STUDENTS’ WRITTEN ARGUMENTATION STRUCTURE FROM AN INTRODUCTORY OCEANOGRAPHY COURSE:
ANALYSIS AND EVALUATION

A Thesis in
Curriculum and Instruction
by
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ABSTRACT

Students’ written argumentation structure from an introductory oceanography course: Analysis and Evaluation

The purpose of this study was to examine ways that students create arguments derived from inscriptions, expertise, and data. The context of this study was an introductory oceanography course with an emphasis on writing that was mainly composed of non-science majors. During the course, students wrote evidence-based arguments on such issues as plate tectonics, monsoons of India, climate change, and fishery health. A random sample of fifteen students’ papers for each of the four written arguments was analyzed to evaluate the students’ construction of evidence and the overall quality of the arguments, which was used to compare across students and assignments. Results reveal students were only partially able to write plausible arguments in the scientific genre. Students used inscriptions, data, and expertise to introduce lines of reasoning, but were often unable to engage in the theoretical aspects of constructing valid scientific arguments. Additionally, average quality scores for each of the assignments improved throughout the time of the class, suggesting students were better able to construct arguments with time. Writing to learn science provides students opportunities to engage in scientific inquiry; however, more opportunities need to exist for students to practice creating arguments. An emphasis should be placed on including argumentation in schools to further the students’ development of scientific reasoning.
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CHAPTER I

INTRODUCTION

The focus of this research was on written, scientific argumentation - the components of an argument, how the argument was constructed, the plausibility and scientific accuracy of the argument, and the strategies students used to create the argument under differing writing tasks. An argument is defined as “a verbal, social, and rational activity aimed at convincing a reasonable critic of the acceptability of a standpoint by putting forward a constellation of propositions justifying or refuting the proposition expressed in the standpoint” (van Eemeren & Grootendorst, 2004, p. 1). An argument consists of a claim or assertion and its accompanying justification (Toulmin, 2003; Zohar & Nemet, 2002); or, in other words, reasons or statements that support a conclusion (Warnick & Inch, 1994; Zohar & Nemet, 2002).

In regards to science education, written argumentation allows students the opportunity to engage in scientifically literate practices. When students become involved in the process of building evidence-based claims, they are able to gain a deeper understanding of science, which helps connect previously learned knowledge with new knowledge (Keys, Hand, Prain, & Collins, 1999). Understanding scientific claims and creating sound scientific arguments are important skills for students to make informed decisions with respect to socio-scientific issues (Takao, Prothero, & Kelly, 2002).

Written argumentation studies commonly employ an argumentation structure to discuss the components of an argument (Jiménez-Aleixandre, Rodríguez, & Duschl, 2000; Warnick & Inch, 1994; Yerrick, 2000), such as Toulmin’s argument pattern.
According to Toulmin, arguments are comprised of the data, the warrant, and the conclusion, or claims (2003). The structure of the argument is defined by these three main components. As an example, let us think about movement along plate boundaries. Volcanoes occur at subduction zones. Since subduction zones occur along plate boundaries, all volcanoes must occur along plate boundaries. The data is ‘volcanoes occur at subduction zones’. The warrant is ‘subduction zones occur along plate boundaries’. The conclusion is ‘all volcanoes occur along plate boundaries’. Although the structure of the argument is sound, the information involved is not. It is possible for volcanoes to occur in the middle of plate boundaries, as is the case with hot spots, such as Hawaii, so the conclusion that ‘all volcanoes occur along plate boundaries’ is incorrect. Analysis using this rubric does not address the need for a more in-depth look at the lines of reasoning being marshaled within the argument, which reveal the scientific accuracy of the argument (Driver, Newton, & Osborne, 2000).

A line of reasoning is defined as the data and warrants used in an argument that lead to the conclusion. An argument must both have a structure that is sound and must lead to the correct conclusion. The scheme used to analyze the argument must be able to determine the underlying or unexpressed premise, which is linked to the written explicit premises, and the conclusion that is reached (van Eemeren & Grootendorst, 2004). Geologic arguments, according to Ault, must have lines of evidence that converge upon a central conclusion. Geologists rely upon describing past patterns to explain current and future situations, all of which assume that change occurs over time in stages and that one stage ends before the next begins. In an argument, when the lines of evidence converge upon the central conclusion, it “increases its credibility, and in this way historical
inferences (retdictions) become convincing” (Ault Jr., 1998, p. 197). This issue was addressed in this analysis through identification of the main components of a plausible argument, which included the correctness of the lines of evidence presented and the geologic processes/mechanisms that the students described.

Characterization of the students’ written argumentation was employed in this study to identify the essential components that make up a plausible argument. These components include the proposal of a problem or research question, development of evidence within and across lines of reasoning, and presentation of a conclusion. Analysis also addressed the overall quality of the argument, thus making the findings comparable across students and assignments.

Identification of the essential components of scientific written argumentation will augment research into inquiry, writing, and literacy. Scientific inquiry helps students come to a deeper understanding about science by connecting previous knowledge with the newly acquired knowledge (Keys, Hand, Prain, & Collins, 1999). One way students can participate in scientific inquiry is through writing. Scientific writing has been found to be a tool to help students make their thinking overt to themselves and also to educators who can better assess the movement of evidence from introduction to conclusion (Keys, 1999). Identification of the main aspects of a plausible written argument will help to incorporate scientific writing into classrooms more easily. For students to understand the scientific issues that our society faces, it is important for them to be scientifically literate. Incorporation of written argumentation into science classrooms is one way to do this. This research addressed this to help further science education research and science education for all. Scientific inquiry, writing, and literacy will be discussed further in
Analysis of the students’ written argumentation was based upon the rubric given to the students for conducting a peer review. Components of the students’ arguments were identified based upon the lines of evidence described in a peer review rubric the professor created. Investigation looked at components within lines of reasoning and across lines of reasoning, in addition to if they stated a research question and a conclusion. In addition, the argument was assessed for a linear progression of thought, so proceeding from a research question to the conclusion.

The current research may support the use of pedagogy that draws from and emphasizes the use of evidence. Use of evidence in science classrooms may be easier to incorporate with the identification of the components of a plausible argument. Educators will be better prepared to assess the evidence students marshal. Argumentation contributes to the assessment of the uses of evidence by pushing students to make their thinking explicit, thus laying their evidence to bear. Instead of recitation of facts, a deeper understanding of science is shown when written argumentation is evaluated. Incorporating argumentation into science classrooms will allow students to participate in the discourse of science, thus helping them to become more scientifically literate.

**Research Questions**

The current research identified and characterized the components of students’ written argumentation, in an introductory oceanography course for non-science majors. This study builds upon a long-term research project assessing the writings of an
undergraduate introductory oceanography course. The methods chosen for this analysis drew upon the body of knowledge created from previous research (Kelly, Regev, & Prothero, 2005; Kelly & Takao, 2002; Takao & Kelly, 2003; Takao, Prothero, & Kelly, 2002). However, this research developed a more succinct assessment of the components that create sound argumentation.

Specifically, the following questions were addressed:

- In written argumentation, what components are necessary to create a plausible and scientifically accurate argument?
- How do non-science majors in an introductory oceanography course construct written argumentation?
- How do students’ arguments vary under different writing task constraints?

The cornerstone of my study was based upon the peer review rubric provided to the students for grading the calibration, their peers’, and their own papers. Each criterion was scored using a developed rubric that emphasized progression of thought. Analysis of the students’ arguments progressed from presentation of a research question, discussion of evidence within and across the lines of reasoning, to the statement of a conclusion. Within the discussion, analysis included the students’ use of inscriptions, data, and expertise to back up their claims, in addition to creating a cohesive and scientifically sound argument. Calculations were then made to compare overall scores across assignments and students. The goal of this investigation was to identify the components of a plausible argument; however, the larger picture was on finding ways for our future generations to become more scientifically literate through the use of the developed rubric and the analysis results.
This chapter will outline several research studies that have focused on written argumentation, discourse, and K-12 argumentation.

**Previous Written Argumentation in Introductory University Oceanography Studies**

This research has drawn upon a body of knowledge created over ten years in which research, development, and application have been completed cyclically by Gregory J. Kelly, William A. Prothero, Jr., and an evolving research team (Diefendorf & Kelly, 2006; Kelly & Bazerman, 2003; Kelly, Chen, & Prothero, 2000; Kelly, Regev, & Prothero, 2005; Kelly & Takao, 2002; Prothero, 2005; Takao & Kelly, 2003; Takao, Prothero, & Kelly, 2002). A short review of this previous research will shed light on the current analysis’ methodologies and framings.

The first study (Kelly, Chen, & Prothero, 2000) took place in an introductory university oceanography course and examined the way teachers and students, as group members, act as social mediators of disciplinary knowledge through the everyday practices of teaching and writing. Through the analysis of videotaped lectures and small group sessions, and reflective essays written by the students, the researchers were able to identify cultural actions, artifacts, and discourse processes that allow the construction of social situations, which are considered routing everyday events. This study emphasized writing in science in relation to 1) how it shapes a community’s procedures, practices, and norms and 2) the requirement of understanding the reasons, uses, and limitations of writing in science as a situated practice specific to the discipline. This study concluded
that use of datasets to help formulate arguments and discuss scientific practices in relation to scientific writing and that teaching of science through building of scientific knowledge and the ways this knowledge was developed need to be emphasized. Although this study revealed the use of writing as a social practice, questions still remain about the students’ use of data in their writing to create an argument that is scientifically sound, which is a main component of the social practice of science, which my study addresses.

The second study (Kelly & Takao, 2002) involved epistemic analysis for students’ use of evidence in writing from an introductory oceanography course. A model was created based upon six epistemic levels by which the students’ arguments were assessed. The epistemic level argumentation model allowed for the use of several claims to support complicated arguments, which could then be visually represented. Results included the finding that students’ arguments were grounded mostly in observations, more so than in interpretations. Although the study focused on the students’ abilities to make inferential claims and the level of those claims, which is an improvement over the Toulmin method, it failed to assess for the inferential connections between the claims being made in the argument. The third study attempted to address this issue.

In the third study (Takao & Kelly, 2003) the use of evidence in writing was examined in two ways – interviews and argumentation analysis. First, interviews were conducted with course instructors, university oceanography students, and non-oceanography university students. The participants were asked to review one high and one low ranking paper from the previous academic year in which they identify and describe their overall opinion of the two papers, the authors’ use of evidence, use of figures, and conclusions. Through this portion of the study, Takao and Kelly found that
the interviewees were able to distinguish between the high scoring and low scoring papers, but had difficulty articulating the reasons for the differences in opinion between the high and low scoring papers. Second, an argumentation analysis was completed on the two papers through application of an argumentation model to evince the differences between the student papers. The epistemic level argumentation model adapted from Kelly & Takao (2002) including a measure for lexical cohesion was applied to the students’ papers. The high scoring paper had propositions across all six epistemic levels, whereas the low scoring paper had few propositions that tied to the higher-inference propositions. This analysis revealed that assessing for evidence in writing is possible, however a question is still left unanswered: How do we assess for the plausibility and accuracy of the information presented in the written argument?

The fourth study (Kelly & Bazerman, 2003) assessed how claims are tied to specific data in the construction of written arguments in an introductory university oceanography course. Analysis consisted of examining students’ written arguments (chosen by the professor to be the highest quality) based on rhetorical moves, epistemic levels of claims, and lexical cohesion. Findings revealed five ways in which the higher achieving students organized their texts. First, the students’ arguments showed a hierarchical arrangement in which the students introduced and sustained the use of key conceptual terms. Second, cohesive links were prevalent across the sentences, which were introduced within the first few sentences of the argument and continued throughout. Third, at the boundary of sections and subsections, cohesive links were more prevalent, tying together the items of multiple epistemic levels. Fourth, variation of the epistemic status of the claims depended upon the rhetorical needs of the differing sections, which
means that the methods and observations sections were more specific in their descriptions. Fifth, theoretical terms that were introduced early in the argument were associated with other salient terms in the argument, which were used in reference to the interpretations. This study shed light on many of the components necessary to create a plausible argument through the emphasis of linguistics, however it is unclear how this type of analysis could easily be incorporated into the science classroom.

The fifth study (Diefendorf & Kelly, 2006) was the last iteration of the current study. It examined the way that students build arguments based on large-scale earth data sets in an introductory oceanography course. Students written arguments were assessed using epistemological criteria such as convergence of lines of reasoning, overall coherence of the arguments, and validity of the conclusions reached in the arguments. Results indicated that the students were only partially able to write in the scientific genre. Students used evidence, but were unable to construct coherent models based on geologic boundaries. Next, let us turn our attention to previous written argumentation studies completed in the K-12 realm.

**Previous K-12 Written Argumentation Studies**

Many written argumentation studies have been conducted in grades K-12 which have focused on such things as the use of software tools (Bell, 2000; Keys, Hand, Prain, & Collins, 1999; Sandoval & Millwood, 2005), students’ perceptions of writing (Prain & Hand, 1999), writing-to-learn strategies (Keys, 1999), and scaffolding to enhance argumentation (McNeill, Lizotte, Krajcik, & Marx, 2006; Patterson, 2001). Although there are many strong analytic frameworks to assess argumentation, there are few that
were designed to study the quality of the arguments made. However, two promising studies address this issue.

