

"Conclusion: Was your hypothesis correct?"

I do not wish to be harsh in my assessment of these guidelines for scientific writing. If we accept that school science needs to imitate adult science in some respects, we must ask *which ones*? Each of the representations of scientific research and reporting described above provides one answer to this difficult question, attempting to reduce an extremely varied, complex and large-scale set of practices to something small and simple, but of value to classroom practice in a variety of local contexts.

Nonetheless, there are significant general problems associated with teaching students about scientific writing and argument. Among these, one that looms large is *situativity*. As I have shown above, many of the forms which we present to students for reporting their work are derivative from ones invented by and for participants in a radically different community of discourse/practice (professional science), in response the unique rhetorical problems that recur there. We cannot expect to simply drop these forms into the classroom and have them fit the native activity there.

In fact, they often do not fit. As an example, below is a "Method" section from a research report produced by a student in a project-based high school science classroom in the 1994/95 school year. This project, on smog, was somewhat unique among high-school projects in that the student was given several weeks to complete it and was required, in that time, to come up with an original question that could be addressed with numerical data. The following excerpt is fairly indicative of the misappropriation of scientific genres that I have seen in this setting:

> **Method:** My problem with this topic was that all I found was the temperature and precipitation data. I sat at Mosaic and Netscape for hours just cruising through the information endlessly. I even tried Lycos and all of the

> other searching mechanisms in order to find the rate of photochemical smog. Nobody had it. This time period was quite frustrating. Finally, I posted on a newsgroup. For awhile, I did not hear anything, but finally a very nice person wrote me back. A man on the California Air Resources Board sent me quite a bit of information. As a result, I had to change my topic. I decided to try and find a correlation between the precipitation and temperature and ozone statistics between 1970 and 1979. That is when I could get down to business. [my underlining]

When I present this quotation in talks I am often asked what I think is wrong with it. Nothing, I reply, unless the goal of having the students write it was to teach them what role a Method section plays in a research article as a piece of persuasion. The underlined portions of the quotation are those that I believe serve the customary function of a Method section. The first two underlined parts explain a practical constraint on the investigation: the desired data could not be located. The next part explains a strategic response to this problem: the question is changed to fit the available data. The balance of the section, however, is more or less an adventure story, told by the student to her teacher, about the difficulty of completing his assignment. This story makes careful appeals to considerations associated with assessment: the long hours dedicated the project, the resulting frustration, and the student's use of all of the resources made available by the teacher. What little the student says about the strategic decisions made in her investigation is almost lost amid this argument over grades.

I would argue that this kind of writing, which is centered on the grades students feel they deserve rather than knowledge-claims justified by their research, can make the imitation of scientific genres in school worse than useless. Having students routinely produce work like this puts us at risk of teaching and reinforcing a caricature of scientific practice, rather than revealing anything of the social and intellectual texture of scientific practice and the importance of particular modes of persuasion within it.

Students' Rhetorical Situations

> ...the situation controls the rhetorical response in the same sense that the question controls the answer and the problem controls the solution. Not the rhetor and not persuasive intent, but the situation is the source and ground of rhetorical activity.... (Bitzer 1968, p. 6)

I would like to argue (and below I will present some evidence that) the misappropriation of scientific genres I illustrated above stems from the structure of the situations in which we ask students to research and write. To illustrate some of the differences between the situations presented by school science and professional science, I have included Figures 3 and 4. Figure 3 is a diagram by Berkenkotter and Huckin (1996, p. 62) which depicts the role of research articles produced for publication in the continuing professional practice of the sciences. Figure 4 is my own depiction of the place of paper writing in school science.

