Reading techniques used by mechanical engineering students

Amy Anne Holland
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Reading techniques used by mechanical engineering students

by

Amy Anne Holland

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: English

Program of Study Committee:
David Roberts, Major Professor
Dorothy Winsor
Kenneth Bryden

Iowa State University
Ames, Iowa
2004

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Graduate College
Iowa State University

This is to certify that the master’s thesis of

Amy Anne Holland

has met the thesis requirements of Iowa State University

Signatures have been redacted for privacy
Acknowledgments

I would like to thank my major professor, Dave Roberts, for giving me valuable suggestions on multiple thesis drafts. I would also like to thank Dorothy Winsor and Mark Bryden for helping me lay the groundwork and arrange the logistics for this project and for serving on my committee.

Thanks to my parents, Bob and Janice Holland, for their love and support and for always being there to help me make it through “learning experiences.”

Finally, I’d like to thank Adam Oline, my fiancé, my best friend, and the reason I made it through graduate school.
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Chapter 1: Introduction and literature review

In “Learning to Read Biology: One Student’s Rhetorical Development in College,” Christina Haas defines becoming literate at the college level as “[learning] the patterns of knowing about, and behaving toward, texts within a disciplinary field” (1994, p. 43). Like writing, reading is a rhetorical act. The relationship between writers and readers of texts is complex and is impacted by social relationships (e.g., does the reader perceive the author as superior, equal, or inferior to him or her?), the surrounding culture (e.g., how does the reader perceive the author if the reader is in academia or industry?), and the persuasive nature of text (e.g., how does the reader respond to authors’ attempts to convince them that their work is valid and important?) (Haas, 1994, p. 44). These factors and others can lead to a gap between the meanings of the text the writer writes and the text the reader reads. Researchers in rhetoric are interested in the rhetorical strategies that readers use when they read, and researchers (Charney, 1993; Haas, 1994) have discovered differences in reading techniques among readers at different levels of education or experience.

The read-aloud protocol, which is a form of verbal report, has been a standard methodology used in studies on reading techniques. Although he does not specifically study scientists at different levels of education or experience, Charles Bazerman, who studies how physicists read physics texts, claims that physicists read either to “add to their background knowledge or to mobilize aspects of the article in their immediate work.... In filling in one’s ignorance, one is likely to read trustingly and uncritically” (1988, p. 245). This suggests that less experienced members of a particular field would be more willing to accept an expert’s claims than moderately experienced members, who in turn would accept more claims than
faculty or researchers who have worked in the field for a number of years. It also suggests that even very experienced scientists would be more likely to read a text less critically if the text’s topic lay outside their area of expertise. According to Bazerman, in addition to knowledge and experience, a reader’s purpose for reading is a significant factor in defining his or her reading strategies (1988, p. 236). It is important to keep in mind that readers’ strategies might change because of their shifting purposes, not only because of an increase in knowledge or expertise.

Davida Charney performed a cross-sectional study to analyze how scientists at different levels of experience and education read Stephen Jay Gould and Richard C. Lewontin’s “The Spandrels of San Marco,” which makes use of rhetorical strategies that are not typically found in scientific discourse. Charney’s conclusion is that more experienced readers (in this case, faculty) are more likely than less experienced readers (i.e., graduate students) to preview, skim, and read nonlinearly, strategies that prevent them from being “victimized” by Gould and Lewontin’s rhetoric. Graduate students tended to fall prey to Gould and Lewontin’s arguments more often than faculty members. Although Charney found that linear reading strategies did not entirely preclude thoughtful critique, a linear strategy did seem to “indicate a greater willingness to follow the author’s lead” (1993, p. 215).

Although Haas performed a longitudinal study with just one biology student, Eliza, her overarching question was similar to Charney’s: how would Eliza’s reading strategies change as she progressed in her studies? Haas found that as Eliza progressed, she moved

---

1 Charney quotes Lawrence Slobodkin’s objection to “the intrusion of Gould’s personality and beliefs into the writing” (Charney, 1993, p. 203): “One of the most difficult aspects of scientific work is reporting what one sees without having it colored by one’s own preconceptions. It may ultimately be impossible. Nevertheless, in most scientific prose the author strives for clarity in the dual sense of expository simplicity and in making oneself transparent so that the empirical world is visible through the text but the peculiarities of the author are invisible” (Slobodkin, 1988, p. 503).
away from linear reading strategies and toward skimming, selective reading, and paying closer attention to figures and legends. Her reading strategies changed such that she advanced from accepting and memorizing information from her textbooks during her freshman year to paying more attention to rhetorical elements, such as “handwaving,” which Eliza defines as the authors not being “sure of their theory. They sort of have data which suggest it. But they can’t come out and say [it]” (Haas, 1994, p. 66), and making connections among texts during her senior year. Eliza’s reading purposes also changed from primarily understanding and memorizing during her freshman year to finding her place in the academic community during her senior year.

Strømsø et al. (2003), Stratman (2002), and Lundenberg (1987) performed studies of law students’ reading techniques. Strømsø et al. examined law students’ linking of multiple sources, or prior knowledge, when they read. They found that students tend to integrate more information from multiple sources as they become more experienced in the profession and therefore have a larger knowledge base. They note that “the reading of multiple texts may facilitate students’ learning especially when they have reached a certain level of competence in the domain … [but] with minimal domain knowledge, the reading of multiple texts may well result in more confusion than learning” (2003, p. 143).