In a study completed by Sandoval and Millwood (2005), the quality of students’ written arguments was assessed in relation to the data that students cited as evidence to warrant claims and how students referred to data within the explanations. Quality included “judgments about the structure of arguments and their conceptual adequacy”, which helped to assess the “right kinds of arguments and that such arguments [made] sense” (Sandoval & Millwood, 2005, p. 24). In this study, students from four introductory high school biology classes constructed arguments about two scenarios in a program called ExplanationConstructor, which was developed by Sandoval and Reiser (2004). This program was meant to support students’ construction of explanations by allowing them to link data they felt to be important evidence to their claims being made in the text. While this study revealed that the majority of students were able to connect data to warrants the students were not able to write explanations interpreting the data cited. A limitation of this study, as noted by the authors, was that they “did not distinguish between data that [was] merely included in an explanation and those that [were] used rhetorically to support claims” (Sandoval & Millwood, 2005, p. 51). The aim of this and my study, presented in chapters III through V, are similar in that structure and quality of the argument were analyzed. However, in my study, analysis followed the use of inscriptions throughout the explanation to track the claims that were supported with evidence to assess the structure and quality of the arguments, while Sandoval and Millwood simply assessed students’ links to claims.
Another tool, the SenseMaker argument building tool, was used in a study conducted by Bell and Linn (2000). In this study, the middle school students’ thinking was made explicit with the use of such software, which provided insight into the structure of the students’ arguments. Despite the fact that students were able to create explanations, they mainly consisted of warrants without backings and the students’ explanations generally relied upon conjectures rather than descriptions of the presented data. Although this analysis shed light upon the structure of students’ arguments, it did not discuss the scientific accuracy or plausibility of the argument, which is necessary to understand how all of the components work together to create an argument that makes sense.

In my search for argumentation and discourse studies, few were found in the university realm. Thus, I present a single study (Sadler & Fowler, 2006) that was found that bridged the gap between K-12 and university argumentation studies. In this study, socioscientific argumentation quality was compared across high school, non-science majors, and science majors. A selection of fifteen students per group was interviewed to discuss the use of genetic engineering to treat Huntington’s disease. Students’ answers were looked at in terms of justifications of claims, which included warrants, backings, qualifiers, and rebuttals according to Toulmin’s argument pattern. It was found that the non-science majors and high school students did not differ greatly in terms of their argumentation quality, and that the science majors revealed higher quality argumentation than the non-science majors and high school students (Sadler & Fowler, 2006).
Previous Discourse Studies

Argumentation studies have also focused upon spoken discourse in the K-12 setting, addressing aspects such as the quality of the argument (Clark & Sampson, 2007; Zohar & Nemet, 2002), use of inscriptions and participation in science (Jiménez-Aleixandre, Rodríguez, & Duschl, 2000; Wu & Krajcik, 2006), epistemic levels (Jiménez-Aleixandre & Reigosa, 2006), socioscientific issues (Kelly & Crawford, 1997; Schweizer & Kelly, 2005; von Aufschnaiter, Erduran, Osborne, & Simon, 2008), epistemic tools (Sandoval & Reiser, 2004), sociology of scientific knowledge (Kelly & Crawford, 1997), and achievement level (Yerrick, 2000). As the research spans a great deal of topics, let us focus upon the use of inscriptions in argumentation and the quality of an argument.

Wu and Krajcik (2006) found in their study of seventh graders’ use of inscriptions that working with inscriptions allowed the students to experience and understand the ways to organize, transform, and connect data or scientific ideas in the scientific genre. However, students did not consider how the inscriptions could be used for reasoning purposes. The students were able to participate in the activity of scientists, however, not fully. Additionally, Jiménez-Aleixandre, Rodríguez, and Duschl found that “providing the students with opportunities to solve problems, discuss science, and talk science...students will use a number of operations (argumentative and epistemic) which make part of the scientific culture” (Jiménez-Aleixandre, Rodríguez, & Duschl, 2000, p. 782). Thus, participation in the discourse of science is a main focus of discourse studies of argumentation.
Clark and Sampson (2007) found that although there are existing analytical frameworks to assess dialogic argumentation, including the structure, interactions, and epistemic levels, there are few frameworks that assess the conceptual quality of the argument. The same point was made by von Aufschnaiter, Erduran, Osborne, and Simon (2008), thus they created a rubric that would be more rigorous at assessing dialogic argumentation. Although their results did not reveal a greater understanding of content after the use of argumentation in the classroom, it was shown that the “students’ familiarity with content (even at low levels of abstraction), rather than a general ability to argue, is the essential prerequisite for developing (high-level) arguments” (von Aufschnaiter, Erduran, Osborne, & Simon, 2008, p. 126).

Through this review of previous argumentation studies, a gap in the research has been revealed. The studies that have been conducted discuss the need to assess quality of the arguments; however, none of them were able to fully assess the structure of the argument while also being able to assess the plausibility and scientific accuracy of the arguments being made. Through my research, a rubric has been created that measures all aspects of the argument, therefore judging its plausibility and scientific accuracy, as well as its overall quality.

The subsequent chapters will shed light on written argumentation in an introductory oceanography course. Chapter II will focus on the theoretical framework upon which my research was based. Chapter III presents the background, methods, and procedures undertaken in my research. Chapter IV is a discussion of the findings of the look into argumentation in an introductory oceanography course. Chapter V discusses the findings and implications for the research. Appendices are to follow.
CHAPTER II

THEORETICAL FRAMEWORK

In a recent article, Lemke pointed out just how important the sociocultural perspective is in science education and science education research. The most important aspect of learning and doing science is the cultural traditions that are learned through society, especially the use of discourses and representations (Lemke, 2001).

The sociocultural theory of learning stems from Vygotsky, who believed that humans create their culture and are affected by their culture. Learning and development occurs as a result of social interaction and the concepts learned must be internalized for them to be useful to the individual (Gredler, 2001; Schunk, 2004). Among researchers, it is now widely accepted that “learners construct their understanding of both science and writing through the social negotiation of meaning” (Wallace, Hand, & Prain, 2004, p. 4).

In a classroom situation, teaching argumentation relies upon knowledge being situated in a context where students bring their own unique knowledge and understanding to the table to be built upon (Blumenfeld, Marx, Patrick, Krajcik, & Soloway, 1997). In this context certain tools are used, such as language, symbols, signs, counting, cultural objects, and social institutions (Schunk, 2004). Several aspects of science education are addressed, which includes, but was not limited to, inquiry, writing, and literacy. Each of which will be discussed in relation to the sociocultural perspective.
Scientific Inquiry & Inquiry Learning

The National Science Education Standards place an emphasis on students at all grade levels having the opportunity to use scientific inquiry through questioning, the implementation of tools and techniques in data collection, and critically thinking about the relationships between evidence and explanations, which allows for analysis and communication of scientific information (National Research Council, 1996). Although researchers have not come to consensus on the meaning of inquiry, Anderson describes scientific inquiry as “the work of scientists, the nature of their investigations, and the abilities and understandings required to do this work” (2007, p. 808). Through scientific inquiry, in which students participate in investigations, students are in an active learning role where conceptions change based on the information learned. Their knowledge is context dependent, so the “more abundant and varied these contexts, the richer are the understandings acquired” (Anderson, 2007, p. 809). In addition, knowledge is socially constructed, by which students’ understandings are enriched through social interaction with others (Anderson, 2007).

This research studied how students engaged in science to learn about the scientific process in a community of practice, namely an introductory oceanography course. As students moved through this process of scientific inquiry, they came to a deeper understanding of science by connecting previous knowledge with the newly acquired knowledge (Keys, Hand, Prain, & Collins, 1999). The students were able to apply their previous knowledge and experience, through the use of cultural tools in social interactions, to internalize and transform their understandings, thus allowing cognitive change to take place (Schunk, 2004). According to Schunk, the tools acquired during
social interactions with others are internalized, then they are used as mediators for more advanced learning. Advanced learning entails higher order thinking such as problem solving (2004).

When educators involve students in the process of building evidence-based claims, the students no longer focus on memorization and recitation, but instead on a deeper understanding of science (Takao & Kelly, 2003). In order for students to build strong arguments, it is essential for them to understand, interpret, and make sense of the relevant data (Duschl, 1990).

**Scientific Writing**

Scientific writing is an important tool for students to develop a deeper understanding of a given topic by pushing students to introduce the information in a logical, concise, and coherent manner, in addition to making the connections between concepts explicit (Keys, 1999). In this manner, the student’s thinking becomes overt, which is especially essential in the earth sciences where processes and mechanisms are very important (Kali, Orion, & Eylon, 2003). Vygotsky believed that mastering the process of transmitting culturally relevant information through the use of language allowed the application of these symbols to “influence and self-regulate thoughts and actions” (Schunk, 2004, p. 294). Through the social negotiation of meaning learners can build their understandings of both science and writing (Wallace, Hand, & Prain, 2004). The components that make an argument logical, concise, and coherent were identified in this research to aid students with scientific writing by making recommendations for teachers.
**Scientific Literacy**

Scientific literacy is a complex concept that researchers have not yet come to complete agreement upon; however, important aspects of the definition of scientific literacy have been described in detail, including the nature or processes of science; the interconnectedness of science, technology, and society; and critical thinking skills, among others (Libarkin, 2001). These aspects work together to create scientifically literate students, who have “the ability to understand scientific claims, critically examine scientific findings, and develop an effective scientific argument [which] are important skills for scientists as well as citizens in a democratic society facing a myriad of technoscientific issues” (Takao, Prothero, & Kelly, 2002, p. 40). In a society where scientific education has failed to empower students to interpret socio-scientific information (Driver, Newton, & Osborne, 2000), it is important that studies such as these shed light on such issues in science education in hopes to advance the research and improve science education for all.

According to Kelly, there are three dimensions to scientific literacy. First, scientific literacy concerns establishing the use of tools, procedures, and strategies to interpret written tasks. There is great value in “being able to ascertain and comprehend the meaning of science concepts from printed materials” (2007, p. 458). The second dimension of scientific literacy is one of communication. Learners need to have ability “to communicate ideas in clear and coherent language” (2007, p. 458). The third dimension of scientific literacy has to do with being able to understand texts as well as spoken and written discourse, which will help students develop conceptual understanding
and aid teachers in assessing student learning (2007). These three key dimensions of scientific literacy work together to help create scientifically literate individuals who will be able to navigate argumentation in their daily lives and act as responsible citizens.

The next chapter, Chapter III, will shed light on the background, methods for analysis, procedure, and research constraints.
CHAPTER III

BACKGROUND

This research is part of a ten-year ongoing study of scientific writing conducted by Gregory J. Kelly, William A. Prothero, Jr., and an evolving research team. Previous research has shed light on the construction of written scientific argumentation in regards to its knowledge and practices and has contributed to the set of tools aimed at mediating this construction (Diefendorf & Kelly, 2006; Kelly, 2005, February; Kelly & Bazerman, 2003; Kelly, Chen, & Prothero, 2000; Kelly, Regev, & Prothero, 2005; Kelly & Takao, 2002; Prothero, 2005; Takao & Kelly, 2003; Takao, Prothero, & Kelly, 2002).

Educational Setting

The setting of the current study was an introductory undergraduate oceanography course at the University of California Santa Barbara during the fall semester of 2005. The class was composed of 78 students, the majority of them non-science majors. Students attended both lab and lecture three hours per week. An emphasis was placed on writing for understanding and the course was designated a ‘writing intensive course’ by the university. Writing intensive courses required students to write one to three papers with a minimum of 1,800 words in at least six pages and to have the opportunity to receive feedback on their work. In addition, the papers, where appropriate, gave the students experience in “participating in the discourse of the discipline”, which this course provided (University of Santa Barbara, 2006).
Course Assignments

The course, taught by Professor William Prothero, focused on four main issues – Plate Tectonics, Monsoons of India, Oceans & Climate, and Fishery Health – each of which included a writing assignment. Each assignment encouraged the students to build an argument based upon data collection, inscriptions, and expertise, thus requiring the students to ground their theoretical assertions in relevant data (Kelly & Bazerman, 2003). Inscriptions are defined as data-derived descriptive materials, such as models, maps, and graphs (Diefendorf & Kelly, 2006).

The purpose of each assignment (also found on the assignment pages - Appendices B, D, E, and F) was as follows:

Plate Tectonics
• To help the students understand the mechanisms behind divergent and convergent plate boundaries using real earth data and to determine the boundary type of two locations – the Tonga Trench and the East Pacific Rise.

Monsoons of India
• To help the students understand the processes causing the Indian Monsoons through the use of various atmospheric and climatic data.

Oceans & Climate
• To help the students understand the effects oceans have on the global climate system, thus informing them about climate change and the possible consequences of global climate change.

Fishery Health
• To aid the students in thinking critically about the sustainability of ocean life and the influence of fishery health on local and global economies.
Each student was supplied with the ‘EarthEd Online’ software packet, which included ‘Our Dynamic Planet’, both of which were created by the professor of the course. For more information on the use of these scientific technological tools see (Prothero, 2005) or go to http://earthednet.org/. The software provided the students with a secure web location for uploading homework responses, calculating grades, looking at course assignments, obtaining Earth science data, and writing assignments and peer reviews (Prothero, 2005). In addition, instructions were given through the course lab book, the ‘EarthEd Online’ software, as well as the professor and teaching assistants. The course lab book provided heuristics on how to write a technical scientific paper (see Appendix A), discussing in detail the layout, which includes methods, observations, interpretations, references, and figures with captions.