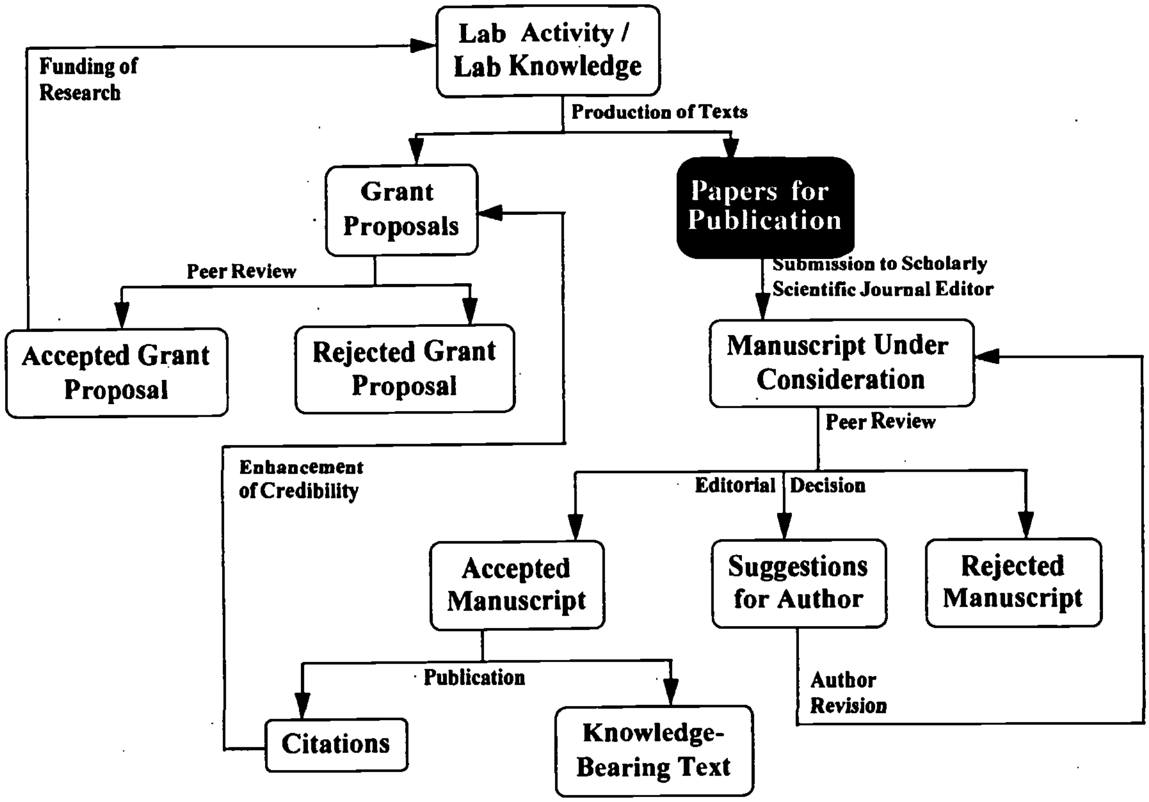

Figure 3: Place of scientific research articles in professional practice

What I would like to draw your attention to in Figure 3 is the prominent place of articles written for publication in the social and professional credit system of the sciences (what Latour and Woolgar (1979) call the "cycle of credit"). While scientists are certainly judged by their peers on a myriad of both professional and personal criteria, published articles clearly have a privileged influence on a researcher's professional fortunes (Myers 1990). The primary output of academic research is publications, which play a major role in "mobilizing" research outcomes in the public sphere.

In contrast to the world of professional science, examine Figure 4, which depicts my own impression of the place of paper writing in the life of a middle school or high school student. Note that in the school environment, there are many more ways to gain credit with the powers that be than by writing. A significant portion of a student's grades may actually derive from the teacher's first-hand observations of how he or she behaves in class: attendance, on-task behavior, contribution to discussions, cooperation with classmates, and so on. This variety of credit mechanisms necessarily makes writing less important for the student than for the adult professional, whose stock of credit can go up or down tremendously from writing (or lack of writing) alone.