In Stratman’s study, students were given three related texts and asked to perform read-aloud protocols. He divided the students into four sections of 14 and gave each section a different task condition to keep in mind while reading: advisory, advocatory, policy, and class recitation. He then recorded the number and significance of problems that students in each group found with the texts. Like Bazerman, Stratman found that reading purpose makes a difference in how readers read: the majority of the students in his study who were given a
"real-world" task (i.e., advisory, advocatory, or policy) read intertextually while the majority of students given an academic task (e.g., class recitation) read linearly. The students who read intertextually “performed significantly better on … problem recognition … than those who read cases linearly” (2002, p. 84). Lundenberg used think-aloud protocols to compare how experts (lawyers and law professors) and novices (law students) read cases. She found that experts previewed, analytically reread, evaluated the court’s decision, and used various other reading strategies that novices did not.

As indicated by these studies, while reading purpose does influence reading techniques in groups that have similar levels of experience, students and professionals also seem to become more sophisticated readers as they gain experience. More experienced and more successful readers tend to use such strategies as reading nonlinearly, skimming, reading selectively, and, in Haas, paying closer attention to illustrations than do less experienced readers. More experienced readers are also less likely to simply trust an author or to be significantly influenced by an author’s rhetoric. Changes in reading techniques and purposes seem to occur throughout academic careers; readers seem to continuously improve their skills from their freshman years throughout their professional lives. I was interested in studying the changes that occurs in the reading techniques of students (in this case, mechanical engineering students) during their first year of graduate education.

Haas describes rhetorical readers as “not content simply to extract information or to accept the arguments of an autonomous text” (1994, p. 50); some characteristics of rhetorical readers that allow them to read critically and not simply accept an author’s arguments include:
• Reading nonlinearly
• Questioning those in a position of authority
• Referencing prior knowledge
• Paying attention to illustrations

For this study, I was primarily interested in determining where science students who have finished one year of graduate studies are in the process of evolving into rhetorical readers, if the evolution has begun at that point in their education. I focused on the differences between the reading techniques of graduate mechanical engineering students at the beginning of their second year of graduate school and the reading techniques of undergraduate mechanical engineering students during their final year of undergraduate work. I looked at a small group of students, two who had nearly completed their undergraduate degrees and two who had been in graduate school for a little longer than one year, to find evidence of how the first year of graduate school might cause students to change the way they read. Making generalizations about how students read based on such a small sample is, of course, impossible, but my findings in this study may pave the way for larger-scale studies that will explore these trends more thoroughly.
Chapter 2: Methodology

I performed a pilot study six months prior to the beginning of this study. The participant was Patrick, a first-year Ph.D. student in the mechanical engineering program. I asked Patrick to perform a read-aloud protocol, instructing him to read an entire article out loud and say his thoughts out loud as he read it (Ericsson & Simon, 1994). With the help of Patrick’s advisor, a mechanical engineering professor, I selected an article for Patrick to read based on the following constraints: I wanted Patrick to have to struggle a little to understand the article, but I didn’t want it to be so far beyond him that he would become frustrated; and I wanted the subject matter to be interesting to him but not necessarily within his area of expertise.

The article we chose was highly technical, and this caused a problem: since the subject matter was not in Patrick’s area of expertise, he did not recognize some of the terms, and he commented six times that he would need to look something up “later.” After he said this three times, I stopped him to ask if, under normal circumstances, he would look up unfamiliar terms or phrases as he read or after he had finished reading. He said that he usually looks up unfamiliar terms and concepts as he reads, but to do so he would need to leave the office in which we were conducting the protocol and return to his desk and resources, which would be inconvenient.

This experience indicated to me that I would either need to provide study participants with the means to look up anything they had questions about while reading the article, which would be very difficult, to make the experience more genuine; or I would need to choose an article that would not require them to look up terms to understand it. I decided to take the
second route with the help of the participants’ supervisor and asked him to find an article that was technical but comprehensible to all of the study’s participants, including the undergraduates. Based on my findings in the pilot study, in which the quality of the illustrations used in the text was important to Patrick, I also requested that there be some illustrations in the new article.

Prior to the pilot study’s read-aloud protocol, I explained to Patrick what I was asking him to do, telling him that he would read as he normally would, that he should not feel compelled to read in any particular order, that he should pretend that I was not in the room, and that he should remember that his purpose in reading the article was to come to terms with it himself rather than to explain it to me. I based this part of my methodology on that used by Charney (1993, p. 207). I followed the protocol with a few questions about Patrick’s background in academic reading and his motives for reading what he does, as well as questions about what he thought of the article. The session lasted for approximately 90 minutes, including both the protocol and the post-protocol interview. Because of the length of the article, Patrick took a five-minute break in the middle of the session. I tape recorded the protocol and the interview and transcribed the tape, which yielded approximately 20 pages.

During the protocol, Patrick’s utterances apart from actually reading the article consisted mostly of rereading, paraphrasing, and commenting. In some cases, he seemed to reread to improve his comprehension; in others, because he had initially misread a word or phrase; in still others, he seemed to reread because he disagreed with the authors and seemed to want to confirm his understanding of a statement so he could refute it. Most of his paraphrasing seemed to be an attempt to come to terms with the article. His comments, which
I divided into further sub-categories, indicated among other things how well he understood the text and what he thought of the authors' research. Patrick read the article linearly for the most part, rarely jumping ahead, although he did jump back several times to reread. In the post-protocol interview, Patrick indicated that his biggest concern with the article was that the authors had not made clear why they had done the research or why it was important.

Based on the findings of my pilot study, the changes I made for this study included the following:

**Article selection:** I asked the participants' supervisor to select a less technical article so the participants would not struggle as much as Patrick did with technical terms with which they were not familiar. The article he chose, in which the authors describe the combustion behaviors of vegetation found in California, contained very few terms or concepts that upper-level undergraduate mechanical engineering students would not recognize.