The first assignment, Plate Tectonics, required the students to use the ‘EarthEd Online’ software packet. The large-scale geologic datasets contained in ‘Our Dynamic Planet’ include earthquake locations and depths, volcanic activity, seafloor ages, and topography. With this data, students were required to create valid arguments based on convergent lines of reasoning as well as the development of a drawn model for each location to describe the mechanisms behind the geologic feature. After collecting data, drawing upon their own knowledge base of tectonic boundaries, and using inscriptions to back up their assertions, students uploaded their papers onto ‘EarthEd Online’ through the ‘Writer’ program. Here, students used software that facilitated peer review. This process was modeled after the Calibrated Peer Review™ created by the UCLA Chemistry department (for more information go to http://cpr.molsci.ucla.edu/). See Appendix B for the Plate Tectonics assignment.
The peer review process was as follows. To complete the assignment, students read three calibration papers provided by the professor, three papers written by their peers administered anonymously and randomly, and their own paper. A scoring rubric was provided for students to use to score each paper. Grades were calculated with a formula for each student’s paper based on his or her assessments of the calibrated, peer reviewed, and their own papers. For a more in depth explanation of the grading process, see (Prothero, 2005). The students completed the peer review process for each of the four assignments. Appendix C shows the peer review rubric the analysis was based upon.

In the second assignment, Monsoons of India, students were expected to use data from outside sources, such as books and the Internet, which the students considered reputable and credible sources. The data taken from these outside sources were used to marshal evidence to describe the mechanisms driving the summer monsoons and the lack of winter monsoons in India. Such mechanisms included land versus ocean temperature, air pressure, wind, and precipitation. After completion of the assignment, the students’ papers underwent the peer review process as previously described. See Appendix D for the Monsoons of India assignment.

For the third assignment, Oceans & Climate, students focused on climate change, including the factors that affect climate, historic climate change, recent climate change, future climate change, and policy recommendations. In comparison to the first two assignments, the social and political nature of the Oceans & Climate assignment allowed the students more freedom in terms of what types of evidence they were able to use. Students were required to present evidence in the form of expert references in addition to
inscriptions to back up their claims. Again, each student completed the peer review process. See Appendix E for the Oceans & Climate assignment.

The fourth and final assignment, Fishery Health, required the students to become familiar with the arguments made by two independent fishery interest groups. Students were expected to create an argument based upon data and expert references. This assignment also gave more freedom to the student to be creative with the form of their argument because of the social, political, and economic nature of the task. After finishing the fisheries assignment, the students completed the peer review process. See Appendix F for the Fishery Health assignment.

**Methods for Analysis**

To avoid sampling bias, fifteen students were chosen at random and after which, all identifying information was removed and numbers were randomly assigned to each student. For each student chosen, all four of his or her assignments were assessed. In order to build a practical research model without redundancy, previous research methods were assessed and incorporated into the analysis (Kelly, Regev, & Prothero, 2005; Kelly & Takao, 2002; Takao, Prothero, & Kelly, 2002; Toulmin, 2003).

The current research into argumentation was comprised of lines of reasoning that were assignment specific. For each assignment, the peer review rubric, created by the professor of the course, was used to define the lines of reasoning. The peer review rubric was created to show the students the expectations the professor of the course had for them in terms of the lines of reasoning they should marshal and what other important
aspects of the argument needed to be touched upon for each assignment. The use of lines of reasoning to create an argument was taught in class, laid out in the students’ lab book, and described in the software provided to the students. During the initial stages of the research, it helped to read the students’ work through the peer review rubric lens to help elucidate the important aspects of the past research that should be included and shed light on gaps that had not previously been emphasized.

**Analysis of the Students’ Work**

It was important in this analysis to assess for the argument components that were emphasized in the course, so they were laid out for each of the assignments in the following paragraphs and illustrated in Table 1.
Table 1. Components of each assignment emphasized in the course, which are the lines of reasoning that were assessed for in the analysis.

<table>
<thead>
<tr>
<th>Assignment</th>
<th>Lines of Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plate Tectonics</td>
<td><strong>Tonga Trench</strong>&lt;br&gt;☐ The trench is linear&lt;br&gt;☐ There are strong earthquakes dipping below the surface&lt;br&gt;☐ There is a linear arc of volcanoes</td>
</tr>
<tr>
<td></td>
<td><strong>East Pacific Rise</strong>&lt;br&gt;☐ There is a linear ridge&lt;br&gt;☐ There are weak earthquakes concentrated mainly at the surface&lt;br&gt;☐ There is a lack of volcanoes in comparison to the Tonga Trench&lt;br&gt;☐ The age of the Earth’s crust is youngest at the ridge</td>
</tr>
<tr>
<td>Monsoons of India</td>
<td><strong>Winter</strong>&lt;br&gt;☐ Precipitation&lt;br&gt;☐ Wind&lt;br&gt;☐ Atmospheric pressure&lt;br&gt;☐ Temperature</td>
</tr>
<tr>
<td></td>
<td><strong>Summer</strong>&lt;br&gt;☐ Precipitation&lt;br&gt;☐ Wind&lt;br&gt;☐ Atmospheric pressure&lt;br&gt;☐ Temperature</td>
</tr>
<tr>
<td>Oceans &amp; Climate</td>
<td><strong>Long Term (past ~2000 years)</strong>&lt;br&gt;☐ Temperature&lt;br&gt;☐ Carbon Dioxide</td>
</tr>
<tr>
<td></td>
<td><strong>Short term (past ~125 years)</strong>&lt;br&gt;☐ Temperature&lt;br&gt;☐ Carbon Dioxide</td>
</tr>
<tr>
<td>Fishery Health</td>
<td>Data&lt;br&gt;Expertise&lt;br&gt;Bias</td>
</tr>
</tbody>
</table>

Depending upon the type of argument raised, each domain elicited different lines of reasoning. The Plate Tectonics assignment was location dependent, so included the Tonga Trench and the East Pacific Rise. For the Tonga Trench domain three lines of reasoning should have been explicitly mentioned within the student’s work: the trench is linear, there are strong earthquakes dipping below the surface, and there is a linear arc of volcanoes. This process is illustrated in Figure 1. In a subduction zone, such as the Tonga
Trench, two tectonic plates are pushed together and one of the plates is pulled under the other in a process known as subduction. When the plates push together, they buckle slightly and raise the surface, thus causing a ridge to be created along the fault. As the plates rub against each other immense pressure builds up, then is released in the form of earthquakes that run deep below the surface. The subducted plate melts as it is pulled into the mantle. The melted material rises up through the mantle to the surface. It moves up through the earth and is expelled from volcanoes at the surface that create an arc shape running parallel to the trench.

Figure 1. Both a divergent and convergent boundary are illustrated here. The divergent boundary illustrates the process occurring at the East Pacific Rise. Notice the lack of volcanoes, few and shallow earthquakes, and the ridge. The convergent boundary illustrates the process occurring at the Tonga Trench. Notice the prominent volcanoes, numerous and deep earthquakes, and linear trench. Image adapted from (Press & Siever, 1998).

In regards to the East Pacific Rise domain, four lines of reasoning were necessary: there is a linear ridge, there are weak earthquakes concentrated mainly at the surface,
there is a lack of volcanoes in comparison to the Tonga Trench, and the age of the Earth’s crust is youngest at the ridge. This process is also illustrated in Figure 1. In a divergent zone, as the East Pacific Rise, the tectonic plates pull apart. As they pull apart, new crust is created and pushed up to form a ridge due to the upward movement of magma from the mantle. This new material adds to the trailing edges of the diverging plates. The crust is youngest where the plates pull apart and oldest farthest from the ridge. While the plates pull apart, pressure is released as a small number of weak earthquakes concentrated at the surface. There are fewer volcanoes at the East Pacific Rise in comparison to the Tonga Trench because as the plates are being pulled apart there is little opportunity for volcanoes to form.

The lines of reasoning for the Monsoons of India assignment were dependent upon two times of the year: winter and summer. For both of the domains there were four lines of reasoning that students should have mentioned: precipitation, wind, atmospheric pressure, and temperature. During the summer, monsoons occur in India. The temperature difference between the water and the land drives the monsoons. Water retains heat well, so stays fairly constant in temperature over time. Land on the other hand changes temperature easily. During the summer, the seas are cooler than the land. India’s land surface is warmed by the sun, which warms the surface air. This warm air rises, creating a low pressure system over India. Meanwhile, there is a high pressure system over the sea. Air moves from areas of high pressure to low pressure, so moist air from the sea blows inland. As the moist air is warmed by the land, it rises and cools causing it to release its moisture as large amounts of precipitation. This process is illustrated in Figure 2.
Figure 2. During the summer, monsoons occur in India. The land is warmer than the water, because land retains heat better than water. The warm surface air rises, creating a low pressure system over India and a high pressure system over the sea. The cooler sea air blows inland carrying with it moisture. As the wind moves over the land, it is warmed up causing it to release large amounts of precipitation.

During the winter, the monsoons do not occur in India. The sea is warmer than the land, so a low pressure system is created over the sea and a high pressure system is created over the land. The cool surface air moves from the land over the ocean, causing the winds to flow outland. Precipitation is minimal over land since no moist air is present. This process is illustrated in Figure 3.
Figure 3. During the winter, monsoons do not occur in India. The sea is warmer than the land. The cool surface air rises, creating a high pressure system over India and a low pressure system over the sea. The cooler land air blows outland. Since the land air is dry, very little precipitation occurs during the winter.

The Oceans & Climate assignment was dependent upon two time periods: long term (past ~2,000 years) and short term (past ~125 years). For each domain, these lines of evidence needed to be discussed: temperature and carbon dioxide. Generally speaking, a corollary relationship exists between temperature and carbon dioxide. When carbon dioxide in the atmosphere increases, air temperature increases and when carbon dioxide decreases, air temperature decreases. In relation to long term climate change, which encompasses approximately the past 200,000 years, records, such as the Vostok Ice Core, have shown a rise and fall in temperature, which correlates with a rise and fall in carbon dioxide values. This relationship is illustrated in Figure 4, which is data plotted from the Vostok Ice Core.
Figure 4. For long term climate change, one of the best examples of changes in temperature and CO2 is the Vostok ice core from east Antarctica. Original source: (Petit et al., 1999). Figure obtained from (GRID (Global Resource Information Database of the United Nations Environmental Program in Arendal, 2005).

Short term climate change, which encompasses only about the past 125 years, also shows a direct relationship between carbon dioxide and temperature. During this time period, humans have kept a real time record of air temperature and atmospheric carbon dioxide. This has allowed for a comparison of past climate change with recent data. The relationship between carbon dioxide and temperature over the last 125 years is illustrated in Figure 5, which is data plotted from Mauna Loa, and Figure 6.
Figure 5. The Keeling curve consists of data taken from Mauna Loa for approximately the last 50 years. Figure source: (National Oceanic and Atmospheric Administration, 2006).

Figure 6. Short term climate change has been recorded with respect to temperature for approximately the last 150 years. This graph is an example of the type of inscription students could marshal to create their argument. Adopted from: (Intergovernmental Panel on Climate Change, 2001).
The Fishery Health assignment had only one domain, so was based upon the following lines of reasoning: data, expertise, and bias. This assignment was different from the other three in that it looked more at the type of inscriptions the students marshaled to build their arguments. Students were expected to create an argument in relation to their opinion on the statements made by the Pew Oceans Commission and the National Fisheries Institute. Students were expected to take a stand on their opinion about the Pew Oceans report and the rebuttal made by the National Fisheries Institute. In this case, there was no right or wrong answer, simply a stand to be taken and backed up with evidence, which took the form of data, expertise, or bias.

The Pew Oceans report provided evidence to back up its claim that America’s oceans are in trouble and that changes need to be made to sustain them in the long run. Information was given in the report that could be used as data in an argument, such as “More than 60 percent of our coastal rivers and bays are moderately to severely degraded by nutrient runoff” (The Pew Oceans Commission, 2003, p. vi). Expertise opinion was given in the rebuttal by the National Fisheries Institute, which could be used as evidence in an argument. An example would be discussing the expertise of the National Oceanographic and Atmospheric Administration or the United Nations Food & Agriculture Organization. Bias in an argument was described by stating that an organization was biased, which would undercut the claims of the organization. For example, bringing attention to the members of the Pew Commission and discussing their motives behind being on the commission, undercuts the Commission’s authority on the world’s oceans.
It is important to mention that the task for each assignment was to create a plausible argument; however, each assignment required a different way of presenting evidence. The Plate Tectonics and Monsoons of India assignments required the students to marshal evidence that was of a concrete nature, which included numbers and figures. The last two assignments, Oceans & Climate and Fishery Health, the students were expected to marshal evidence that was not so concrete, such as expertise opinion and data based on opinion or bias. The differences in the tasks affected the way in which the assignments were analyzed; however, it is important to note that consistency in analysis was upheld throughout the research endeavor to ensure comparisons between and across students and assignments could be made.

Additionally, during the research endeavor, the students’ work was compared to the aforementioned criterion. In the analysis, the information the students presented was not assessed based upon sentences, but rather ideas represented by one or more phrases. Students’ work was examined in the context of the assignment and was not broken down by sentence. For the analysis to be correct, it was important to examine each thought since the argument pieces needed to cohere to make the argument plausible. The argument pieces analyzed, although not perfect, act as a lens by which it was possible to assess the students’ ability to create a plausible argument and thus his or her understanding of the content.

The established lines of evidence for each assignment were analyzed against several epistemic criteria: 1) Pose solvable research question; 2) Within lines of reasoning; 3) Across lines of reasoning; 4) Value of argument. Each epistemic criterion also included salient variables that help to create a sound argument.
1) **Pose Solvable Research Question**

To pose a solvable research question in each argumentation assignment, the student needed to state the problem or research question to be evaluated and identify a conclusion answering the question posed. For both of these criteria the student could earn either between 1 and 0. So, if the student stated the problem or research question, he or she earned a 1 and if the student stated the conclusion, he or she earned a 1. The next step was to normalize this section, thus the two criteria were averaged. The purpose of normalizing this section was to make all parts equal so they were weighted the same, which made it possible to compare between and across students and assignments. So, for example in the plate tectonics assignment for each location, the student first stated that he or she would be attempting to deduce the type of plate boundary they observed based upon the data collected. Then, at the end of the argument, the student should have concluded the location’s boundary type.