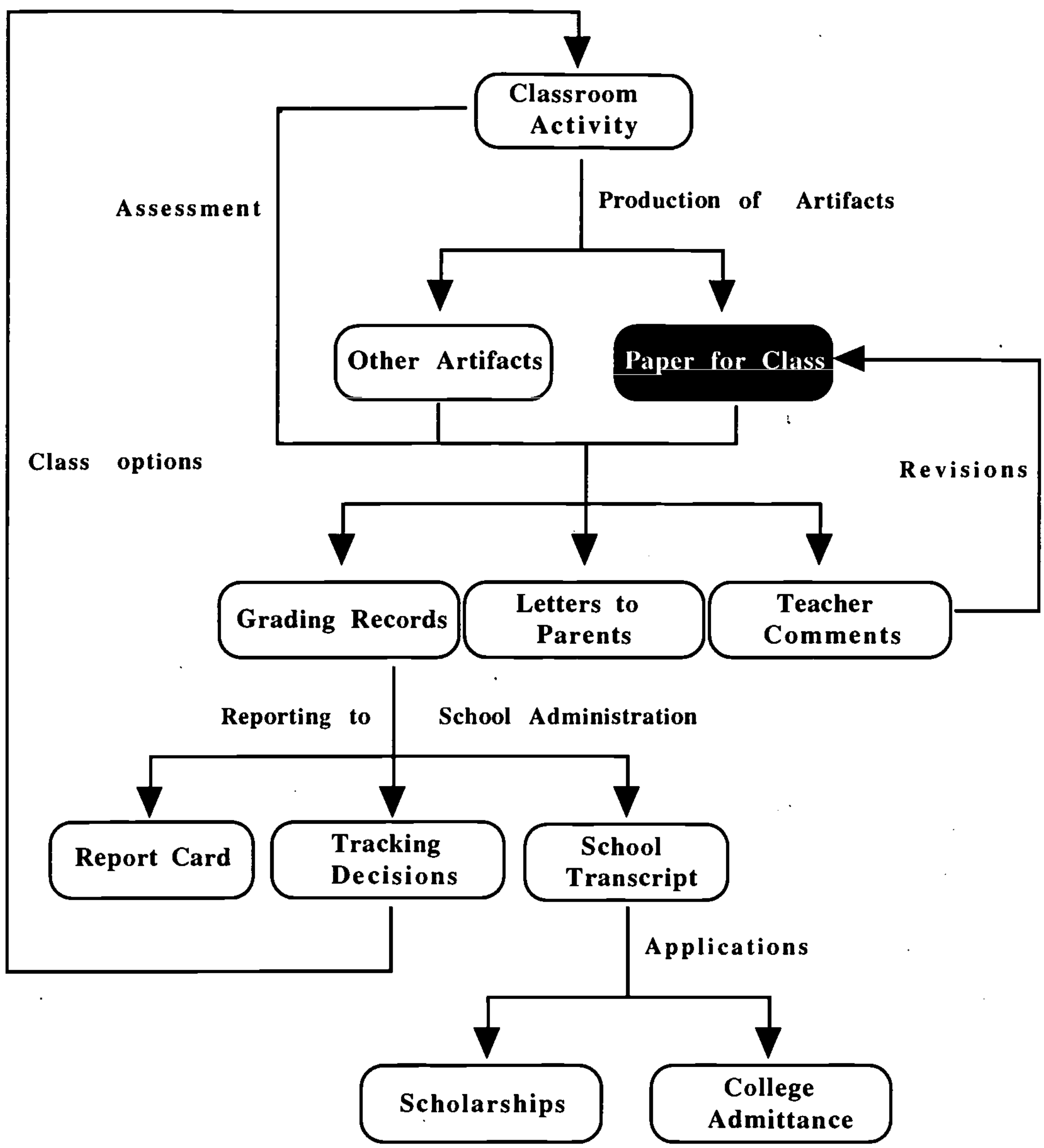

Figure 4: Place of writing in school life

As a result of the differently-structured credit system that surrounds students' writing, they find themselves in very different rhetorical situations than scientists. It should not be surprising to us that these situations effect how students appropriate genres of scientific writing, and what the writing task consequently teaches them about scientific research. The highly formulaic nature of the reports that students write for labs cannot help but engender notions of science as an isolated, intellectually and morally risk-free affair:

> The lack of student learning in labs...is directly related to the lack of thinking it requires. The careful procedures, the concern for safety, and the general atmosphere that penalizes mistakes all mitigate against questioning, risk-taking, thinking, and learning. It is as though both teachers and students subscribe to a mechanistic model of learning which posits that going through certain steps...will somehow magically result in learning. (Tinker 1993, pp. 236-237)

The Problem of Audience

I began this paper by arguing that students' encounters with genres of scientific writing, particularly those that we ask them to prepare work in, are likely to have a strong influence over their understandings of scientific practice. In the previous section I carried this argument further by suggesting that the rhetorical situations in which we place students will, in turn, have a strong influence on the ways that students appropriate, or misappropriate, genres of scientific writing.

The belief that stands behind this position is that teaching students about scientific argument means considerably more than teaching them about syllogistic logic or about the formal features (e.g. heading structure) of genres alone. These ideas are, as Russell (1991) argues, as absurd as teaching someone the rules of movement for chess pieces without teaching them the objective of the game. Our objective in teaching students about scientific writing should be to provide them with tasks and situations in which they can faithfully appropriate the trappings of scientific argument to their own persuasive goals. To the greatest practical extent, those situations and those goals should be a match for those of adult scientists.

It is well enough to assert this, of course, but the trouble becomes *how to do it*? My observations and discussions with teachers over the past four years have led me to believe that the best way is to provide students with an attentive audience for their work that doesn't read it simply to grade it. One way that my research partners and I have found practical to do this has been through telementoring (O'Neill, Wagner and Gomez 1996), a process in which adult volunteers use e-mail to consult with teams of students on their ongoing project work. In this context , my audience argument can be stated as a testable hypothesis. Through telementoring, my research partners and I suspected that both the form and substance of students' written work would become more authentic, because:

- They would have a critical audience that was not reading their work in order to grade it
- They would have additional guidance on the selection of data resources, their origins and the limits of their meaning

Of course, my audience hypothesis presented a measurement problem. How would I know if my research collaborators and I had changed students' rhetorical situations in the ways that we wanted? To address this issue, I developed a coding scheme to support the systematic comparison of genre appropriation patterns across students' papers. As it happens, one of the most closely studied genres of writing at the present time is the scientific research article (see Swales 1990, Chap. 7 for an extensive review of literature). This provides a substantial base of scholarship on which to build.

The RA Genre Appropriation Instrument

The current version of my coding scheme represents a synthesis of observations about the Research Article genre from literature in the sociology of science (Bazerman 1988, Myers 1990) and Linguistics (Swales 1990) with observations made through close reading of a corpus of roughly 150 research articles written by middle and high school students in two project science classrooms. One of these classrooms is in an inner-city setting, the other in an affluent suburban setting.