**Placement of interview questions:** In the pilot study, I asked Patrick about his reasons for reading and his perception of his reading techniques after the protocol. This time, I asked those questions of the participants *before* the protocol. I knew that asking these questions before the protocol could lead the participants to change their reading techniques during the protocol to match how they said they read during the interview, but I decided that I would rather risk that than have them answer the question after the protocol based on how they had read during the protocol.

Asking the questions beforehand did not seem to affect the participants’ protocol performance; in fact, one undergraduate participant said that he was not aware of his reading techniques and the other undergraduate participant and both graduate participants read differently than they said they do during the interview. The second undergraduate
student told me that he tends to look for the main point, sometimes only reading the first few lines of a paragraph before moving on. During the protocol, however, he read the entire article, very rarely skipping any sections except those that contained several variables or scientific terms, such as the names of the leaves, which were difficult to pronounce. His unwillingness to skip text despite saying that he usually does may have been caused by the protocol situation; he may have felt that, because he was participating in a study, he needed to read the entire article. The first graduate student’s answer to the question about his reading techniques was that he tends to read abstracts first to see if reading the whole article is worth his time. In this case, because of the artificial situation of the protocol, he read the entire article after reading the abstract without considering whether it was worthwhile. The second graduate student said that he often has to read journal articles twice to understand them, which he did not do in my study. Based on his reaction to the article when he finished reading it, this was probably because he didn’t feel the need to read it any more closely to understand what it said.

**Length of reading:** For the pilot study, I asked Patrick to read the whole article instead of asking him to read for a pre-determined period of time. Because he seemed daunted by the prospect of reading the whole article out loud and because he had to take a break in the middle of it at about the 45-minute mark I decided this time to ask the participants to read for 30 minutes. Because the article I used for this study was significantly shorter and less technical than the one I used in the pilot study, the two undergraduate participants and the second graduate participant finished reading it within the 30-minute time frame. The first graduate student was within about three pages of finishing at the 30-minute mark and agreed to keep reading to the end. He finished reading after about 40 minutes.
Participant selection

For this study, I decided to examine how the reading techniques of students who have completed one year of graduate school differ from those of undergraduate students in the final semester of their degree program. Therefore, I chose two graduate students in mechanical engineering, John and Eric, and two undergraduate students who were also in mechanical engineering, Seymor and Apu. I chose John and Eric because they had been in graduate school for slightly longer than one year. I chose Seymor and Apu because they were both in the last semester of their undergraduate curriculum and also because they were both planning to go on to graduate school in mechanical engineering. All four of the participants were men because I did not want sex differences in language development and use (Knopik et al., 1998; Frith et al., 2001; Baxter et al., 2003) to add another variable to my study. All four participants are also native English speakers who have lived for several years in the Midwest. I wanted their backgrounds in English speaking and the speech they had been immersed in to be similar. Significantly different backgrounds might add comprehension problems or interpretation differences beyond any technical terms with which they were unfamiliar.

This study conformed to the Institutional Review Board standards in place at Iowa State University. All participants, including Patrick, signed consent forms informing them of the purpose of my research and assuring them that the project’s data would be kept confidential. I provided the participants with copies of the final write-up for their review and approval.

2 To keep their data confidential, I asked each participant to choose a pseudonym. Apu's name comes from the popular television show The Simpsons. John and Seymor chose their names for personal reasons. Eric requested that I choose a pseudonym for him.
**Article selection**

I asked the participants’ supervisor, who is a mechanical engineering professor, to select an article that all four participants would be able to understand and that had some technical information in it. I also wanted the article to cover a topic that would interest all four participants so they would not become bored during the protocol. The article the supervisor selected, in which the authors use experimental methods to analyze how various types of California vegetation combust in forest fires, met all these goals. It was published in *Combustion Science and Technology*, which is a good professional journal. It is one of two well-respected combustion journals and has a journal citation report (JCR) impact factor of 0.604. The JCR impact factor is a citation-based tool used by those in scientific and technical disciplines that measures how quickly and how often articles from a journal are cited. It is calculated by dividing the number of times articles from a given year are cited by the number of articles published during that year. Impact factors among engineering journals typically range from .1 to 3. Very few engineering journals have a JCR impact factor of greater than 3. A good impact factor is .5 or higher; an outstanding one is higher than 1. *Combustion Science and Technology*, like most engineering journals, is not blind-reviewed; authors’ names are attached to articles throughout the review process.

**Site selection**

At the beginning of this study, John, Eric, Seymour, and Apu were all working for the same supervisor, who was also John and Eric’s academic advisor, at the Virtual Reality Applications Center (VRAC) at Iowa State University. At the beginning of this study, I had been a research assistant at VRAC for more than two years, so I was fairly well acquainted
with the participants. Graduate students at VRAC tend to do research-intensive work such as writing and analyzing code and analyzing results, writing papers to present at conferences or publish in journals, and, of course, writing theses and dissertations. The undergraduate research helpers tend to do less research-intensive work such as drawing models that will represent data in a virtual environment or testing applications to ensure that they run properly. For the interviews and protocols, I obtained the participants’ supervisor’s permission to use his office while he was out of town. Although this location might have caused the participants, especially the undergraduates, to feel intimidated, it was the only feasible location.

Protocol methodology

I asked John, Eric, Seymor, and Apu to read an article out loud for 30 minutes and to say their thoughts out loud as they read it (Ericsson & Simon, 1994). Prior to each protocol, I explained to each participant what I was asking him to do, telling him that he should try to read as he normally would, that he should not feel compelled to read in any particular order, that he should pretend that I was not in the room, and that his purpose in reading the article was to come to terms with it himself, not to explain it to me. (Charney, 1993, p. 207).