For the next two portions of the analysis, the argument was broken into two parts; argumentation that takes place **within** the lines of reasoning and argumentation that takes place **across** the lines of reasoning. The argument could take place within lines of reasoning where each line of reasoning within the argument was augmented with data, inscriptions, and expertise, which was built up with explanation. When discussing the argument that occurred across the lines of reasoning, the lines of reasoning worked together and converged to form a coherent argument. It is important to note that the students could have and should have argued within **and** across lines of reasoning, when necessary, to create a plausible argument.
Within Lines of Reasoning

(a) Use Data Inscriptions or Data from Secondary Sources

Analysis of data inscriptions encompasses the students’ use of data-derived descriptive materials. The data were drawn from books, the Internet, and the ‘Our Dynamic Planet’ software. Examples of data inscriptions include topographic profiles; area maps of the location described; precipitation graphs; carbon dioxide data; and expert opinions regarding fishery health. Evaluation of the data inscriptions involved answering questions such as: Do the students name the inscriptions? Do they describe the data they have presented? Do they use the data in their explanation? and Does their explanation support the conclusions they have previously described? All of these questions were answered independently of each other to build an argument.

In regards to the Tonga Trench in the plate tectonics assignment, the students should have presented several inscriptions including three elevation profiles of the trench and a map with location, length, and depth of the trench; a profile of the earthquakes with depth and strength and a map of the locations; and a map of the linear arc of volcanoes. The Tonga Trench portion of the plate tectonics assignment required the students to marshal evidence for each line of reasoning, i.e., there is a linear trench, there are strong earthquakes that dip below the surface, and there is a linear arc of volcanoes. The students received between 1 and 0 for each line of reasoning. Again, they needed to answer the questions aforementioned to receive a 1. This form of analysis was also applied to the Monsoons, Oceans & Climate, and Fishery Health assignments.
(b) *Articulate Multiple Lines of Reasoning*

After the students answered the four previous questions, the number of lines of reasoning were normalized to compare across the assignments and the students. This gave an idea into how well the students marshaled lines of reasoning for each assignment. For each portion of the assignment the students needed to marshal all of the lines of reasoning that had been previously mentioned. When students marshaled all of the lines of reasoning for the argument, they were showing that they understood at least the components necessary for the argument.

3) *Across Lines of Reasoning*

(a) *Use Models to Support Conclusions*

The first two assignments, Plate Tectonics and Monsoons, called for the students to draw a model of the process or mechanism they were explaining. For example, in regards to the summer monsoons in India, they needed to draw a model with high pressure over the ocean and low pressure over land, wind blowing inland, and precipitation on land. Identification of these key features were counted and normalized. In addition, the model needed to match what the students described in their paper. All of the lines of reasoning needed to work together to create a coherent argument in regards to the description of the models. A model should relate to the audience the process or mechanism that the students described in their writing. It should be noted that this portion of the analysis could only be utilized for the Plate Tectonics and Monsoons assignments. The Oceans & Climate and Fishery Health assignments did not require the students to draw a model, as it was not the nature of these two tasks.
(b) *Coherence Across Lines of Reasoning*

Analysis also focused on the coherence across lines of reasoning. A plausible argument in which a mechanism or process is being discussed shows the lines of reasoning converging at the conclusion. The Plate Tectonics and Monsoons assignments both lead the students to converge their lines of reasoning to their conclusion, or in other words build the argument upon previously discussed lines of reasoning to reach the conclusion. For example, when aligning the evidence to discuss a divergent plate boundary, the written discourse needed to follow a progression of thought. First, one oceanic plate is subducted or pulled under the other creating earthquakes as it is moves. Then, melting of the subducted oceanic plate occurs, after which the melted material rises to the surface to create volcanoes. One can conclude from these lines of reasoning that the object under consideration is a divergent plate boundary. Each line of evidence affects the next, therefore cohering to create a solid argument.

(c) *Sufficiency of Lines of Reasoning*

In this part of the analysis, the sufficiency of the argument was examined. For an argument to be sufficient, it must follow a progression of thought from the student presenting the data to coming to a supported conclusion. Sufficiency was measured by comparing the presentation of data with the support of the conclusion. The lines supported were divided by the lines of reasoning named to produce the sufficiency of the argument. If the student marshaled all lines of reasoning and they all worked to support
his or her argument, then the argument was a sufficient argument. This number was again normalized to allow for later comparison.

4) Quality of Argument

The quality of the argument was based upon all of the previous analyses, as all of the analysis was important in creating a feasible argument. The quality of the argument was calculated by adding together the following: 1) Pose Solvable Research Question, 2) Articulate Multiple Lines of Reasoning, 3) Use Models to Support Conclusions, 4) Coherence Across Lines of Reasoning, and 5) Sufficiency of Lines of Reasoning. The criteria of using models to support conclusions, again, were not possible for the Oceans & Climate or the Health of Fisheries assignments. Once all of the possible numbers were added, they were divided by the number possible. Normalization of this number then allowed for comparison across the four assignments; however, this number did not totally reveal the value of the argument. All components needed to be taken into account to decide how convincing an argument was. The quality of the argument took into account many of the components previously discussed to measure the overall value of the argument.

PROCEDURE

The procedure by which the research was conducted is as follows:

1. The peer review rubric for the Plate Tectonics assignment, the actual assignment, and the ‘Our Dynamic Planet’ software was scrutinized to pinpoint the exact expectations of the professor, which would serve as a guide for analysis.
2. A small (15 out of the 78) randomly selected group of students’ papers were read several times for completeness in regards to the expectations of the professor, as laid out in the peer review rubric for the assignment. As I read the papers, I looked for clues as to how the students crafted their arguments, the types of evidence, and how they used the evidence they brought to bear. All identifying information for the fifteen randomly chosen students’ papers were removed and a number from one to fifteen was assigned randomly to act as the new identifier.

3. The lines of evidence described in the peer review rubric for the Plate Tectonics assignment was written out and assessed for within the 15 randomly chosen students’ assignments. This process was iterative. As more information was drawn out of the students’ assignments due to seeing trends among the students’ papers and looking closely at the students’ papers that read better and made more sense, the rubric for assessment of the assignment was altered to reflect these improvements. Along with another researcher, a consensus about the final analysis rubric was decided upon.

4. The rubric created for the Plate Tectonics assignment was used to assess the Monsoons, Oceans & Climate, and Fishery Health assignments. Again, as the research was an iterative process, portions of the analysis rubric were added, removed, or changed to reflect the four assignments. Great care was taken in creating a rubric that could be used for all four of the assignments. The intention was to look for trends across time in the course for all fifteen students, individual change between assignments, and the spread of scores in the same assignment.
As with any research, there were limitations, the current research was no exception. One concern was the small sample size of 15 out of 78 students’ assignments sampled. However, analyses have proven to be effective in showing a range of students’ abilities in creating arguments. Additionally, the components identified as being necessary for an argument to be plausible also showed a variety in scores, which moved the analysis toward being useful for many scientific disciplines. Applicability was of utmost concern when thinking about the main purpose of this research.

Analysis of students’ work required making judicious interpretations based on the science content presented for the argument, the application of the assessment rubric, and knowledge of the global features of the argument presented. Thus, variability may have been introduced, so reproducibility is of concern. Working closely with an independent researcher, several iterations took place until results were consistent within a subset of randomly sampled works. Therefore, a strong rubric was created that will be able to create reproducible results.

Now that the background, methods, and procedure have been laid out, it is time to turn our attention to the findings of the analysis, which will be discussed in detail in the next chapter, Chapter IV.
CHAPTER IV

FINDINGS

In this chapter, the findings of the students’ assignment analysis will be laid out. Each finding will be described and accompanied by student examples and overall analysis findings. Out of the analysis of the four assignments across fifteen students came the following results:

- Within the lines of reasoning, it is possible to follow the evidence through the progression from Name, Describe, Explain, and Support Conclusion. The majority of students had high scores for Name and Describe, slightly lowered scores for Explain, and dramatically lowered scores for Support Conclusion.

- On average, students scored the highest quality on the Oceans & Climate assignment and the lowest quality on the Plate Tectonics assignment. With such great variability in the scores, the only conclusion that can be made is that despite efforts, writing in the scientific genre is clearly not well understood by the students.

Two students (3 and 14) will be used as illustrative examples to demonstrate the differences and similarities between students in the same assignments and across assignments. All student scores can be found in Appendix G. Student 3 was chosen because out of all of the students, his average quality scores were some of the lowest for
all of the assignments. Student 3’s analysis can be found in Table 2. Student 14 had considerably higher average quality scores for all of the assignments, but had lower scores than the highest scoring student, so was chosen as an ‘average’ student. Table 3 shows student 14’s analysis.

Student 3 and 14 will first be compared and contrasted for the Plate Tectonics assignment. Student 3 received an overall quality score of 0.22 out of 1.00 for the Tonga Trench portion and 0.21 out of 1.00 for the East Pacific Rise portion of the assignment. This was the lowest scoring of all for this student’s assignments. In contrast, student 14 received 0.93 out of 1.00 on the Tonga Trench portion and 0.78 out of 1.00 on the East Pacific Rise portion of the assignment. This was the highest scoring for all of this student’s assignments. What are the differences and similarities between these two students and their use of inscriptions to create a plausible and scientifically sound argument? This will be answered in the next section, but first let us look at how these students posed a solvable research question.
Table 2. Student 3’s highest average quality score was on the Oceans & Climate assignment and his lowest was on the Plate Tectonics assignment.
### Table 3.

Student 14’s highest average quality score was on the Plate Tectonics assignment and his lowest was on the Fishery Health assignment.
1) Pose Solvable Research Question

First, let us look at the similarities by referring to Table 2 and Table 3. Both students posed a solvable research question, which included stating the conclusion to each domain, in this case the Tonga Trench and the East Pacific Rise. For the Tonga Trench and East Pacific Rise research question, student 3 stated, "I will discuss the characteristics and differences of convergent and divergent plate boundaries. Specific regions were observed in the Tonga Region and the East Pacific Rise. Using the data collected from using the Earth Ed I was able to distinguish these two boundaries" (PT, 3). Student 3 clearly stated what was going to be discussed and how the argument would be constructed. Additionally, student 3 stated a conclusion for both regions in the interpretations section of the assignment, "My study shows the EPR [East Pacific Rise] and the Tonga plate boundaries. I explain certain aspects of the regions that make them different. Each region is either a subduction zone like the Tonga Region or a Spreading [sic] center like the East Pacific Rise" (PT, 3). Although student 3 was lower scoring, he was still able to identify the research question and the conclusion.

2) Within the Lines of Reasoning

The most important finding from this analysis is how students marshaled evidence to support their conclusion. The median scores for all students (n=15) for each line of reasoning were averaged and plotted, which is shown in Figure 7. It illustrates the movement from naming the inscriptions used in the argument, describing the inscriptions, using the inscriptions to explain the process or mechanism, to supporting the conclusion.
According to Figure 7, students were able to marshal a large portion of the lines of reasoning for the Plate Tectonics, Monsoons, and Fishery Health assignments, with values somewhat lowered for the Oceans & Climate assignment. However, students continued to use the inscriptions in their description and explanation at the same level as naming the inscriptions for the Oceans & Climate and the Fishery Health assignment. This means that the lines of reasoning that were originally discussed were followed through to using them in the students’ explanations of the process or mechanism. More notable is the drastic drop from Use in Explanation to Supports Conclusion for all of the assignments. For the Monsoons and Oceans & Climate assignments, students partially supported the evidence brought to bear; however, the Plate Tectonics and Fishery Health
assignments, students, for the most part, were not able to explain the evidence enough to support their conclusion.

When moving through the process of building claims student 14 scored much higher than student 3 (see Table 4), mostly due to marshalling more evidence that supported the conclusion. Let us look at student 3 and 14. Student 14 marshaled all lines of evidence in the argument for the Tonga Trench, i.e., trench, earthquakes, and volcanoes. Student 3 marshaled only one-third of the lines of evidence in the argument, i.e., earthquakes; however, he was able to name the earthquake inscription, but did not describe the earthquakes, so did not use them in his explanation. Student 3 named the earthquakes in the Tonga Trench region as such, "Like the EPR region the Tonga Region is also well elevated, but its trench is followed by a large amount of earthquakes and volcanoes, shown on {link: Figure_2.jpg}Figure 2 [sic]" (PT, 3). Although this portion of the assignment sounds plausible, the only inscription he refers to is an aerial map of the area, which should have been augmented with an earthquake depth profile (see Figure 8) to make this portion of the argument complete. In addition, there is no discussion of the depth, location, or strength of the earthquakes, so does not support his conclusion that the Tonga Trench is a subduction zone.
Table 4. A comparison of the use of inscriptions marshaled throughout the argument for students 3 and 14.

<table>
<thead>
<tr>
<th>Plate Tectonics</th>
<th>Use Data Inscriptions or Data from Secondary Sources</th>
<th>Articulate Multiple Lines of Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Name (#/n)</td>
<td>Describe (#/n)</td>
</tr>
<tr>
<td>Student 3</td>
<td>TT:</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>EPR:</td>
<td>0.25</td>
</tr>
<tr>
<td>Student 14</td>
<td>TT:</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>EPR:</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Figure 8. This aerial map of the sea floor shows the location of volcanoes (red triangles) and earthquakes (red dots) at the Tonga Trench. In addition, it shows where the student took a profile of the area (yellow line). The following is student 3’s caption of the above diagram: "This displays how in Region A along the area studied how volcanoes run along its vertical trail (fig: Figure_2.jpg)” (PT, 3).