In its current form, my scheme codes for customary rhetorical moves in the sections of IMRD (Introduction, Method, Results, Discussion) Research Articles and their placement, as well as many of the other trappings of argument in this genre, such as:

- The text types employed (narration, expository prose, overt persuasion)
- Audience and persona indicators (who appears to be writing, and who they appear to be writing to)

- Ways in which sources and authorities are used to reinforce argument (e.g. precise citation of supportive research or vague references to straw men)
- Number and types of sources used (periodicals, encyclopedias, World-Wide Web pages, personal communications, etc.)
- Treatment of perspectives and opinions (e.g. anticipating objections to the research and attempting to address them)
- Use of hedges and qualifications on arguments

The current version of this instrument is included in Appendix A. It is worth noting that despite having taken inspiration from researchers who have studied genres of professional science, the development of this coding scheme was largely inductive. That is, no behaviors are included in the scheme that I haven't observed in students' writing, or that aren't simple logical complements to behaviors I have observed. Thus, I am not unfairly applying the standards of professional science to the work of students.

The Research Setting

The setting for the research I will report here was a project-based Earth Science class at a suburban Chicago high school. The teacher, Rory Wagner, began developing his project-based teaching style 4 1/2 years ago, with the goal of helping his students learn more about how scientific research is done and reported. He is now at a stage of development in his teaching at which students' independent project work takes up three contiguous quarters of the school year. (This is quite impressive given that his non-AP class primarily draws students with low motivation to study science.)

In the first academic quarter, Rory lectures to his students about Earth Science in order to give them a grounding in the phenomena they might choose to investigate in the remainder of the year. This quarter ends with a typical content test. From that point forward, students are evaluated largely on their performance on project work, which they conduct in self-selected teams, pursuing research agendas of their own formulation. (When asked to describe what phenomena his students are permitted to do research on, Rory responds, "Anything that isn't living — that's Biology.") Each project lasts for roughly seven weeks, and the only strict requirements are that students pose a clear research question which they can address with some form of numerical data analysis, and that they submit a quasi-professional research report on their work. Along the way, portions of the paper are submitted as "milestones" and assessed: for example, their research questions and the data they plan to analyze.

Of course, one of the most unusual aspects of the students' working conditions is that each team is assigned a volunteer telementor, recruited by Mr. Wagner, to advise and assist the research through exchanging periodic e-mail. These telementors, many of whom are professionals or masters students in the geosciences, have on many occasions been of great help to students in locating data sources for their research and/or suggesting manageable lines of investigation. They can also provide a critical sounding-board for students' ideas. While they may have some past teaching experience, they are not specially trained. Their orientation to telementoring, in fact, consists entirely of a series of e-mail messages describing the nature of the class the students are enrolled in, the work they are expected to do, and the kinds of help they will need. They are aware that students produce written reports of their work, and sometimes see these reports, but they are *not* complicit in our agenda to teach students about genres of scientific reporting.

Telementoring Activity

While I have collected a great deal of data on the telementoring activity that took place in this setting, I will leave extended discussion of it for another paper. For my purposes here it will be sufficient to broadly characterize this activity and the relationship it bears to students' appropriation of the Research Article genre.

Figure 5 illustrates the volume of e-mail that teams of students reported exchanging with their telementors in the 1995/96 school year. On average, teams sent or received a little more than one message per week over the length of each project. While a few teams sent or received a message every day or every other day, most corresponded with their telementors much less frequently than this. In fact, a few teams who were assigned a volunteer mentor claimed never to have sent him or her a single message. In written surveys and focus groups, these students seemed satisfied that they could do a good enough job on their projects by themselves, and preferred not to have their lives complicated by the involvement of a remote collaborator. In these cases, the teacher usually did not attempt to force discussion to occur.