Because Seymor, the first undergraduate participant and second participant overall, had trouble pronouncing a few words (primarily leaf names), I reviewed these words with Apu and Eric before their protocols. I also asked each participant a few questions about his educational background and history of reading prior to the protocol and asked them to describe the reading techniques they typically use. All four participants finished reading the article in fewer than 30 minutes (Eric, Seymor, and Apu) to about 40 minutes (John). After
the protocol, I asked them questions about their perceptions of the article. John’s session, including the protocol and interviews, lasted about 75 minutes. Eric’s session, including the protocol and interviews, lasted about 65 minutes. The undergraduates’ sessions lasted fewer than 45 minutes each (Table 1). I tape recorded the protocols and interviews and transcribed each tape. The transcriptions yielded about 45 pages of data, which I read several times to look for patterns and themes.

Table 1: Length of time of read-aloud protocol and entire session, including interviews, for each student

<table>
<thead>
<tr>
<th></th>
<th>Article</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>John</td>
<td>40 minutes</td>
<td>75 minutes</td>
</tr>
<tr>
<td>Eric</td>
<td>28 minutes</td>
<td>65 minutes</td>
</tr>
<tr>
<td>Seymor</td>
<td>25 minutes</td>
<td>40 minutes</td>
</tr>
<tr>
<td>Apu</td>
<td>25 minutes</td>
<td>40 minutes</td>
</tr>
</tbody>
</table>
Chapter 3: Data collection and analysis

In this chapter, I will describe the participants’ reading backgrounds and analyze the data I collected using the four characteristics of rhetorical reading as outlined in Chapter 1.

Participants’ reading backgrounds

John’s experience with college-level English classes was limited to a series of classes called “Paideia” that he took at Luther College, a small liberal arts college in Decorah, Iowa where he earned his bachelor’s degree in physics. Paideia is also a term in rhetoric, defined by Mark Longaker as a “pedagogical tradition designed to transmit communal ideals to the ruling class through education in, among other things, rhetoric” (2005, p. 80). According to Luther’s Paideia program website, the use of the term paideia is “a recognition that life in community depends on centuries of shared wisdom.”

As a freshman in college, John took one Paideia class that combined English and history by requiring students to read and write critically about history texts. Later in his undergraduate education, he took another Paideia class that focused on an area that was more closely related to his course of study; in his case, this was astronomy. Outside of his Paideia classes, John’s reading was limited primarily to textbooks and some non-textbook reading in classes such as history and political science. In his first year of graduate school, John found that his reading became more technical and in-depth; it tended to cover specific topics rather than general background information. During our interview, he said that his reading techniques had changed primarily because he now read an article’s abstract carefully first to “make a decision about whether the article’s going to be worth reading. So there’s more of an
evaluation process prior to reading it as to whether it’s going to serve the purpose I want it
to.” In his 1988 study, Bazerman found that professional scientists tend to look for keywords
in the title of an article first, then look at the authors of the article, and finally to read the
abstract before deciding if the rest of the article is worth reading (1988, p. 241). The fact that
John now reads the abstract before the rest of the article indicates that he is beginning to use
the same strategies that Bazerman found among professional scientists.

Eric earned his undergraduate degree in mechanical engineering from the Iowa State
University, where he was also working on his master’s degree at the time of this study. Iowa
State requires that all students take a two-course sequence of first-year composition courses.
Eric tested out of the first course and took the second. He also took a junior-level class in
technical writing that is required of most of Iowa State’s engineering students. Apart from his
undergraduate English courses, Eric’s school-related reading was limited to mostly textbooks
and lecturers’ notes. He very rarely read journal articles; specifically, he “could count on one
hand” the number of articles he read as an undergraduate. During his first year of graduate
school, however, Eric said that he read at least one journal article, technical paper, or
conference proceeding per week. Although he thought that his reading had progressed since
he started college, he found that with the more difficult material he was reading in graduate
school, he had to read some material more than once to understand it.

Seymor and Apu, because they were both pursuing undergraduate degrees at Iowa
State at the time of the study, had had almost identical experiences with communication
classes: they had both taken the two-semester sequence of first-year composition as well as
an upper-level technical communication course. As an undergraduate, Seymor’s class-related
reading was primarily from textbooks and occasionally from the American Society of
Mechanical Engineering (ASME) journal. When I asked him how he thought his reading had changed during his college career, he said, “I’d say I look more for the main point now, sometimes just read the first couple of sentences in a paragraph instead of reading the whole thing.” When I asked him if he ever goes back and reads the rest, he said, “No, not usually.” However, he skipped very little text during the protocol, which may have been due to unfamiliarity or discomfort with the protocol situation.

Apu also said that throughout his undergraduate career, his class-related reading had come primarily from textbooks with only occasional articles assigned individually or as part of a course pack. When I asked him how he thought his reading had changed since he was a freshman, he replied, “I don’t think it’s changed too much. I’m not much of a reader beyond textbooks and even then I don’t read too much of those.” When I asked specifically about the methodology he used when he read assignments, he replied that he was not aware of how he read.

Because both Seymour and Apu were planning to attend graduate school in mechanical engineering, I asked them what kind of reading they expected to do once they were in graduate school. They both anticipated more research-related reading that would be focused on a single topic. Apu also said, “Obviously I’ll have to pay a lot more attention because of my thesis, and now I kind of read what I need to read to get by.” This statement reflects a similar change in purpose to Haas’s findings that Eliza’s reading purposes changed toward the end of her undergraduate years: her reading during her freshman year focused primarily on getting what she needed from the texts to do well on exams; her goals were “to learn it,” “to understand it,” or “to memorize it” (1994, pp. 59-60).
Based on the results of the interviews in my study, it seems to be unusual for undergraduate mechanical engineering students at Iowa State to be regularly assigned journal articles to read for class. Their assigned reading seems to come mostly from textbooks or, occasionally, newspaper articles; they read very few academic publications. Once they begin graduate school, however, they are immediately immersed in research. Their professors expect them to be able to read and understand journal articles and integrate them into their own research, usually with little or no discussion about how to read them. They are expected to teach themselves this skill or to ask for help from other graduate students. John told me that although he still had not done a great deal of academic reading during his first year of graduate school, he did more than he had as an undergraduate: “At Luther, I read maybe a total of four or five research articles. Here, I read about two or three per month. I know I should be reading more.” It is interesting that, although he was already doing much more academic reading than he did as an undergraduate, John felt pressured to do even more. This could have been because he was observing his peers reading more academic pieces than he was or because he realized that more of this type of reading could improve his research. Eric, who attended Iowa State for both his undergraduate and graduate work, also said that he could count the journal articles he read as an undergraduate on one hand, while in graduate school he had been reading at least one per week.