In contrast, student 14 was able to completely support the Tonga Trench argument and his conclusion that, “At the Tonga / Kermadec Trench, at the border of the Pacific and Indo - Australian Plates, the data seems to suggest a {link: SUB ZONE.jpg}subduction [sic] zone” (PT, 14). For example, let us follow the argument that
there are earthquakes occurring in the area. He begins by naming the inscriptions that will be described to support his argument, “When one looks at an earthquake profile of the exact same spot, one can see that about half of the earthquakes in the Tonga region occur very deep under the sea floor, at almost 675 km below the sea floor. The location of the quakes gradually rises up, to the sea floor. Also, the magnitudes of these quakes, while wide in variety, are rather large in magnitudes, with many 7 or 8 magnitude quakes” (PT, 14). See Figure 9 for student 14’s earthquake plot for the Tonga Trench region.

![Figure 9. This is the earthquake profile student 14 referred to to reinforce his claim that earthquakes occur at the Tonga Trench. The following is student 14’s caption for the figure: "Profile of the depth of earthquakes in the Tonga Region" (PT, 14).](Tonga_Q_Profile.jpg)

Next, he describes the earthquakes in detail, "The next series of earthquake plots shown in Figure 8 demonstrates a downward trend of earthquake activity, descending 800 km" (PT, 14). To use the inscriptions in his argument he continues, "One can infer from this data that the plates are sliding past each other with trentouse amounts of force" (PT, 14) and states that “...the leading edge of a subducting plate produces seismic activity as it submerges and melts" (PT, 14). Finally, I find that he supported his conclusion that the Tonga Trench is a subduction zone based on this one line of evidence. Each line of evidence was supported just as well for the rest of the Tonga Trench portion of the Plate Tectonics assignment, which shows that he was able to marshal evidence and
create a plausible and scientifically sound argument. See Figure 10 for a layout of student 14’s whole argument for the Tonga region. This figure was previously used by Diefendorf and Kelly (2006) and has been adapted from showing epistemic levels of the argument to supporting the information presented in the ‘within lines of reasoning’ section of the analysis. Next, let us look at student 14 and 3’s use of evidence across the lines of reasoning.
Figure 10. Student 14 marshals all lines of reasoning, which supports his claim that the Tonga Trench is a subduction zone. This figure was adapted from (Diefendorf & Kelly, 2006).
### Across Lines of Reasoning

Table 5 shows student 3 and 14’s use of evidence across lines of reasoning. For this section of the analysis students needed to draw models that would describe the phenomenon, in this case the subduction of the plates of the Tonga Trench, and discuss the process in their arguments. In addition, the lines of reasoning needed to tie across to the other lines of reasoning to create a sufficient argument. As is shown in Figure 11, student 14 was able to create a model that showed the features necessary and matched them to the written portion of the argument. In addition, all of the lines of reasoning that were marshaled were tied to the others, so coherence and sufficiency were high. The ties between the evidence can also be seen in Figure 10 under the explain section.

<table>
<thead>
<tr>
<th>Plate Tectonics</th>
<th>across lines of reasoning</th>
<th>Coherence Across Lines of Reasoning</th>
<th>Sufficiency of Lines of Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Use Models to Support Conclusions</td>
<td>Coherence Across Lines of Reasoning</td>
<td>Sufficiency of Lines of Reasoning</td>
</tr>
<tr>
<td></td>
<td>Correct Features in Sketch (#/n)</td>
<td>Match Text to Model (#/n)</td>
<td>Ties Across Lines of Reasoning (#/n)</td>
</tr>
<tr>
<td><strong>Student 3</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TT:</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>EPR:</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Student 14</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TT:</td>
<td>0.67</td>
<td>0.67</td>
<td>1.00</td>
</tr>
<tr>
<td>EPR:</td>
<td>0.25</td>
<td>0.50</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Table 5. Student 3 and 14 reveal their understandings across lines of reasoning.

As student 3 failed to produce a model, which was specified in the assignment, we will focus on student 14’s Tonga Trench model, which is shown in Table 5. Student 14
shows the two plates pulling together with one being subducted under the other, earthquake locations, and the rise of magma to form volcanoes. Although the trench is discussed in the argument, it is not being subducted in the correct direction in relation to the description in the argument. Student 14 stated for earthquakes in the Tonga Trench region that,

Where the continental plate rests directly on top of the brittle oceanic plate, they rub against each other and when the rock reaches its elastic point, it shatters, creating shock waves that radiate outward in all directions. These are the earthquakes that are register [sic] all throughout, as shown in the previous figure. This also explains the depth of the quakes in this region. Because the plate has subducted under the continental plate, the breaks happen at great depths (PT, 14).

Additionally, student 14 stated that, "As the plate continues to sink under the continental plate, it melts under the extreme heat and pressure of the interior of the Earth. When this ocean crust melts, it is now hot and has expanded, (magma) loosing [sic] some of its density and rises to the Earth's surface, through the continental crust. As it reaches the surface, it erupts and creates volcanoes on the surface" (PT, 14). This student was able to marshal evidence to back up the claims about the process of a subduction zone well enough to receive 0.67 out of 1.00 for creating a model that showed the correct features of the subduction zone and matching the argument to what was drawn in the model for the Tonga Trench portion of the assignment. Student 14 also tied the lines of reasoning together to show the causal relationship each of the lines of reasoning has with the next. This is evidenced in the following passage, which can also be seen in Figure 10 and Figure 11.
As can be seen in the attached sketch, these zones are where dense, oceanic crust converges with lighter continental crust. When they meet, the oceanic crust is heavy enough to subduct, or sink under the lighter continental crust. Because of the geometry involved, as can be seen in the drawing, a trench forms at this collision, which explains the deep trench at Tonga. As the plate continues to sink under the continental plate, it melts under the extreme heat and pressure of the interior of the Earth. When this ocean crust melts, it is now hot and has expanded, (magma) loosing [sic] some of its density and rises to the Earth's surface, through the continental crust. As it reaches the surface, it erupts and creates volcanoes on the surface. Where the continental plate rests directly on top of the brittle oceanic plate, they rub against each other and when the rock reaches its elastic point, it shatters, creating shock waves that radiate outward in all directions. These are the earthquakes that are register [sic] all throughout, as shown in the previous figure. This also explains the depth of the quakes in this region. Because the plate has subducted under the continental plate, the breaks happen at great depths (PT, 14).

Figure 11. Student 14's model of a subduction zone, which was labeled as {fig: SUB_ZONE.jpg}.

4) Quality of Argument

With fifteen students’ scores across assignments plotted (see Figure 12), there was much noise that made it difficult to see a pattern, so it was decided to take the median score for each assignment to see the general trends. Later in the discussion, individual
student arguments will be examined to illustrate some of the differences and similarities between the students and across the assignments.

![Quality of Students' Arguments Across the Four Assignments](image)

Figure 12. All of the students’ average quality scores for each of the assignments, in addition to the median quality score.

After calculating the median quality score for each assignment (see Table 6), they were plotted on Figure 13. Looking across the four assignments, the students’ median quality scores are highest for Oceans & Climate ($n = 0.48$), followed by Fishery Health ($n = 0.42$), Monsoons of India ($n = 0.39$), and finally Plate Tectonics ($n = 0.33$).
Table 6. The median quality score for each student across the four assignments.

<table>
<thead>
<tr>
<th>Assignment</th>
<th>Median Quality Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plate Tectonics</td>
<td>0.33</td>
</tr>
<tr>
<td>Monsoons of India</td>
<td>0.39</td>
</tr>
<tr>
<td>Oceans &amp; Climate</td>
<td>0.48</td>
</tr>
<tr>
<td>Fishery Health</td>
<td>0.42</td>
</tr>
</tbody>
</table>

Figure 13. For all of the students, the median quality for each of the four assignments was calculated. The above graph shows that students scored highest on the Oceans & Climate assignment and lowest on the Plate Tectonics assignment.

According to the median quality scores for each assignment (shown in Figure 13), the students’ scores increased slightly from the first assignment to the last; however, since there was a large amount of variability in the scores for each assignment, the increase in scores was negligible. Although Figure 13 shows an increasing trend for the quality of the arguments, the large range in scores seen in Figure 12 for each assignment makes the median scores an ambiguous measure for change over time. There is too much
noise in the data to be able to claim that quality increased; nonetheless, what can be discerned from the data is that despite efforts, writing in the scientific genre is clearly not entirely understood by the students.

Now, let us look at the quality scores for student 14 and 3. As can be seen in Table 7, student 14’s quality scores for both the Tonga Trench and East Pacific Rise are substantially higher than student 3’s scores. For the Plate Tectonics assignment, quality was calculated the same for each student. Student 3’s score was greatly reduced because of the lack of a model to explain the phenomenon of plate movement. In all actuality, many of the students did not draw models that were included in their assignments, or if models were included the students did not fully explain the process behind the inscriptions that were marshaled.

Table 7. The overall quality of the arguments for both the Tonga Trench and the East Pacific Rise show that student 14 has higher scores than student 3.
The highest scores occur with the Oceans & Climate assignment. This may partially be due to the lesser sensitivity of the analysis, both with the limited number of lines of reasoning and their accompanying scores and the lesser number of items to be included in the quality score. The scores were not as sensitive to change because of the nature of the assignment and differences in analysis. Either the students mentioned temperature or they didn’t and they either mentioned carbon dioxide or they didn’t. Although, the analysis rubric follows the expectations of the professor for the types of inscriptions the students should model and the form of the argument (see Appendix A and Appendix C), the analysis was still flawed in that the four assignments were analyzed slightly different depending on the nature of the task. For the Plate Tectonics and Monsoons of India assignments, students were expected to create a model to illustrate the phenomenon or mechanism being described in the argument. However, the Oceans & Climate and Fishery Health assignments did not necessitate the creation of a model, so there were fewer components to analyze for. Thus, when it came time to calculate the quality for these assignments the values were divided by a smaller number, so may be skewed slightly higher than the two previous. In addition, analysis was completed by a human, which means that error and bias could still be included. Consistency was a priority though, so myself and another researcher worked through the analysis together, in addition to individually, to came to a consensus on all student scores.
CHAPTER V

DISCUSSION

The purpose of this study was to examine ways that students create arguments derived from inscriptions, expertise, and data, in addition to investigating the components necessary to create a plausible and scientifically accurate argument. From this analysis it was found that

- students were able to pose a solvable research question and marshal evidence within and across lines of reasoning; however, students were limited in their abilities to explain and thus support their conclusions, and

- quality scores reveal that students’ arguments show great variability, which evinces that writing in the scientific genre is clearly not well understood by the students

- theoretical aspects of the assignment may have been more difficult than the actual building of the argument

As the students moved through the assignments, their ability to marshal evidence became stronger in comparison to the first assignment. In particular, several students were able to name the inscription, describe it, use it in the explanation, and have it support the conclusion stated. This could be partly due to becoming familiar with the expectations of the professor and the type of task, or perhaps they felt more comfortable with the assignments that were slightly less constraining. In either case, it could mean
that creating arguments using inscriptions, marshaling evidence, creating models, and writing about socio-scientific issues has impacted the students for the better.

Even though slight improvement was seen across students and assignments, the majority of students still had difficulty backing up all of the claims that they brought to bear. Although students could name the inscription, describe it, and use it in their explanation, when it came so supporting the conclusion, the students’ arguments fell short. The theoretical aspects of the assignments may have been more difficult than the actual construction of the argument. In other words, understanding of the process or mechanism behind each domain and the lines of reasoning that were necessary to create the argument may have posed the most serious remaining challenge for the students. Previous studies (Kali, 2003; Kali, Orion, & Eylon, 2003) have found that “the more an understanding is based on connections between parts of a system, the more it expresses a higher dynamic view of the system” (Kali, Orion, & Eylon, 2003, p. 557). Thus, perhaps the students did not obtain a higher dynamic view of the system because of the missing conceptual understanding and connections between using the information in the explanation and supporting the conclusion.

Although the students showed slight improvement across assignments as they moved further from data-driven concepts to socio-political ones, the variability in the scores made this improvement difficult to ascertain. Writing in the scientific genre was clearly not fully understood by the students despite efforts to engage students multiple times in reading and writing of scientific materials and guidance from the professor, TAs, and fellow classmates.
Teachers have difficulty implementing effective argumentation discourse in the classroom, so students are not given the opportunity to practice scientific argumentation (Driver, Newton, & Osborne, 2000). This research has successfully identified the components of a plausible argument, which will make it possible for science teachers to be better informed as to how to assess their students’ written argumentation. Close attention should be paid to students posing a solvable research question and to looking at the use of evidence across and within lines of reasoning. If educators are better able to differentiate the plausible and scientifically accurate arguments from the not so plausible and not so scientifically accurate, then this will help in guiding the teaching of argumentation. These science teachers may then be able to produce informed citizens, which will improve scientific literacy (Bezzi, 1999). It is important for young people to be able to practice constructing and analyzing arguments related to science and society (Driver, Newton, & Osborne, 2000).

An important educational implication is the development of scaffolds to provide students with ways of understanding the process of scientific reasoning. In addition to addressing students’ misconceptions, the use of technology may be a valuable tool. Previous research has established that the use of computers reduces cognitive load, thus allowing students to focus on the key components of the argument (Blumenfeld, Marx, Patrick, Krajcik, & Soloway, 1997). The use of technology, such as ‘Our Dynamic Planet’ allows students the opportunity to think more about the processes involved in the
assignments and less about the collection and processing of data. Future development of a tool that teachers could use in the classroom may be the most beneficial way to incorporate this analysis rubric into the daily lives of students. To this date, research and design continues to play a role with the EarthEd Online software and curriculum units are being created to accompany this powerful piece of software. Perhaps in the future, the argumentation rubric will also be incorporated to help students gain an understanding of the layout of an argument and the types of things to look for when encountering one.