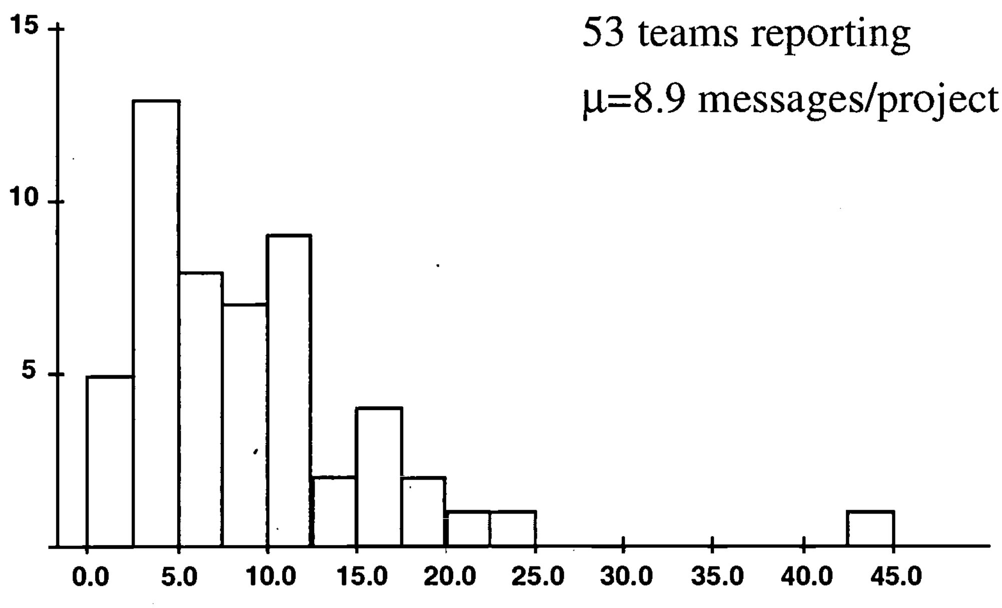

Figure 5: Number of messages per project that student teams reported exchanging with telementors over the 1995/1996 school year

Most teams' e-mail exchanges with their telementors, while friendly, were quite unlike the well-known pen-pal relationships in which the corespondents spend considerable time getting to know one another and locating common interests. Rather, these discussions grew directly from and supported the students' ongoing project work, which was described to the telementors in advance. In the words of one student, the conversations were "straight down to business", relating largely to the data sources that students might employ in their research, they questions they might pose, and how they would go about answering them. This provided a basis for students to broach career or other interests with their telementors, but these discussions did not take center stage.

Research Design and Results

I did not wish to disrupt the unique work ongoing in the research setting simply to establish artificial conditions to test my audience hypothesis. Instead, I chose to follow the research model of design experiments (Hawkins & Collins 1997), which focuses on exploiting the natural variation in the activity and outcomes in a setting to explore the relationships between a set of interacting variables . Using the genre appropriation instrument, I coded a sample of 22 reports written by teams of students for their second and third projects of the 1995/96 school year. In line with my audience hypothesis, my goal was to explore the relationships between genre appropriation and:

- The volume of correspondence between the team and its mentor

How do the papers written by teams toward the left (low message traffic) end of the scale in Figure 5 compare with those written by teams toward the right (high traffic) end of the scale?

- Team members' average grades on a typical Earth Science content test

  Are the students who appropriate scientific genres in an authentic manner the same ones who perform well on a traditional academic task?

- The types of research sources the team mentioned using in its paper

  Do the kinds of source materials used by students in their research bear a measurable relationship to patterns of genre appropriation?

The IMRD Customary Functions Score

One of the scores I constructed from the coded papers is an indicator of how well the sections of the paper fulfill the customary rhetorical functions of the research article. For instance, in an IMRD paper one normally expects the Introduction to state the question or problem the authors are attempting to address, explain the importance of this problem to the field, summarize the research methods employed by the authors, and summarize the results obtained. Likewise, one expects the Discussion section to state the conclusions the researchers have drawn in some detail, to explain how the data support these conclusions, and to elaborate on the importance of the results with reference to the problem framed in the Introduction. (See Appendix A, "Section-Specific Rhetorical Functions" for a complete list of the rhetorical functions coded for in the scheme.)

Over the hundreds of years that the IMRD genre has been developing (Bazerman 1988), these rhetorical functions have become customary because they help readers to understand and digest the writers' knowledge-claims. Thus, I argue, they come more naturally if the rhetorical situation the authors see themselves in lends itself to arguments about knowledge-claims rather than grades.

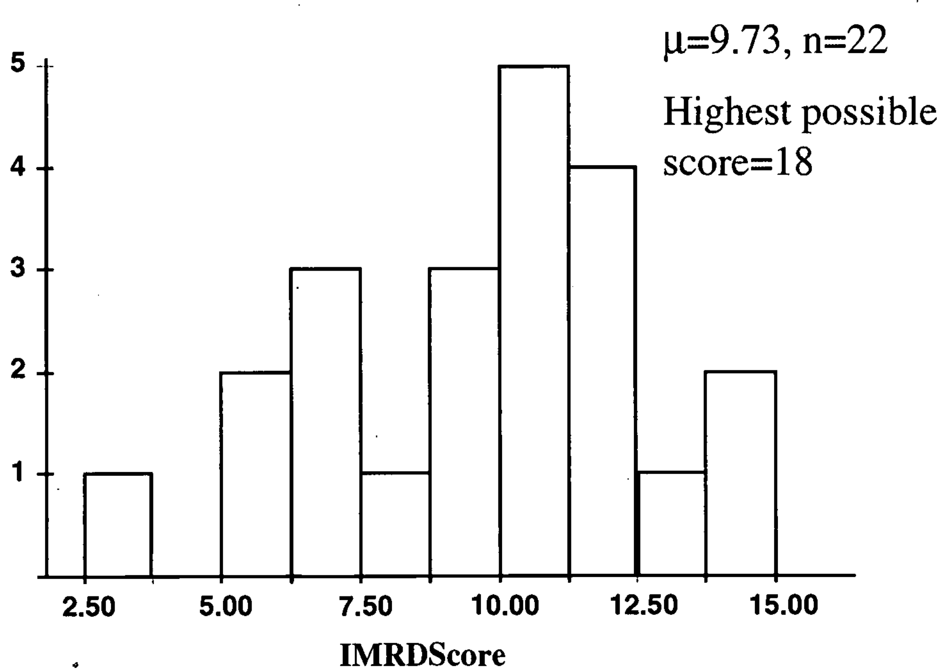

Figure 6: Distribution of scores on the IMRD Functions dimension for the sample of papers coded