When I asked John about his introduction to academic reading in graduate school, he said that when he began his graduate work, he was not used to finding what he needed to read on his own. He worked with one of the Ph.D. students in his research group early in his first year of graduate school to learn how to look at indices and find what he needed. He also mentioned that he thought the purpose of the few academic articles he read as an
undergraduate was to show students interesting new research in the field, perhaps to pique their interest and offer general background information. In graduate school, however, he found that he was expected to adequately process the articles he read to be able to use the information in his own research.

**Data analysis**

I will analyze the data I collected based on the four characteristics of rhetorical reading as outlined in Chapter 1: nonlinear reading, questioning authority figures (researchers/authors), references to prior knowledge, and attention to illustrations. Table 2 shows the techniques used by all four participants. A capital “X” indicates that the technique made a significant appearance in the participant’s protocol; a small “x” indicates that the participant used the technique a few times but that it did not seem to be essential to how he read the article; and no “x” indicates that the participant did not use the technique.

**Table 2: Rhetorical reading techniques used by each participant**

<table>
<thead>
<tr>
<th></th>
<th>John</th>
<th>Eric</th>
<th>Seymor</th>
<th>Apu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonlinear reading</td>
<td>X</td>
<td>X</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Questioning authority</td>
<td>X</td>
<td>X</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>References to prior knowledge</td>
<td>X</td>
<td>X</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Attention to illustrations</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Nonlinear reading

Eric was the only one of the four participants to preview the article. He looked at how long it was and glanced at several of the illustrations, reading some captions before returning to the beginning of the article. Once begun, he read linearly for the most part. After asking me whether he needed to read word-for-word (to which I replied “no”), he skimmed large portions of the article although he did not appear to skip very much. Most of his rereading entailed going back to look at illustrations rather than rereading parts of the article’s main text. He did paraphrase or summarize sentences several times rather than reading them word-for-word. John reread when he wanted to make sure he understood a particular fact or concept, occasionally flipping back to a previous section. While Seymor and Apu occasionally reread, they never went back more than two sentences and their rereading usually appeared to be triggered by stumbling over a word or phrase. Studies have shown that the use of the rereading strategy can differ among various age groups (Stine-Morrow et al., 2004) and, in some scenarios, is not a reliable indicator of text comprehension. If this study were larger, I might be able to determine more accurately whether rereading is as much a characteristic of critical reading as other types of nonlinear reading.

Both John and Seymor incorrectly recalled pieces of information. John checked the information to see if he was correct: “The chamise samples were separated from the broad leaf samples.... I had to look because for some reason I remembered the chamise samples being called broadleaf samples above, but I see that they weren’t.” Seymor did not check: “Gas temperatures ... were shown to be repeatable to plus or minus twenty degrees C. That’s interesting, I thought it was 17.” The temperature 17°C does appear in the article, but not in
reference to gas temperature. John and Seymor’s different reactions to incorrectly recalled information indicate the difference in their willingness to reread: Seymor was so unwilling to reread that even when he questioned a piece of information he did not double-check it.

**Questioning authority figures**

Because the transcripts contained a relatively large volume of data about questioning authority figures, I have organized this section into subsections on graduate students (which is also organized into more specific subsections) and undergraduates.

**Graduate students**

John and Eric were far more willing to question authority than were Seymor and Apu. Eric made a few comments about the shortcomings of the article while he was reading it, but most of his criticism occurred during the post-protocol interview. As soon as he reached the end of the article, he looked at the references to see when the newest one was published (2003), then at the article’s copyright information to see when it was published (2004). When he saw this information, Eric seemed surprised: “There’s nothing earth-shattering here.” John, however, commented on the quality of the article both while he was reading it and during the post-protocol interview. He questioned the authors’ methodology, their findings, and the way they organized the presentation of their findings.

**Inclusion and exclusion of information**

One important issue for John seemed to be how the authors decided what to include and what to leave out. The first time he questioned this was in the “experiment description” section of the protocol article, when the authors claimed that they used standard techniques to measure gas temperature but did not describe those techniques. Later, he questioned their
methodology when they claimed, in the “specific objectives” section, that they wanted to study the combustion behavior of freshly cut leaves despite the fact that earlier in the article they had stated that the leaves had to be shipped from California to Utah. John also questioned the authors’ classification of the leaves as “freshly cut” because they had been shipped, albeit via express mail, from California to Utah and had been sitting in the lab for several days.

Eric questioned this point as well. When the authors stated that the “effects of moisture content [after the leaves had been shipped from California and had been sitting in the lab] are currently being explored” (Engstrom et al. 2004, p. 1579), Eric commented that he “would think that would make more of a difference.” In the same section, John became annoyed because of the number of times the authors repeat the names of the leaves (manzanita, oak, ceanothus, and chamise). I suspect that if he had been reading the article to himself rather than out loud, the repetition of the leaf names may not have bothered him as much because he would have been able to skip over them more easily. Eric was also annoyed with the number of times the authors repeated certain pieces of information. Although he excused the repetition to a certain degree, his final judgment seemed to be that there was too much: “They, like in many journal articles, repeat a lot of the same information several times over…. It seems like this article in particular mentions things more repeatedly than others. Which … reinforces what their main point is, but they could go through it a little bit quicker.”