With the difficulty of writing in the scientific genre that was revealed in this study, it is important to scaffold student learning to allow for further development of argumentation. One way to scaffold writing in science is to place an emphasis on theoretical knowledge in the classroom, since understanding an argument depends upon the student’s conceptual understanding. Discussing argumentation in classrooms must emphasize the importance of the connections between the knowledge pieces, which will allow students to gain a clearer understanding of the interactions between what they know and what they are learning. An understanding of cycles in the earth sciences should be focused upon in the classroom to stress the importance of the interconnections. With a deeper understanding of the pieces and how they interact, this will further articulate the theoretical knowledge upon which to build the understanding of argumentation in the scientific genre.

This study will help to guide future research toward identification of ways to improve and incorporate written argumentation into schools by bringing the struggle students face with writing and argumentation to the forefront. If, as the AAAS has suggested, argumentation is seen by the administration as being a key component to
science learning, then the first step will be to give policy-makers the tools to understand argumentation themselves. It is possible that as argumentation comes to the forefront this and other useful argumentation rubrics will help guide educational standards, especially if we want to raise the next generation of scientifically literate citizens.
Appendix A: Anatomy of a Science Paper

Resource 3
Anatomy of a Science Paper

Writing the paper
The following sections explain, in great detail, how to put together a science paper. Please read them carefully. This format is very common in science writing and will help you present your thoughts in an organized and clear way.

This description is specific to the plate tectonics paper. The other writing assignments will follow the same format and principles, but will vary in some details, so be sure to carefully read each assignment.

General writing tips:
1) The paper should be organized carefully. Follow the structure discussed below.
2) Each section of your paper will be composed of paragraphs. Each paragraph should begin with a topic sentence which states the point you will make in that paragraph. Every sentence after that should support the topic sentence. Paragraphs are typically four to eight sentences long and each sentence should address only one point.
3) Make your sentences simple but vary their lengths to make the paper interesting.
4) Avoid the passive tense. It is boring. An example of the passive tense is: "It was shown that......." An example of the active tense is: "I have shown that ........."
5) Avoid contractions. These are for more informal writing, like that in this workbook. Say "can not" instead of "can't."
6) Be careful with "Replace All" on your word processor. You may replace words that you don’t intend to replace.

Visual Presentation:
The online EarthEd writing software makes it easy for you to write your paper by providing the basic topic headings and guiding you regarding what each section should contain. Your printouts will have a consistent format. Printing is meant mostly for proofreading and as backup in case something goes wrong. Your paper should be thoroughly proofread. If you want, you can do your writing in a word processor, do a spell check, then cut and paste into the EarthEd writing software. In fact, this might be a good procedure to follow, since it will give you added protection from loss.

All figures are linked from your personal storage area, or from the common graphics library accessible to all students. Getting figures into your storage area is extremely easy with the EarthEd software. You can upload figures from any source, or draw your own using the graphics drawing tool. Do not scan in figures from the book. Your work must reflect your own thinking and the book may provide beautiful images but a crude sketch that shows that you understand the material is preferable.
Figure 1. This diagram shows the headings that must be used for this science paper. Please pay careful attention to the boxes with arrows pointing at each elliptical heading box. These boxes are reminders of the content that belongs with each heading.

**Headings**

Technical writing follows a specific format. This format varies, depending on the subject and requirements of the magazine or journal publishing the article. However, there are common features to all formats. The format described here is the basis for your writing assignments.

Each writing assignment may have different headings, but the standard headings are listed below:

- Abstract
- Introduction
- Methods
- Observations
- Interpretation
- Discussion
- Conclusions
- Figures and Captions
- References
Abstract:
The abstract is a short summary of your paper, including the conclusions. It should be self-contained, meaning that there are no references to the paper or to figures in the paper. The reader who wants to see whether the paper is of interest will read the abstract first. Different journals and publications vary in their abstract requirements. For this paper, make it less than 1/2 page. The abstract should be the last section you write.

Introduction Heading
A very important part of a science paper is the introduction. It is in this section that the reader decides whether or not you have something pertinent to say. The introduction should orient the reader to the following: Why are you writing this essay? What are you going to discuss? Why should the reader be interested in this topic? What is the scope of the study and what ideas do you want to explain? Although there are many approaches to writing an introduction, a good rule is to make sure the reader could read it alone and come away with a basic understanding of your work. This is particularly important when writing a proposal for research funds. The reviewer, who is usually very busy, may only read the introduction. Even worse, a weak introduction may cause a negative first impression that is difficult to change later in your text.

Here are some examples of weak and strong sentences that might appear in an introduction:

**Strong statements:**
I will discuss the general shape of the sea floor and discuss how the motion of the plates affects that shape. I will show how the topography is related to the distribution of volcanoes and earthquakes and how these data can be used to determine the kind of boundary between the various plates.

**Weak statements:**
Throughout my essay I will discuss many various topics that are all interrelated to plate tectonics.

**Introduction checklist**
The Introduction should cover:

___ What is the topic of investigation in your paper?
___ How does your work fit into and advance the existing knowledge? Some background may be needed in order to do this. This is also where you try to convince the reader that your work is worthwhile and interesting. Don’t just say it’s interesting and important. Say what is interesting and why.

Methods Heading
This section is where you discuss how and where you got the data. Maybe you made your own measurements, for example, if you went to the sea and measured depth profiles, or possibly you measured earthquakes with seismic equipment. For this course, you will be accessing data from existing databases. You should describe those databases and explain any of the inherent limitations of the data.
Here are some examples of statements that might appear in a Methods section:

**Strong statements:**
This study is based on sea surface temperature data acquired by the Nimbus satellite. The data are available from NASA at http://www.nasa.gov/data/nimbus/SST/ and are accurate to about 0.5 C. The temperature data are available on a 5km grid spacing at 1 week intervals.

**Weak statements:**
I researched Sweden and the Eurasian Plate mainly through the use of the internet and maps. The only setback about the information was that I was not sure how accurate it was.

**Methods checklist**
The Methods section should contain:
___ A description of how the data were collected
___ A discussion of the source and accuracy of the basic data that you will use
___ A discussion of what you did with the data, once it was found
___ References to data sources (see Lab #3 for a description of the CD-ROM data)

**Observations Heading**
Your observations or "data" are described in this section. It is not appropriate to talk about conclusions or reasoning here. Just stick to what you observed.

**Qualitative Observations:**
Qualitative observations are not really specific, often relating to some arbitrary and unspecified reference. For example: "the waves are big," or "that hill was quite steep." To an experienced big wave rider, the waves may be quite small, but to a non-surfer, they may seem quite large. Steepness of a hill on a hike is also very subjective. A person who hikes a lot may find a hill much less steep than a couch potato. Qualitative observations are not very useful in technical writing, unless you are specifically discussing your reaction to an observation (which is rarely done).

**Quantitative Observations:**
Quantitative means you are actually observing Quantities. For example: "the waves are between 10 and 12 feet high," or "the hill rises at a 45 degree angle," or "the hill rises at a 50% grade."

**Clarity of Observations:**
The discussion on "Using Figures" should be read carefully. You should be sure to first tell the reader where you made your observations. The location could be marked on a map. When maps are of a very local area, an inset showing a larger area that is more familiar to the intended reader should be provided.

**You observations should include statements that:**
___ Describe the data you are presenting (including figures). Note that figure captions should point out the most important features in a figure. Use the figures you need but be economical with figures. See the discussion on figures.
Examples of observations:

Strong observations:
Many volcanic mountain ranges (chains) such as the Andes, the Aleutians, and the Japanese Islands run parallel to deep, long oceanic trenches.

The Japan-Kuril trench is ____ km long and ranges in depth from ____ to more than 9000 m.

The East Pacific Rise begins at about 56°S 118°W and ends near the end of the Gulf of California. It has a typical elevation of ~2800 m, significantly higher than the surrounding seafloor which is typically 4000 m or more beneath the sea surface.

Weak observations:
Volcanoes are next to trenches.

The trench near Japan is deep and long.

Observations checklist:
The observations section should contain:
____ A description of each observation
____ Screen printouts illustrating your data
____ A reference to each figure in the paper. Don’t assume that the reader knows why you put in a particular figure. Explain, in the text, what the figure shows.
____ Quantitative observations, whenever possible
____ Figures must be in the order they are referred to in the text. Refer to Figure 1, then 2, etc.
____ Make sub-headings, if appropriate, for observations in different areas. For example, you might have, for area sub-headings: South America, Tonga-Fiji Region, Global Observations, etc.
____ Use more than one profile to characterize a linear feature. There may be interesting variations along the feature that will add substance to your paper.

A good way to get a poor grade on this paper is to ignore the data on the CD-ROM “Our Dynamic Planet,” and make a book report on plate tectonics. This kind of paper misses the point of the assignment.

Interpretations Heading
Here is where you relate your theory or model to the observations. You may need to adjust the theory to fit the data. Generally, this is an iterative process of creating a model or prediction of the outcome, taking data, and then modifying the model to fit the data.
Each interpretation must be backed up by one or more observation(s). Simple sketches or cartoons should be used at this point.

Conflicts in the data:
Unfortunately, the real world is not so nice as your textbook. Data rarely agree perfectly with your interpretation. Data also have errors, which could allow for multiple interpretations. At the very least, data errors will ALWAYS result in some uncertainty in the resulting interpretation. It is important to be forthright about where the data disagree with your model. Maybe you can refine or improve your model if you expand your thinking to consider modification or complexities in your model.

You will find that earthquakes do not always produce "classic" textbook patterns, and the volcanoes dataset may be missing volcanoes where observations are not available.

Honesty:
It is very important to refrain from over-interpreting your data, or exaggerating its accuracy. It is also important to include all of your data, rather than only select data which agree with your preconceived ideas. Sometimes we observe data that do not fit with our expected conclusions. It is very tempting to just forget about it or blame it on a malfunctioning measuring instrument. Discarding good observations is a way to miss a very important discovery that might just disagree with preconceived ideas.

Science has a very high "trust factor." This is because the ethics of science are based on honesty and openness of reporting. Experiments must be repeatable by others, and important experiments are always checked or repeated. Journal articles are critically reviewed by other scientists who are experts in the field. Of course, there may be great debates about the meaning of the observations. These debates are part of the scientific process. Scientific honesty means that the person making the observations is scrupulous in reporting "just the facts." The facts are not only the observations, but also the accuracy of the observations.

Your interpretations section should include statements that (refer to Lab 3 homework, part 2):

- Emphasize relationships between observations (e.g. volcanoes and trenches)
- Describe your plate tectonics model (a sketch, not a figure from a book or web page)
- Show correspondence between your model and the observations
- Discuss areas where the observations do not support the model. This could occur from genuine conflicts between observations and model, or simply because there are no data that can tell you about it.

Example, Observation and following Interpretation:
The Observation: The topography shows a trench-like feature (Figure 3) which plunges to a depth of 8,000 meters from a depth in the West of 3,000 meters. This trench extends along the full Western margin of South America, for about XXXX km. The Andes Mountain Range lies to
the West, along the western boundary of South America. The Interpretation: The many active volcanoes in this mountain range suggest that it was built by volcanic activity (Figure 4). Several cross-sections of earthquakes (Figure 5) show a descending pattern characteristic of subduction zones. Figure 6 shows a sketch of my model for this structure, which is a classic subduction zone. Note that these interpretations are backed by observations.

You should be particularly careful to look at more than one profile in your study area. For South America, you would want to do a number of profiles along its western boundary. This might allow you to make a more detailed picture of the shape of the descending slab. A single profile is not enough to define a 3-D feature. It may have crossed a trench, but it may have crossed a basin too. The profile game provides an opportunity for you to experiment with identifying features using profiles.

Interpretations checklist:
The Interpretations section should contain the following:
___ Interpretation of each of the observations that you present in the Observations section
___ How your interpretations relate to those of others (e.g. your textbook)
___ References (see “References” discussion) to any material discussed from other sources
___ A sketch (model) of your interpretation of the observations
___ A discussion of the sketch (model) and how your observations support it
___ A discussion of any data that disagree with your observations

Discussions Heading
Your findings are put into a broader context in this section. This is also where you can write about aspects of plate tectonics theory that are not supported by your investigation, and how these ideas add to an understanding of your investigation. For example, you could discuss mechanisms that cause plate motion, and other plate tectonics ideas that you have no data to support, but would like to discuss because they add breadth to your paper. You are cautioned that this should not be a general review of plate tectonic theory just to pad the paper, so be sure that your discussion is relevant to your investigation.

Conclusions Heading
Here you summarize your findings while carefully explaining your logic or reasoning. The busy reader who is not a specialist may skip or skim the Methods and Observations section of a technical paper, focusing on the Introduction, Figures, Figure Captions, and Conclusions. So, leave out everything but "the Beef." Don't worry so much about paragraph structure in the conclusions because you are supposed to summarize many results together.

Examples of phrases that might be used in Conclusions follow:

**Strong statement:**
The western boundary of the South American continent is a convergent plate boundary. This conclusion is supported by topography, volcanoes, and earthquake hypocenter locations.

**Weak statement:**
This study shows that the western boundary of South America has a trench, volcanoes, and lots of earthquakes.

I really learned a lot from writing this paper.

Conclusions checklist:
The conclusions section of your paper should contain:
___ A summary of each of your main conclusions
___ Any speculation about interpretations that you would like to make, but are not fully supported by the data.
___ A discussion of what further research on the topic might be needed, and the significance of its possible outcome

Using figures to illustrate your paper:
The old cliché that says a picture is worth a thousands words applies especially in science and technical writing. This kind of writing can get complicated and extremely difficult to understand. Any time you can illustrate a point with a picture or sketch, the clarity of the presentation is enhanced. Most people are not really very good at visualizing geometrical shapes and physical phenomena that have been described with words. A picture fills in questions in the reader's mind and lessens the tedium of pages of text.