Figure 6 shows the distribution of IMRD Elements scores for the sample of 22 student papers I will be discussing. Note that the shape of this distribution is roughly normal. Because this dimension refers to structural elements in the paper's rhetoric, papers with high scores do not necessarily reflect the highest-quality research, but report it in a way that more clearly indicates its value, or lack of value, as a piece of scientific research. Papers with very low scores on this dimension are typically what one would describe as book reports, whose content has been shoehorned into the required sections of the research article. In other words, low-scoring papers use some of the formal features of the IMRD genre, but the conduct of the research and the content of the paper have not been informed by their implicit messages.

As it turns out, the volume of correspondence that teams reported sharing with their telementors correlated significantly with their IMRD scores ($r=.499$, $p<.02$). That is, in this sample, correspondence with telementors and authentically-structured papers go together. Interestingly, students' survey reports concerning the *nature* of relationship they had with their telementor (for instance, their impressions of the mentor's friendliness or the respect he or she demonstrated for the students) do not correlate significantly with the IMRD score, though perhaps when more papers are coded this relationship will come into focus.

It would be natural to suspect that the students whose papers had the most authentic rhetorical structure might be the most dedicated or the brightest. While I do not have data to address the "brightness" issue, I can report that I found no significant correlation between the IMRD scores earned by each team's paper and the average grade received by team members on the Earth Science content test administered at the start of the 95/96 school year. Whether one considers performance on this test an indicator of students' learning ability or their dedication to success in the class, it was not the case that students who performed well on this traditional academic task necessarily produced the most authentically-structured rhetoric in their reports.

Last of all, in light of my argument above concerning the importance of source materials in shaping students' genre knowledge, one might expect to find an empirical relationship between measures of genre appropriation and the types of research sources students used in their work. Surprisingly, I did not find any significant correlation between the IMRD scores of my sample of reports and the particular types of research sources (e.g. encyclopedias, popular press articles, web pages) students mentioned having used in the preparation of those reports. So within the scope of this (admittedly small) dataset there was no clear suggestion of the effects of research sources on students' genre appropriation.

The Perspectives and Opinions Score

Another score that I constructed for each team's research article is intended to draw together evidence of even-handed argument. This dimension distinguishes between papers that simply make bald assertions about the research findings and those that make careful qualifications or strategically give ground to strengthen their arguments. Students earn points on the perspectives and opinions dimension by:

- Anticipating possible objections and attempting to address them (e.g. admitting that sampling bias may be an issue in the research design and arguing that the sampling strategy used was adequate)
- Acknowledging the viability of alternate interpretations (e.g. admitting other possible interpretations of the data left by measurement error)
- Summarizing and weighing the merits of more than two theories or interpretations that explain the data
- Drawing attention to a point of general disagreement in the field (e.g. weaknesses in data sources)

The score awarded to the paper, and the group of students who authored it, is the total number of occurrences of all of these features. Therefore, a team can earn two points by anticipating two possible objections to their research methods or data analysis, and so on with each of the components of this score.

