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Teaching Engineering Students to Communicate Effectively: a Metacognitive Approach*

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This article begins with an outline of the basic skills and knowledge students must acquire to write effectively. It then examines the concept of learning to learn and presents methods for teaching students how to transfer the skills and knowledge they learn from one assignment to the next, from one course to the next. Although this article focuses on the transfer of learning in technical communication, the methods can be used in engineering as well. It explains how we can help students learn to learn by teaching them to transfer knowledge through metacognition, analogical reasoning and cognitive flexibility. The article concludes with an example of a sequence of technical communication assignments that lead toward transference regardless of whether they are being taught in a standalone communication course or as part of an engineering class.

INTRODUCTION

> *It is not sufficient . . . that engineering students only possess superior technical skills. They must also communicate well, understand how to perform in the global workplace, use creative problem-solving strategies and critical thinking skills . . .* [1, p. 150]

The need for engineering students to learn to communicate effectively has never been greater if they are to have the ideas they propose accepted, the products they design developed, and the systems they develop utilized appropriately. Today's engineering students must acquire an array of rhetorical strategies and skills that have expanded exponentially over the past twenty years. With the introduction of TQM and its concomitant concept of concurrent engineering, students must learn to communicate with an audience that not only includes their colleagues but also people in disparate fields and roles, including marketing analysts, financial resource managers, and clients, in addition to assembly line foremen and parts suppliers [2]. Furthermore, with the advent of a global economy, they need to understand how various cultures affect their readers' perceptions of a text [3, 4]. In addition, they must learn the conventions of a continually evolving set of new documents, such as environmental impact statements, incident reports, and multifaceted procedures that continue to emerge as the result of companies assuming responsibility to consumers and the environment.

Students, if they are to eventually become effective managers, also need to learn about 'needs assessments,' 'focus groups,' and 'ISO 9000' and to write the documents related to these aspects of the workplace. Moreover, verbal communication skills are no longer sufficient; PowerPoint presentations have become *de rigueur* in presenting new ideas in the workplace. Students must learn to communicate visually, designing slide and poster presentations as well as incorporating graphics into their written reports. Finally, the amount of information generated by computer data banks has created a need to present data so that it is understandable to a wide range of readers and can also be used to make far-sighted management decisions [5].

The problem for engineering departments is including all of these skills and strategies in a curriculum that is already overloaded. Either another class would have to be added to the single semester technical communication course to which most engineering students in the United States are currently exposed or all engineering courses would need to become writing-intensive. Neither is an option [1]. How then can we provide our students with all of the knowledge they need for writing effective technical discourse? The answer is 'We can't.'

It would appear that the only way we can provide for all of our students' needs is to teach them the basic concepts required for writing any engineering document and then to help them learn how to transfer these basics to the various documents, audiences and situations they will encounter. To learn to do this, students must learn to learn. For most of us, whether we teach a technical communication or an engineering course, this has always been an implied goal. However, recent research in the area of cognitive psychology

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indicates that we need to make our goal overt and that furthermore we need to introduce methods into our classroom that explicitly teach our students to learn to learn [6].

BASIC SKILLS FOR WRITING EFFECTIVE ENGINEERING DOCUMENTS

Students' major problems in writing effective discourse relate to the following rhetorical and graphical decisions.

1. Determining the content to be included and excluding information that is extraneous.
2. Keeping related information together.
3. Organizing information logically.
4. Using appropriate language and voice.
5. Determining appropriate graphics to supplement content.
6. Using appropriate conventions for a specific document.
7. Formatting and laying out a page so it is readable.

Thus, the basics for any engineering communication course must necessarily revolve around helping students learn to make these decisions so that their written discourse is effective. The criteria for making these decisions is based on the following:

- the way in which the audience will read the document;
- the purpose for the document;
- the context (economic, political, and social) in which the document will be read;
- the conventions for that particular type of document.

To determine the criteria related to the specific document they are assigned to write, students need to learn to engage in the following skills and strategies:

- analyzing their audience;
- determining the purpose for a document;
- understanding the context in which a document is being written and read;
- analyzing the conventions of a document similar to the one they are to write.

For example:

- in terms of content, if writers know that readers are familiar with background information, then they know they don't need to include it;
- in terms of style and voice, if writers know that their readers are not experts in a topic being discussed, then they know they should not use technical language;
- in terms of organization, if writers know that the readers are hostile to a proposed idea, then they know that they should organize proposals by beginning with the problem that the proposal will solve and then lead up to the solution rather than begin with the solution.

Once students learn these strategies, they must learn how to transfer them from one document to another, from one assignment to the next.

LEARNING TO LEARN THROUGH TRANSFER OF KNOWLEDGE

What do we mean when we say students have to learn to learn? What exactly must they learn to do?