The busy reader may only look at your figures and read the captions. This underscores the importance of good captions. Figure captions should briefly describe what the figure shows. For this example, Figure 2 would have a caption that said something like: "Locations of the three studies discussed in this paper." That would be enough.

When writing a technical paper related to the Earth, it is important to show the reader where the study took place. Where is the study location on the Earth? Figure 2 shows how this can be done on a Mercator map of the world like the one in your lab manual. Each study area is clearly marked so that you can refer to it in the text without requiring the reader to remember
previous location descriptions. All locations that you mention in the text must be indicated on the location map.

Since you will be using profiles in your paper, you will want to use figures to show samples of profiles. Maybe you want to illustrate the geometry of a trench, or show profiles across a mid-ocean ridge. Figure 3 shows a representation that would successfully show the location of a number of profiles.

Figure 4 shows an example of how you might print a series of detailed profile plots which give vital information like the elevations and distances. You should think of the Figure 3 profiles as merely locating the profile positions while Figure 4 shows the actual profile data.

**Mistakes using figures:**
Believe it or not, you can over-use figures. A big pile of figures showing everything you did will simply not produce a good paper. It is the job of the technical writer to condense the information so that the reader can easily assimilate the information and come away convinced of the correctness of the conclusions. That is the main purpose of using figures, but do not overdo it. If you have a lot of figures, you might try combining them. However, each figure should not be too complex. You have to exercise some judgment and restraint to keep the balance between having too many figures and having figures that are too complicated.

**Notating figures:** Another mistake is just using raw figures. A reader should be able to glance at the figure and caption and get a good idea of what the figure expresses. This means you should use the graphics editing tool to draw arrows to important features that you are examining in your investigation. Captions should also describe the purpose of the figure.

Figure 4. Detailed plots of profiles shown in Figure 3.
Here are the Figures referred to in the text. For readability, it is best to put the figures near to where they are referred to, rather than grouping them all at the end of your paper.

**Symbols to use on maps:**

The symbols to the left can be drawn on the map to indicate the presence of mountains. If the mountains are volcanoes, you could put a wiggly line indicating smoke coming out. Colored pencils can be used to advantage, to make your map more readable.

![Ridges and Trenches Symbols](image)

The above symbols are used to represent ridges, which are places where the lithosphere is spreading apart, and trenches, where the plates are pushing together. The cross section view shows the geometry of the down-going side of the trench. The saw teeth are pointed in the direction of motion of the plate that is being subducted.

**Legends:**
Although the use of particular symbols may follow a convention, it is always important to include a “legend.” This is a section on the map that shows the meaning of the symbols. An example of a legend is shown at the left. It is simply a listing of what each symbol, line type, or line color means. Other information that you should put on a map is an arrow showing the direction of north. For the world map, north is obvious, so you don’t need it. Smaller maps require a north arrow.

**Figures checklist:**
- Each figure shown has a numbered caption, which describes the figure.
- Each figure is mentioned and explained in the text.
- Figures are numbered according to the order in which they are mentioned in the text.
- Figures are clear and easy to read. If the data do not show up clearly on the figure, mark on it with colored pen.
- There are no figures that are photocopied/scanned from the text, or any other source.

**References:**
All data, text, and figures that you get from other sources must be referenced. When you speak of other peoples’ work in the body of your text, you use a reference. For example:
In recent years, considerable effort has been directed towards investigating the biological consequences of climate change (see Bolin et al. 1986; Chapin et. al. 1992; Fautin et al. 1992, for reviews).

Or:

Ocean uptake of carbon is simulated with the world ocean general circulation model (OGCM) of Toggweiler et al. [1989], as modified by Toggweiler and Samuels [1993], etc.

There are various styles for referring to others’ work, and you may choose any style that is clear. However, do not mix styles. Notice that you are referring to the author’s name, and a date. This will identify a specific reference in the reference list, which must appear at the end of your paper.

Samples follow:

References:


Note that the first reference is to a book and the second is to a scientific journal article. Each journal requires a slightly different format for references. You may use the format above.

Form of book reference to use:
<Author>, <Year>, <Title>, <Title of book>, <editor or edition of book>, <page numbers of your reference>, <Publisher>, <City of publisher>.

Form of paper reference to use:
<Author>, <Year>, <Title>, <Name of journal>, <Volume number of journal>, <page numbers of article>.

Internet references:
An action-alert posted on the web:

An article from a newspaper on the web:

Be sure to reference quotes from your textbook and from the lab workbook.

Final checklist:

___ Name, section, and perm number at the top.
__ All specified headings included (see "Format of Paper").

__ The paper may include any number of figures and drawings. Small figures should be included in the text (drawing them on the computer is optional). Full page figures can be inserted at the closest spot where they are referred to.

__ Do not include any figures photocopied/scanned from the textbook.

⚠️ All papers will be handed in on-line through the EarthEd system, unless otherwise specified. Consult the Oceanography Class Web
Appendix B: Plate Tectonics Assignment

Plate Tectonics:

The purpose of this writing assignment is to help you understand how convergent and divergent plate boundaries differ and how to use earth data to determine the boundary type.

Preparation for the assignment:
1) Carefully read this description. You can print it out by clicking the "Print" icon below this text field.
2) Read the textbook on plate tectonics. You can also watch the Virtual Lecture in the "Our Dynamic Planet" module. This shows animations of how plates move on the earth. Next, read the "Plate Tect Summary" file. You can access this file from the help files list on the right. This document emphasizes the data that can be used to develop your interpretation, so is very pertinent to this assignment.
3) You will also need to become proficient with annotating the figures that you capture from the "Our Dynamic Planet" module. The Guide has several tutorials about annotating figures, and they will save you time on this and future writing assignments, as well as improve your grade.

To begin the assignment:
1) Select "Our Dynamic Planet" from the "Data" dropdown list that is visible on the Assignment Index screen.
2) Go to the MAP module.
3) Select "Small Area Maps" from the "Data" dropdown menu.
4) The two regions you will focus on will be the Tonga region at about 29deg S, 180degW (region A), and the East Pacific Rise at about 50deg S, 115deg W (region B). You can find these places on the MAP by clicking on a location and noting the label in the location field.

Your task(s):
1) Use the data available in the MAP module of the "Our Dynamic Planet" module to characterize the plate boundaries at the two specified locations specified above. Make a "model" of each location. This must be a simple sketch that you draw yourself. It doesn't have to be pretty, but does have to include the most important features that characterize the particular plate boundary. Use as many different data types as are appropriate (and available on the CD) to support your model.

2) Follow the structure given in "Anatomy of a Science Paper". This resource is in your lab book, or can be downloaded from here from the Resources list (here it's called "Science Writing Styles").

Ways students improve their grade:
1) Start early so there is time to interact with the TA and Prof., and recover from any computer problems.
2) Read the instructions.
3) Write clearly and briefly. If you were telling your non-science friend about this, how would you express it to him/her?
4) Explicitly demonstrate how the data that you illustrate lends support to the model figure that you draw. It is not enough to just show a data plot. You must describe the salient features and show how it agrees with your model's features and predictions.
5) Attend class, where these issues are often discussed.

Ways students sometimes lower their grade:
1) Don't read the instructions for the assignment
2) Don't read "Anatomy of a Science Paper", in your lab book, which clearly spells out how to write this paper.
3) Use too many figures
4) Use too few figures
5) Scan your model figure from the book, rather than drawing your own.
6) Write a "book report" where no data are used.
7) Don't use a location map
8) Don't annotate figures
9) Don't start until the last evening before the due date
10) Don't interact with your TA or professor when questions arise. This can happen when you start so late that they are not available.

Detailed instructions for how to write this assignment can be found in "Anatomy of a Science Paper", which is in your lab book. Note: these instructions should also be followed for the other writing assignments in this course, even though the examples in the document refer to plate tectonics.

http://earthednet.org/EEDMaterials/assignment/PlateK20Tectonics_Assig.htm
Appendix C: Peer Review Rubric

Summary of the CPR Rubric

**Plate Tectonics Paper** (2 pts for each criterion, total =42)

**Introduction**

1) The topic of investigation is easy to identify.
2) The region A and B study areas are clearly indicated on a world map and more detailed country map, if needed. This item should also receive credit if the location map is linked to the Observations section.

**Methods**

1) Methods of data collection are described.
2) Accuracy and limitations of the data are discussed.
3) Data and sources are accurately referenced.

**Observations**

1) The location of all elevation, volcano, and quake cross-section profiles that are discussed in the text are shown on the detailed area map.
2) All cross section profiles are labeled so their location on the detailed area map can be determined.
3) Observations are clearly supported by figures that show data and location of data.
4) Data and data representations are described in the text. Quantitative descriptions are used (e.g. depth of trench, depth of quakes, etc.).
5) Multiple data sources are used, when appropriate, to identify geological features. Elevation, quake, and volcano data should be used for region A, and elevation, age, and quake data should be used for region B.
6) Relationships among observations are made clear (e.g. does author show how quakes and volcanoes lie parallel to the trench?).

**Interpretations**

1) A simple sketch model of both of the regions shows the most important features of the boundary type. Locations of the various data types should also be shown (e.g. shows where are the quakes expected, shows where are the volcanoes expected.).
2) The author describes clearly how the data match with the features illustrated in the model (simple sketches).
3) The author correctly identifies region A as a convergent boundary.
4) The author correctly identifies region B as a divergent boundary.

References

References are cited in correct format.

Overall

1) Author shows an understanding of the theory of plate tectonics.
2) Punctuation and spelling are accurate.
3) All paper sections are included and include the appropriate content. This means that observations are in the observations section and interpretations are in the interpretations section.
4) Figures are numbered, referred to in the text, have informative captions, and are organized in the order that they are referred to in the text (Credit is reduced for using irrelevant or superfluous figures).
5) Data and others’ work are adequately referenced throughout the paper.

Monsoons Paper (2 pts for each criterion unless otherwise stated, total=50)

Introduction

1) The topic of investigation is easy to identify.
2) The study region is clearly indicated on a world map.

Methods

1) Methods of data collection are described.
2) Accuracy and limitations of the data are discussed.
3) Data and sources are accurately referenced.

Observations

1) A clear data figure is shown that shows how precipitation varies throughout the year, or between the winter and summer seasons.
2) A clear data figure showing how the winds vary between summer and winter, is included.
3) A clear data figure showing how the atmospheric pressure varies between summer and winter, is included.
4) A clear data figure showing how the temperature varies between summer and winter, is included.
5) Data and data representations are described in the text. Quantitative descriptions are used (e.g. amount of rainfall, temperature values, etc.).
6) Relationships among observations are made clear (e.g. does author show how wind direction, rainfall, and barometric pressure relate to and influence each other?).

7) Data figures are clearly annotated where needed, so the reader can easily identify the important information being referred to in the text.

**Interpretations**

1) A simple conceptual sketch should illustrate the relationship between atmospheric pressure, wind direction, and rainfall.

2) The author describes clearly how the data match with the features illustrated in the sketch. The author should make a connection between the atmospheric pressure, wind direction, and rainfall. Partial credit if atmospheric pressure is not mentioned. (0, 1, 2, 3, or 4 pts)

3) The interpretation correctly describes the phenomena and processes responsible for the Indian Monsoon. (0, 2, or 4 pts)

**References**

The study region is clearly indicated on a world map.

**Overall**

1) Author shows an understanding of the data and kinds of data that illustrate the processes important in the Indian Monsoon.

2) Punctuation and spelling are accurate.

3) All paper sections are included and include the appropriate content. This means that observations are in the observations section and interpretations are in the interpretations section.

4) Figures are numbered, referred to in the text, have informative captions, and are organized in the order that they are referred to in the text (Credit is reduced for using irrelevant or superfluous figures).

5) Data and others’ work are adequately referenced throughout the paper.

6) Extras: Has the other brought in related information to show how the monsoon is important to India’s economy and population? (0, 2, or 4 pts)

**Oceans and Climate Paper** (2 pts for each criterion, total = 82)

**Introduction**

1) The topic of the investigation is easy to identify.

2) The introduction captures the reader’s interest and clearly states the importance of understanding the earth’s climate.

**Causes of Climate Change**
1) The sun and distance from the sun is mentioned as the main factor controlling the earth’s average temperature.
2) The earth’s albedo is mentioned for its effect of reflecting solar energy to space, and influencing the average temperature of the earth.
3) The atmosphere is mentioned for its role in the greenhouse effect.
4) CO$_2$ concentration in the atmosphere is mentioned for its role in the greenhouse effect.
5) The greenhouse gases (water, methane, nitrous oxide, and ozone) are mentioned.
6) The residence times of the greenhouse gases are mentioned.
7) The balance of greenhouse gases entering the atmosphere with greenhouse gases leaving the atmosphere to the oceans or other sinks is mentioned.
8) Clouds are mentioned as affecting the climate.
9) Pollution and/or aerosols are mentioned as affecting the climate.

Earth Climate History

1) Methods of data collection are described.
2) Data and sources are accurately referenced.
3) A clear data figure shows the earth’s temperature for the last 400,000 years.
4) A clear data figure shows the atmospheric CO$_2$ concentration for the last 400,000 years.
5) Data and data representations are described in the text. Quantitative descriptions are used (e.g. amount of temperature change, etc.).
6) Relationships among observations are made clear (e.g. does author show how temperature and CO$_2$ track each other for 400,000 years?).