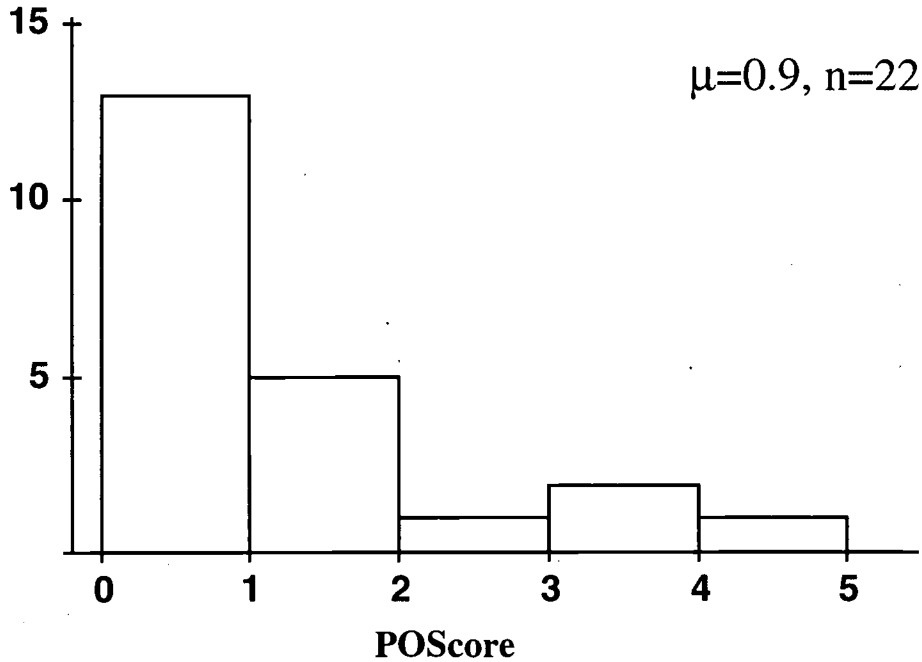

Figure 7: Distribution of scores on the Perspectives and Opinions dimension for the sample of papers coded

As the skewed distribution of scores in Figure 7 illustrates, it was relatively rare for the student research teams to display this kind of even-handedness in their written reports. However, when they did, they were very likely also to have reported a high volume of correspondence with their telementors ($r=.759$, $p<.0001$). While correlation does not imply causation, it is reasonable to suspect that the strength of the relationship between these variables is a result of students' conversations with their telementors, in which they became acquainted with the flaws in their work and the range of possible objections to it. A careful analysis of the e-mail exchanges between the student teams and their telementors will be conducted in the near future to investigate this hypothesis, and to determine if particular strategies on the part of telementors might have led to these positive outcomes.

Finally, it should be noted that as with the IMRD score above, there was no significant correlation between the team's P/O score and its average grade on the first-quarter content test. Therefore, it is more reasonable to attribute the students' even-handed arguments to their experience of telementoring than to their previously-demonstrated studiousness or aptitude in the content area.

Summary/Conclusions

I opened this paper by arguing that the development of students' understanding of genres of scientific writing is an important and long-traditional objective in science education. Not only do genre conventions represent a common way of organizing and assessing individual and group activity in science classrooms, but they are a useful vehicle for developing students' understanding of communities of practice in science. Unfortunately, genre theory and the research reported here suggest that the ways in which students appropriate scientific genres in the classroom are strongly dependent on the situations in which we ask them to write. In common teaching and learning practice, the lack of an audience for students' work other than their teacher puts them at risk of misappropriating scientific genres and learning crude caricatures of scientific practice.

The latter part of this paper presented an argument and some preliminary research findings to suggest that by involving new audiences in students' work, such as volunteer telementors, it is possible to change the "rhetorical situations" in which we ask students to emulate scientific genres of research and writing, so that they can more faithfully appropriate these genres. Through the use of coding instruments such as the one discussed here, it is also possible to measure the influence of novel teaching techniques on students' genre appropriation. Such measures, if duly validated and tested on larger corpora of students' work, could serve a crucial role in the evaluation and re-design of interventions aimed at developing students' understandings of communities of scientific discourse and practice.

Acknowledgments

I would like to acknowledge the support of the National Science Foundation under grant #RED-945729 and the Illinois State Board of Education. I also offer my sincere thanks to Rory Wagner of New Trier High, Winnetka, IL and Judith Lachance-Whitcomb of Jordan Community School, Chicago, IL for the invaluable contributions of time, effort, encouragement and guidance they have offered in this research.

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Appendix A: Student Science RA Rhetoric Coding

Paper Title: ______________________________

Team Number: ________

Date Submitted: ______________________________

Writers & IDs ____________________ ID ____________
____________________ ID ____________
____________________ ID ____________
____________________ ID ____________
____________________ ID ____________
____________________ ID ____________

Teacher, Period: ______________________________

Date Coded: ________ Coder: ______________________________

Notes:

Section-Specific Rhetorical Functions

RA Sections Present (i.e. marked with a labeled heading)

❒ Abstract	❒ Introduction (sometimes labeled "Background")	❒ Method (sometimes labeled "Procedure")	❒ Results (sometimes labeled "Data")	❒ Discussion (sometimes labeled "Conclusions")	❒ References (sometimes labeled "Bibliography" or "Literature Cited")

Other Sections Present

❒ Materials	❒ Purpose	❒ Acknowledgments	

Abstract/Introduction

❒ States a purpose in the form of a problem, question, or issue to be resolved In this section? ❒ Y ❒ N	❒ Explains the significance of this purpose to the general audience (i.e. why do we care?) In this section? ❒ Y ❒ N	❒ Summarizes Method In this section? ❒ Y ❒ N	❒ Summarizes Results In this section? ❒ Y ❒ N
❒ Provides background research into the broad topic area In this section? ❒ Y ❒ N	❒ Summarizes important findings from earlier work on the problem by others (names names and gives citations) In this section? ❒ Y ❒ N		