*Article structure*

At the end of the “specific objectives” section, John paused to say that the article didn’t flow very well and that he didn’t “necessarily like the placement of all the data.”
During his post-protocol interview, Eric also mentioned that the article could have been organized better: "They did bring up good points at the end that they probably should have mentioned to begin with." According to Charney, commenting on or trying to come to grips with the structure of the article is another sign of active reading habits displayed by more experienced readers (1993, p. 216).

**Intuitive information**

Throughout the protocol, John made several comments about whether he thought a piece of data or a concept made sense or was intuitive. Initially, I grouped these comments together, but while analyzing the transcripts I realized that his comments in this category changed from being primarily "that makes sense" toward the beginning of the article to variations of "that's intuitive" toward the end of the article. Until page six (of 11 pages) of the protocol section of the manuscript, 100% (six of six) of John’s comments in this category were some variation of "that makes sense." By the final page, only 62.5% (15 of 24) of his comments in this category were a variation of "that makes sense"; the remainder were comments about how intuitive or obvious the information was. One of his comments in the "conclusions and recommendations" section was, "[This is] all kind of boring because it seems very, very intuitive."

In the post-protocol interview, when I asked John about his opinion of the article, he replied, "It seemed like a lot of things that an engineer with some background should know pretty easily and that a lot of the data really verified common knowledge." John’s shift from saying that the author’s findings made sense to saying that they were intuitive or even obvious or boring indicates that, around the middle of the article, he became more frustrated with the presentation of what he considered to be unnecessary, intuitive data and that he
questioned the value of the article. In fact, in the article’s conclusion, John said of the authors’ list of future work, “That seems to me like a list of problems with their experiment and pretty much all of them I thought about as I was going through it, in a sense. It kind of feeds the question of what is the true value of what they’ve done here.”

Eric also made comments that indicated frustration with the repetition of certain information. Instead of being concerned with information that he felt was intuitive, at four points in the article Eric made comments such as “We knew that from before [in the article].” Combined with Eric’s post-protocol interview comment about the amount of repetition in the article, these comments seem to indicate that he felt that all the repetition was unnecessary.

Undergraduates

Seymor made no comments indicating that he questioned the authors’ claims during the protocol. However, when I asked him about his general impression of the article, he said that he found it interesting that they were trying to model forest fires, but that he did not think their way of modeling would be accurate because “it seemed like all they did was put the leaves over a burner to see how fast it was going to take for them to start on fire.” Seymor had the same general concern with the article that John did: the data didn’t mean very much. The fact that he didn’t say anything about this during the protocol, in addition to the difference in his description of his reading techniques and the way he actually read this article, could indicate that he felt some discomfort with the read-aloud protocol rather than that he didn’t notice the problem with the authors’ methodology while he was reading.

Apu, like Seymor, did not make any comments indicating that he questioned the authors during the protocol. However, during the post-protocol interview, while describing a phenomenon with the burning leaves that he found interesting, he said, “[The authors] should
have explained why [that happened].” Eric also mentioned that phenomenon during his post-protocol interview, saying that he had learned why it happened in a graduate-level combustion class and that “before [he] took combustion, [he] would have thought that was pretty cool, but that’s the way most combustion goes.” He went on to say, “There was probably … a gas phase before the ignition around the edge of the leaves, which they failed to mention in here.” Unlike Eric, Apu did not have the background knowledge to understand why what he viewed as a strange phenomenon occurred.

Seymor and Apu also experienced some awkwardness with the use of the phrase “data were” throughout the article; they repeatedly read it as “data was.” When I asked Seymor about his impression of the authors, he mentioned that “‘were’ didn’t really flow right,” but he also said that he wasn’t sure if “were” or “was” would be grammatically correct. Apu also mentioned in his interview that “some of the sentences were confusing.” The fact that these sentence-level issues bothered Seymor and Apu so much but that John and Eric did not notice them at all could be an effect of the small amount of school-related reading they have done and their lack of familiarity with academic writing.

Attention to illustrations

The transcripts also contained a relatively large volume of data about attention to illustrations, so I have organized this section into subsections on graduate students and undergraduates.

Graduate students

Illustrations were very important to John, who looked at all of them in the article except one, which he did not notice until he had finished reading. This could have been
because the reference to the image within the text is surrounded by leaf names that were unfamiliar to him (Engstrom et al., 2004, p. 1579). Because the image is large and prominently positioned—it occupies the top third of the third page of the article—I was surprised that he didn’t notice it even without seeing the textual reference. However, if he thought it was not referred to in the text, he may have thought it was unimportant. Twice, when no illustration was available or when an illustration had not yet been referred to in the text (i.e., if there was a description of a piece of equipment of a process that was pictured on another page but no textual reference to go with that description), John tried to picture the equipment or process in his mind before he resumed reading. When I asked him about the quality of the images in the post-protocol interview, he said, “The graph made sense, [but] the pictures were unclear…. With a little bit of knowledge about combustion and how they explained [the pictures], and then what you see, you can kind of pull it together.” So although John thought the photographs were unclear, he was willing to put effort into integrating the information he had in order to make sense of them.