Historical Climate Change

1) Methods of data collection are described.
2) Data and sources are accurately referenced.
3) A clear data figure shows the earth’s temperature for the last 200 years.
4) A clear data figure shows the atmospheric CO$_2$ concentration since 1880.
5) Data and data representations are described in the text. Quantitative descriptions are used (e.g. amount of temperature change, etc.).
6) Relationships among observations are made clear (e.g. does author show how temperature and CO$_2$ track each other since 1880?).

Climate Change Scenarios

1) Data and sources are accurately referenced.
2) Author notes that the global temperature could rise in response to greenhouse gas increases.
3) Author notes that the global temperature could fall in response to shutdown of global oceanic heat conveyor belt, plunging the earth into an ice age.
4) Author notes that changing rainfall and temperature patterns are a possible result of climate change.
5) Author notes that sea level rise due to melting ice caps is a possible result of climate change.
6) Author notes that economic disruption due to resource distribution changes and population migration are possible results of climate change.
7) Extras: added discussion that is well-referenced and not covered in the previous items for this section.

**Policy Recommendations**

1) Kyoto Protocol is mentioned.
2) Kyoto Protocol agreement action items and member commitments are listed.
3) Author discusses US refusals to ratify the Kyoto Protocol and reasons for that refusal.
4) Carbon emissions trading is explained.
5) Extras: added discussion and plausible action items that are not covered in the previous items for this section.

**References**

References are cited accurately, so the reader can find the source materials. URLs are ok. The sponsoring agency should be listed.

**Overall**

1) Author shows an understanding of the data and kinds of data that are used in the study of the earth’s climate.
2) Punctuation and spelling are accurate.
3) All paper sections are included and include the appropriate content.
4) Figures are numbered, referred to in the text, have informative captions, and are organized in the order that they are referred to in the text (Credit is reduced for using irrelevant or superfluous figures).
5) Data and others’ work are adequately referenced throughout the paper.

**Fisheries Paper** (2 pts for each criterion unless otherwise stated, total = 72)

**Pew Report**

1) The Pew Ocean Commissions Report is adequately introduced and includes some information about the commission’s membership and their expertise.
2) Mentions destruction of coastal wetlands.
3) Mentions degradation of rivers.
4) Mentions overfishing.
5) Mentions invasive species.
6) Mentions sea level rise.
7) Mentions loss of coral reefs.
8) Mentions changes in upwelling patterns.
9) Mentions management changes that modify government and management functions.
10) Mentions protect habitat.
11) Mentions minimize pollution.
12) Mentions national policy on fish farm practice.
13) Mentions more funding for management.

The Controversy

1) Includes in main points of the National Fisheries Institute: US fisheries are now healthy.
2) Includes: current management is working well.
3) Includes: regulations now in place work well.
4) Includes: overfishing claims are exaggerated.
5) Includes: no new government agency is needed.
6) Includes: progress is being made.
7) Includes: no need to restrict fish farms.
8) Includes: no need to regulate by-catch. Progress is being made.

My Analysis

1) The author accurately summarizes the two sides of the controversy.
2) Data on fisheries is presented, from NMFS or other sources.
3) Quotes and data are used effectively to support one or the other side of the controversy. (0, 1, 2, 3, or 4 pts)
4) A credible position is developed, that is supported by the data and quotes used to support it.
5) Data and sources are accurately referenced.

Sustainability

1) A short discussion of sustainability explains that the harvesting of a fish stock should not be so severe that the fish population can no longer survive, or that the replenishment of the stock through natural reproduction should replace fish that are harvested.
2) Other threats are mentioned. These could include by-catch, destruction of the bottom habitat by trawling, pollution, and nutrient runoff.
3) Practical ideas for citizen action are offered. These could include donations, involvement in organizations, letters to legislators and newspaper, or making sound choices as a consumer of ocean products.

References

References are cited in correct format.

Overall
1) Author shows and understanding of the issues involved in sustaining the world’s marine life for fishing and a healthy ecosystem.
2) Punctuation and spelling are accurate.
3) All paper sections are included and include the appropriate content.
4) Figures are numbered, referred to in the text, have informative captions, and are organized in the order that they are referred to in the text (Credit is reduced for using irrelevant or superfluous figures).
5) Sources and others’ work are adequately referenced throughout the paper.
Appendix D: Monsoons Assignment

The Indian Monsoon is a climatic phenomenon where the ocean and land interact to create a major weather system that is vital to the Indian (and other Southeast Asia regions) economies and well-being of their population.

The purpose of this assignment is to use various kinds of atmospheric and climatic data to illustrate and understand the important processes that cause the Indian Monsoon. Data are available on the class web site. A page containing links to temperature, pressure, rainfall, wind and other relevant data, is available. Please go to the class web site and link to these data sources.

You must also create a simple sketch or "conceptual model" of the processes that control the Indian Monsoon.

Use as much data as you find necessary to explain the monsoon. The data links connect to all of the data that you will need, but it will also be useful if you Google the Indian Monsoon and read some of the links that seem relevant. There will be credit give for briefly discussing the importance of the monsoon and how it affects India's economy and population. <Link to Environmental Data for this assignment>

Your task(s):
2) Follow the structure given in "Writing a Science Paper". This resource is in your lab book, or can be downloaded from here from the Resources list.

Ways students improve their grade:
1) Start early so there is time to interact with the TA and Prof., and recover from any computer problems.
2) Read the instructions.
3) Write clearly and briefly. If you were telling your non-science friend about this, how would you express it to him/her?
4) Explicitly demonstrate how the data that you illustrate lends support to the model figure that you draw. It is not enough to just show a data plot. You must describe the salient features and show how it agrees with your model's features and predictions.
5) Attend class, where these issues are often discussed.

Ways students sometimes lower their grade:
1) Don't read the instructions for the assignment
2) Don't read "Writing a Science Paper", which clearly spells out how to write this paper.
3) Use too many figures
4) Use too few figures
5) Scan your model figure from the book, rather than drawing your own.
6) Write a "book report" where no data are used.
7) Don't use a location map
8) Don't annotate figures
9) Don't start until the last evening before the due time
10) Don't interact with your TA or professor when questions arise. This can happen when you start so late that they are not available.

http://eart hednet.org/EEDMaterials/writing_assignments/MonsoonCPR_Writing.htm
Appendix E: Oceans & Climate Assignment

The purpose of this writing assignment is to help you understand how the ocean affects the global climate, and to inform you about the climate change debate and possible consequences of climate change.

Note: This is a "Calibrated Peer Review" assignment. Your lab book explains how this works.

The assignment contains the following sections:

1. Introduction
2. Causes of Earth's Climate
3. Summary of the history of the earth's climate
4. Historical climate change
5. Predicted climate change and various scenarios of consequences of climate change
6. Policy recommendations: how should our institutions respond, how should we personally respond?

Data links for this assignment: <data links>

Preparation for the assignment:

1. Carefully read the assignment description and what content will go into each of the paper sections
2. Review "Writing with Integrity" from your lab book <download link>
3. Read or review the lab week 6 in your lab book. Understand the major influences on our climate system. Understand the idea of climate feedbacks. <downloads 1, 2, 3, 4> The paper data links also have a lot of info on the climate, so pay attention to that material too.
4. Browse the links on the assignment data page <assignment data>
5. Google on the subject to find resources and references

You will need to exercise caution when analyzing and referencing web pages. The critical thing is to determine the difference between reputable, contrarian, and whacko web sites. Read "Analyzing Scientific Claims, Evaluating Web Sites" in your lab workbook <download link>. When referencing, be sure to identify the viewpoint of the website authors. Is it a government agency, energy industry, environmental group, university scientist? Especially for contrary viewpoints, browse the site to see if the author has an "axe to grind" or is generally contrary about many science issues. Is the web site up to date? The science changes rapidly. Newer findings may have solved an older controversy. Is there a political bias? Sites run by political organizations generally favor one point of view over another and may selectively report on studies that support their view, ignoring new studies that are contrary.

Paper sections content:

1) Introduction: a brief introduction to the topic. Don't get into too many details. The point is to capture the reader's attention by explaining what you will discuss and why it is important. How can you do this in less than 150 words?

2) Causes of Earth's Climate: What are the major factors that cause the earth's climate? Only a brief discussion of each factor is needed. For example: The atmosphere causes the greenhouse effect because it traps the sun's heat, warming the earth. Or: "blah blah gas is a greenhouse gas which tends to warm the earth when concentrations increase." So, you want to name the factor and state the effect it has on climate. Don't forget to mention the earth's place in the solar system as it relates to climate. Figure 6 of the lab reading is a good diagram of factors affecting the earth's surface temperature.

3) Earth Climate History (last 400,000yrs) : this section will include a discussion of the earth's past climate using data from paleoclimate studies. Show the data plots and explain how the temperatures were gotten from the data, and the accuracies or limitations of the data. Be quantitative. Be sure to cover major changes due to ice ages.
4) **Historical Climate Change** (~last 200yrs): how has the climate changed during recorded history? How do these changes compare to natural changes determined in the paleoclimate data? Try to find multiple ways that global temperature rise is measured or inferred. Is there contrary evidence of global temperature rise? Is the contrary evidence credible? Why or why not?

5) **Climate Change Scenarios**: what might happen if the climate does change by predicted amounts? What are the worst consequences that could happen? What are the most likely consequences?

6) **Policy Recommendations**: how should world governments respond to the possibility of climate change? What programs are already in place or being implemented (hint: think "Kyoto" and "Carbon Emissions Trading"). Are the programs too expensive? Should we act now? Is the science good enough? What kind of actions should be taken by the United States? What kind of actions should an individual take? How should policy decisions respond to uncertainties in the predictions?

**Ways students improve their grade:**
1) Start early so there is time to interact with the TA and Prof., and recover from any computer problems.
2) Read the instructions.
3) Write clearly and briefly. If you were telling your non-science friend about this, how would you express it to him/her?
4) Explicitly demonstrate how the data that you illustrate lends support to your argument(s). It is not enough to just show a data plot. You must describe the salient features and show how it supports your assertion(s).
5) Attend class, where these issues are often discussed.

**Ways students sometimes lower their grade:**
1) Don't read the instructions for the assignment
2) Don't read "Writing a Science Paper", which clearly spells out how to write this paper.
3) Use too many figures
4) Use too few figures
5) Write a "book report" where no data are used.
6) Don't use a location map
7) Don't annotate figures
8) Don't start until the last evening before the due time
9) Don't interact with your TA or professor when questions arise. This can happen when you start so late that they are not available.
Appendix F: Fishery Health Assignment

The purpose of this writing assignment is to help you understand critical issues regarding sustainability of life in the world ocean, and economies that depend on healthy fisheries. This is an issue that has stirred a strong response from commercial fishing organizations, so you will have to be very careful to identify the stakeholders of an assertion, and assess the credibility of their statements.

Note: This is a "Calibrated Peer Review" assignment. Your lab book explains how this works.

Preparation for the assignment:

1. Read the assignment description below.
3. Read the "Contrary View to Pew Report", page R-35 of your lab book. This was published by the National Fisheries Institute. <Download link to Rebuttal to Pew Report>
4. Browse the links on the data links page <data links page>. Note sites that have particularly useful information so you can return later if needed.
5. Google to find other information and viewpoints.

When using the readings in your writing, you may choose to quote directly (don't forget to reference the source) or take notes on your reading and construct your own sentences. Still, don't forget to reference the source of data and significant claims that are key to your paper.

Assignment headings description:

Pew Oceans Commission Report: This is a report, whose executive summary is contained in your lab book. It has created a big stir among the commercial fishing industry, government regulators and lawmakers. This section will focus on the executive summary of this report. Be sure you answer the following questions:

1. Who are the commission members? What viewpoint does the commission represent. Is it balanced or skewed in some way? Be specific.
2. What threats to ocean health does the report identify?
3. What strategies does the report recommend (summarize most important, only)?

You can directly quote the report. Reference carefully.

The Controversy: The commercial fishing industry has attacked this report. The goal of this section of your paper is to identify the areas of controversy in this report. Don't copy each of the assertions, but attempt to summarize the arguments arrayed against this report. Be sure to access the National Fisheries Institute web site to identify their viewpoint and other data they offer to support their assertions.

My Analysis: Carefully analyze assertion 3 of the "Contrary View" (beginning: "The Pew Report Says: Proven, workable solutions to fisheries management..."), page R-37 of your lab book. You should develop a personal position on the issue. This assignment is like the previous assignments, but you have more latitude in how you approach it. Use data when possible. There isn't a lot of data, so you will probably end up using a lot of quotes from various articles and online sources that are in the data links.

Sustainability and health of world oceans: In this section you discuss the subject of the global ocean and fisheries sustainability more generally. Identify threats and issues not discussed previously, and recommend actions that individual citizens can take, if any, to support the long term health of the world's oceans. This section can be a general discussion and include your informed opinions.

Ways students improve their grade:
1) Start early so there is time to interact with the TA and Prof., and recover from any computer problems.
2) Read the instructions.

http://earthhednet.org/EDMmaterials/writing_assignments/FisheriesCPR.htm
### Appendix G: Student Scores for Plate Tectonics Assignment

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## Appendix H: Student Scores for Monsoons Assignment

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<th>Use in Explanation (# of lines of reasoning)</th>
<th>Supports Conclusion (# of lines of reasoning)</th>
<th>Lines of Reasoning</th>
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<th>Match to Model: Text</th>
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Note: The table provides a detailed analysis of student scores for different aspects of the Monsoons assignment, including correctness, sufficiency, and tie scores across lines of reasoning.
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<th>Conclusion Stated</th>
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## Appendix I: Student Scores for Oceans & Climate Assignment

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Prothero, W. A., Jr. (2005). Earth data, science writing, and peer review in a large general education oceanography class (Manuscript written at the 2005 On the Cutting Edge NAGT workshop ed.).