Methods

❒ Describes what was done by the investigators (built a physical model, collected samples, gathered research sources from libraries or electronic archives, etc.) In this section? ❒ Y ❒ N	❒ Does this description in terms and with precision appropriate to others who might want to reproduce the results In this section? ❒ Y ❒ N	❒ Explains why the method followed by the writers could be expected to lead to a resolution of the problem, or to an answer to the question In this section? ❒ Y ❒ N	❒ Mentions specific search goals and/or criteria employed at library or in Internet searches (e.g. 'we searched with the keywords "sea surface temperature'") In this section? ❒ Y ❒ N

Results

❒ Foreshadows results briefly (in a sentence or two) In this section? ❒ Y ❒ N	❒ Presents the data collected or found (in tabular or graphical form, a set of images, etc.) In this section? ❒ Y ❒ N	❒ Characterizes or "glosses" the data for the non specialist In this section? ❒ Y ❒ N	❒ Provides an interpretation of data with respect to the original question (in the form of calculations and/or prose that refers specifically to the data) In this section? ❒ Y ❒ N

Discussion

❒ States the conclusions that can be made about the original question or problem from the data or information collected In this section? ❒ Y ❒ N	❒ Attempts to explain how the data support, refute, or are unrelated to a question or problem mentioned earlier In this section? ❒ Y ❒ N	❒ Discusses the importance of the results with reference to the significance of the original question In this section? ❒ Y ❒ N	❒ Makes suggestions for further study In this section? ❒ Y ❒ N

Persuasive Features

Text Types Used (check *at least one*)

❒ Expository (lays out facts, frameworks, or key terms)	❒ Narration (relates a sequence of events in past tense)	❒ Overt Persuasion (argues for a particular interpretation with words like "since...then...", "therefore", or "because")

Persona Indicators - how do the writers present themselves? (check all that apply)

❒ Describes scientists as Other (e.g. "Scientists say...")	❒ Assumes guise of scientist (e.g. "In our professional opinion...")
❒ Speaks in first person (uses "I", "We", "Our")	❒ Uses passive voice to exclude self (e.g. "A data table was constructed" rather than "We constructed a data table")

Audience Indicators - who does this seem to be written to? (record line numbers and count)

+ ❒ Refers to teacher in 3rd person, or not at all	- ❒ Addresses teacher by name (e.g. "Well Mrs. Whitcomb, what we decided to do was...")	- ❒ Refers to experience shared with teacher or assumes knowledge that only the teacher or other classmate(s) would have	- ❒ Uses colloquialisms common to students but not to adults

Use of Sources and Authorities (record line numbers and count)

+ Cites named sources for support (e.g. "As (Myers 1985) has said...")	+ Cites named sources as examples of opposing views (e.g. "Counter to findings by Wallin (1995), our research showed...")	+ Provides precise machine addresses, paths and filenames for Internet resources	+ Identifies originators of data or information used *by name of person or institution, or title of work* (not just by the media through which they were obtained, e.g. World Wide Web)
#	#	#	#
- Uses unnamed authorities for support (e.g. "Many scientists believe...")	- Alludes to unnamed opponents, perhaps as straw men (e.g. "many people think...but really...")	- Makes vague references to books or Internet sources (e.g. "The following data come from a Mosaic page" or "This data came from a weather book")	+ Acknowledges the contributions of non-team-members to the work presented (e.g. other student, mentor, teacher, or other adult)
#	#	#	#

Types of Sources and Authorities Mentioned (check) - (these do not need to be bibliographical refs.)

❒ Textbooks	❒ Encyclopedias	❒ Popular Press	❒ Internet resources (e.g. web pages)	❒ Personal Communications	❒ Scientific Journals

Treatment of Perspectives and Opinions (record line numbers and count)

+ Anticipates possible objections and attempts to address them (e.g. "It could be said that...but on the other hand...")	+ Summarizes and weighs several perspectives on a point (i.e. evaluates more than two possibilities for their relative merit)	+ Acknowledges viability of a view(s) not shared by the writers (e.g. "It could still be the case that...")	+ Draws attention to a point of general contention in the field (e.g. "There seems to be little consensus over how to interpret the ice core data...")
#	#	#	#

Hedging (record line numbers and count)

+ Acknowledges possible flaws in method or calculations performed by the writers	+ Acknowledges the limits of the writer's own experience or data	+ Emphasizes the provisional nature of the conclusion or argument put forward (e.g. "More data are needed for a definite answer to this question")
#	#	#

Overall Reflections (record line numbers and count)

Proclaims success	Proclaims lesson learned about the nature or practice of science	Proclaims that important science content was learned.
#	#	#
Proclaims failure	Proclaims lesson learned about doing investigations	Proclaims lesson learned about working in groups
#	#	#

Complaints, Excuses, etc. (record line numbers and count)

Claims crucial resources were not available or convenient enough	Claims team conflict impeded progress	Claims the problem looked deceptively easy, but later proved hard
#	#	#
Claims teacher was unhelpful	Claims mentor let the team down	Talks about long hours or hard work invested in the project
#	#	#
Claims there wasn't sufficient time to do the assignment	Claims the assignment was hard to understand	
#	#	

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