Eric also paid attention to the illustrations, though not to the extent that John did. He agreed with John on the quality of the different types of illustrations in the article; he was disappointed by the fact that the photographs were in black and white, but he thought that the charts and graphs “seemed pretty professional…. And the way they label their figures looks all right.” He also mentioned the need to pull together pieces of information to understand what they were saying. In discussing the photograph of the experimental apparatus (p. 1580), Eric said, “That picture looked kind of small and a little crowded … so you maybe had to piece stuff together, but I think you could figure out what their apparatus was and repeat [the study] if you desired to.”
**Undergraduate students**

Seymor and Apu hardly looked at the illustrations but indicated that they thought the illustrations were bad. With one or two minor exceptions, they did not read the captions to try to piece together what the authors were trying to show them. I asked them their opinion of the illustrations, but I did not ask why they didn’t spend more time looking at them. It is possible that they typically don’t look at illustrations when they read. During Seymor’s post-protocol interview, he said that he thought the illustrations that showed data were “kind of crowded,” and that the fact that all of the illustrations, including charts and graphs, were black and white was “not good.” When I asked Apu about the illustrations, he replied, “I didn’t think they were very good. I glanced at them, but I didn’t really get anything from them from glancing quickly, so I didn’t look any longer.” Seymor and Apu did not attempt to integrate information from the illustrations with information from the text to understand what the authors were saying.

Seymor and Apu’s attitude toward illustrations could be caused by their prior experience with illustrations used in their academic reading (i.e., textbooks). Philippa Benson (1997) studied problem detection rates and methods of experts in publishing, editing, and biology who are involved in writing instructional materials. She asked the experts to perform think-aloud protocols while studying three text/illustration combinations typical of those that appear in high school biology textbooks. First-year college students in biology also participated in the study to provide a comparison between how experts predicted their audience would interpret the text and how the audience actually interpreted it. Benson found that the experts had strong, often incorrect, characterizations of the students in mind as they
read the texts; they viewed students as "having limited topic knowledge and [being] less than optimally motivated learners" (p. 154). Benson blamed the experts’ tendency to overlook problems in the visual/verbal passages she gave them in part on their classification of students as unmotivated. If experts’ attitudes toward students lead them to overlook problems with textbook illustrations and captions, students’ tendency to disregard illustrations in their academic reading should not be surprising. Even if students still view textbook authors as authority figures within the field, problems that they detect even subconsciously with illustrations in textbooks could cause them to disregard illustrations in other academic writing.

References to prior knowledge

The amount of prior domain knowledge possessed by readers makes a significant difference in how they process what they read (Paul & Charney, 1995; Miller et al., 2004). For the purposes of this study, I define “references to prior knowledge” as references to knowledge that the participants had probably acquired from classes or experience during their college careers.

John made two references to prior knowledge. When the authors stated that leaf shape affected time to ignition but chemical composition determined ignition temperature, he said, “That makes sense based on what I know about combustion.” When the authors said that the class to which a piece of vegetation belongs (e.g., leaves vs. bark) makes more difference in pyrolysis behavior than differences in leaf species, John said, “That makes sense to me because of the composition.” When I asked John about his background knowledge on the
article's topic in the post-protocol interview, he said that he had taken a class on combustion
the previous semester, so the knowledge was fresh in his mind.

Eric made three references to prior knowledge. When the authors described how they
measured gas temperatures using thermocouples (Engstrom et al., 2004, p. 1580), he said,
“That sounds about right from my experience a few months ago [at a stove design camp].”
When they discussed using LabVIEW, he says, “OK, I’m familiar with that.” When Eric
looked at the equations on p. 1588, he said, “OK, I’ve seen that before.” John and Eric
seemed to use prior knowledge in two ways while reading: to help them make sense of the
article and also, as indicated by statements such as “That makes sense to me” and “That
sounds about right,” to judge the quality of the article.

Apu made no references to prior knowledge, and when I asked him how much
background knowledge he had on the article's topic, he said, “Not too much.” Seymor made
one reference to prior knowledge, an inference about heat transfer in the “conclusions and
recommendations” section: “However, the time to ignition was significantly affected by the
size, shape, and orientation of the sample. The heat transferred through it probably.” I
counted this comment as a reference to prior knowledge because it was probably based on
information he acquired during one of his classes. After the protocol, Seymor said that he had
been discussing some of the article's topics with a few people during the previous week, but
had no other background knowledge on the subject.

Although the participants made few references to prior knowledge and did not link
this article to texts they had read previously, it should be noted that the graduate students,
who had more background knowledge, made more references and were more critical of the
article than the undergraduate students, who had less background knowledge.
Chapter 4: Conclusion and implications

Overall, there were significant differences in how John and Eric read the article compared to how Seymor and Apu read it despite the fact that John and Eric had only one more year of education than Seymor and Apu. There were limitations to the study, which I will describe below, followed by a summary of how my findings relate to the literature used in this study and a description of the implications of the study and possible future work.

Limitations

Because my sample size was so small, it is impossible to make meaningful generalizations about how engineering students at different levels of education read based on the data I collected. However, my data does show that John and Eric, who are graduate students, read more rhetorically than Seymor and Apu, who are undergraduates. John and Eric reread more often, questioned the authors more often, made more references to prior knowledge, and paid more attention to the illustrations in the article than did Seymor and Apu.

Such characteristics in John and Eric's reading could be caused by the development of their reading techniques and purposes that they have experienced during their first year of graduate school. However, the differences in undergraduate English classes and reading backgrounds between the undergraduates and the graduate students should also be considered. While Seymor and Apu both took the same three English classes as undergraduates, Eric tested out of the first class and John, because he attended a different school for his undergraduate work, took a different series of English classes that required
critical reading. Despite the differences between John and Eric’s reading backgrounds, they showed the same tendencies in their reading techniques.

Along with the small sample size, another shortcoming of this study is its cross-sectional nature. Despite my elimination of as many variables as possible, the fact remains that the participants are different people with different experiences and attitudes. Without longitudinal data, it is impossible to say how, individually, they have changed as readers. Finally, the read-aloud protocol methodology is itself a limitation; the participants in my study did not seem to overcome the awkwardness of the situation. However, because all four participants were under the same constraints, it is still possible to compare the reading techniques they used in this situation if not to draw definite conclusions about the reading techniques they typically use.

Relation of findings to literature

The data I collected comparing two graduate students to two undergraduates is similar in some ways to the findings of Charney and Haas. In Charney’s study, she found that “more professionally advanced readers [are] more prone to treat … text rhetorically” (1993, p. 228). The participants in her study ranged from master’s candidates who, like John, read the selected article in sequence, to a full professor. Graduate students tended to be concerned primarily with understanding the text, while the faculty were more concerned with “coming to grips with the text structurally and rhetorically” (1993, p. 216). John and Eric did not make all of the rhetorical moves that the faculty in Charney’s study made; John didn’t preview and Eric did so only briefly; and neither of them, for the most part, read nonlinearly. Nonetheless, the data I collected indicate that they did read more rhetorically than Seymour and Apu.
Haas found that Eliza, an undergraduate biology student, became more sophisticated in her reading, partly because of changes in her technique and partly because of changes in her reading purposes. As a senior Eliza, like John and Eric, paid in-depth attention to illustrations in the texts she read and was aware of the human authors behind the texts, whom she (and John and Eric) saw as fallible. Eliza’s (and John’s and Eric’s) reading purposes also changed. John said that he viewed the few research articles he read as an undergraduate simply as a means to add to his knowledge about the discipline, but as a graduate student, he was aware that he needed to apply his academic reading to his own research. In Eliza’s freshman year, she simply wanted to understand and memorize scientific concepts. As a senior, she was more concerned with gaining a place in the biological academic community (1994, p. 73).

According to Bazerman, reading purpose and prior knowledge both play important roles in the way scientists read. When scientists have little prior knowledge and are reading to fill in gaps in their knowledge, they are likely to read trustingly. Although the participants in my study made very few references to prior knowledge while reading the article, John and Eric, who had by far the most knowledge about the article’s topic, read much more critically than Seymour and Apu, who had very little knowledge about the topic. Bazerman says that scientists accept new information “based on how well they integrate the existing schema of how work should go” (1988, p. 251). The information in the article John read did not fit with his idea of how such research should be conducted or presented, and therefore he criticized both the methodology of the study and the structure of the article.
Implications and future work

Should undergraduate mechanical engineering students be expected to read more critically? If they should, how can we get them to? Because of the importance of broadening students’ knowledge bases to get them to read more critically, one strategy is to have them read more widely than simply textbooks and lecturers’ notes. Strømsø et al., who are concerned primarily with how students link multiple texts to form their knowledge base, suggest having course instructors demonstrate to students “how they use multiple sources strategically while engaged in scholarly work”; they suggest focusing teaching in part on a text’s external characteristics (e.g., its authors and setting) and on its rhetorical goals (2003, p. 143). However, they warn against confusing students with very little domain knowledge by presenting them with multiple texts; they suggest waiting until students have reached “a certain level of competence in a domain” (2003, p. 143).

Aside from broadening students’ knowledge base, encouraging them to read more widely would also cause them to become more familiar with the types of academic or professional reading that they are more likely to do throughout their careers (that is, journal articles rather than textbooks). Because reading purpose is also a factor in how people read, instructors of undergraduate students could ask them to read with different purposes in mind. As suggested by Stratman (2002), using case studies—asking students to read and analytically write about or discuss specific cases—could help students understand the different purposes for which they might read; however, inventing scenarios that truly imitate the real world and convincing students that they did might be difficult. Even though students
would know that the case studies were not “real,” such strategies might help them become more aware of how and why they read.

During his post-protocol interview, Eric made the comment that “you can never tell a good article until you’ve seen a bad one.” Based on this, another way to get students to read critically might be for instructors or professors to intentionally assign weak articles to their students. This could facilitate classroom discussion about when an article is weak and allow students to see that having their own opinions on papers written by authority figures, even if those opinions are unfavorable, is encouraged. Professors could also assign students to find at least one article per semester to read and critique. With this assignment, students would have a chance to read lower-quality articles and explain how these articles could be improved. These types of assignments would not only show students that all articles are not equal; they would also teach students what to look for in an article and strengthen their trust in their own opinions. Professors should also encourage students to understand that, as subject matter experts who write journal articles are not infallible, nor are experts who write textbooks. As shown in studies such as Benson’s (1997), problems can just as easily slip past experts who work on textbooks as experts who write and edit journal articles.

Future work in the subject area of this thesis includes performing more read-aloud protocols with engineering students so that more meaningful generalizations can be made about how engineering students read. Engineering classrooms could also be observed to see how reading and writing is currently taught to engineering students and whether there is room during the class period to improve reading skills without taking away from other important skills or information that students need to learn. Professors could encourage students to read nonlinearly, perhaps guiding them through nonlinear readings of articles.
They could teach students about the typical article format, explaining that, despite appearances, articles are not objective; that they contain arguments and that the article’s arrangement is one means authors use to get readers to agree with their points of view. Students, particularly in technical fields, are often not aware of the rhetorical strategies that authors use. If they were aware of the strategies that authors use, they might be better able to see past them to the authors’ underlying claims.

Even if getting mechanical engineering undergraduates to read more critically is not a high priority, professors of both undergraduate and graduate students should at least remember that students need experience to develop their reading techniques. They should either expect undergraduates to read less critically than professors and other professional engineers, or they should do what they can to help their students become critical readers. If professors and other field experts who work with inexperienced readers point out rhetorical reading techniques, and if students understand what is expected of them, their growth as readers could be more efficient and complete. Learning to read critically, whether during their undergraduate years or later, is extremely important for students because critical reading skills encourage critical thinking, which improves communication skills, and good communication skills are always desirable.
References