In a general sense, learning to learn means that persons assigned to write a type of document that they have never written before can figure out how to write the new document effectively. In learning to learn, students must become active learners and their goals need to encompass the acquisition of procedural (process) and conditional (context) knowledge as well as content (declarative) knowledge. Weinstein [7] sees learning how to learn as the ability to convert new information into meaningful knowledge that can be used for higher-order reasoning tasks and that can be transferred to new demands and contexts.

The term 'transfer' is the key to learning to learn. To learn to learn students must be able to transfer appropriate prior procedural knowledge to a new task. Transfer occurs along two paths: the 'low road' and the 'high road' [8]. Low road transfer occurs unconsciously while 'high road transfer' is based on conscious behavior. In this article we will focus on high road transfer since it is the result of a conscious decision to use a specific procedure to solve a specific problem. For example, when we are responding to an RFP (Request for Proposal), we consciously consider a number of potential strategies that fulfill this request and then select the one that most nearly matches our resources to our readers' needs. We may have learned about the various strategies in a formal course or workshop, or we may have learned about them informally in a conversation with a colleague who talked about how she worked in a similar situation, or we may have read about them in a journal article. Regardless of how we learned the strategies, they are based on our prior experience and knowledge which we internalized in our long-term memory where we could retrieve them when we needed them.

For some of us, transferring the procedures we used for one task to solve a new task seems obvious. However, many of our students do not engage in 'high road' transfer when they are faced with a new writing assignment.

There are several reasons for their failure to do so. One is that they seldom think of assignments in reading and writing as problem-solving tasks. But if students are to understand that they can transfer the knowledge that they acquire in one writing assignment to another, then they need to perceive their lessons as more than the acquisition of pieces of information and sets of rules. They need to perceive their writing assignments as problems to be solved rather than as templates in which information can simply be inserted according to a set of rules.

Another reason for their failure, and one that is closely related to the first, is that students often perceive the content knowledge they learn as independent bits of information rather than as parts of larger related constructs and schema. They perceive a letter of request for information as different from a letter requesting reimbursement for a damaged product and file each of these subgenres in their memory as separate entities without recognizing that the strategies for writing both are analogous. Thus they fail to build bridges that relate their prior knowledge to new learning tasks and therefore cannot transfer knowledge across tasks [9].

For students to transfer information, they must recognize that they have not only acquired content information but that they have also acquired procedural knowledge related to the processes they used to accomplish their task and dependent upon the conditional knowledge of the context under which those tasks were conducted. To become aware of the procedures they are using to accomplish a task or solve a problem, students need to engage in forward- and backward-reaching transfer using metacognition.

ENGAGING IN FORWARD- AND BACKWARD-REACHING TRANSFER THROUGH METACOGNITION

'Forward-reaching transfer' involves recognizing that strategies used to solve one problem can be used to solve other future problems [8, 10]. This recognition causes the brain to store the strategies in the chunks of our memory related to those future problems, thus, enabling us to locate them when we need them which is 'backward-reaching' transfer. Faced with a new problem, we search our memories for knowledge that might help us solve it. If that knowledge was stored through forward-reaching transfer, then we should be able to retrieve it.

It is the ability of 'intelligent novices' to use forward-reaching high road transfer that enables them to retrieve appropriate processes for acquiring new skills or learning new knowledge more quickly than others [11, p. 453]. The key is that the processes have been consciously learned and stored. We can make these processes conscious for our students by asking them to engage in metacognition.

Metacognition

Metacognition is the act of thinking about thinking. Metacognition requires that, as students engage in various activities, they reflect on their thinking processes, the heuristics they are using, to determine what they are thinking and how they translate their ideas into actions. Brown found that when students become consciously aware of the heuristics they use and then internalize them, they not only learn 'how to get a particular task done independently, but how to set about learning new tasks, and are able to transfer the process knowledge that has been acquired from one task to the next' [12, p. 65].

Students need to take the time at the conclusion of a lesson to reflect on the strategies they have just used and to consider how they might use these same strategies in solving future problems (forward-reaching transfer). They also need to take time during the planning phase of the problem to reflect on previous tasks that might be analogous to the one on which they are working and to consider whether the procedural knowledge they used to complete the previous task can be used to solve the new one (backward-reaching transfer).

DEVELOPING ANALOGICAL REASONING THROUGH REFLECTION

Because transfer of knowledge requires that students compare their new task to previous ones in their search for appropriate heuristics, they need to become adept at analogical reasoning. They need to recognize the similarities and differences between tasks. 'Analogy is a device for conveying that two situations or domains share relational structure despite arbitrary degrees of difference in the objects that make up the domains. Common relations are essential to analogy: common objects are not' [13, p. 45].

The problem encountered by most people, regardless of whether they are interpreting a metaphor or transferring information, is in recognizing analogous features. In transferring knowledge people often have difficulty differentiating between those aspects that directly affect a solution and those that do not [14, 15]. After completing a segment on writing letters requesting a change in plant-specific procedures in a workshop at a nuclear power plant, I was asked to provide a segment on writing letters recommending changes in procedures being proposed for the industry. The nuclear engineers with whom I was working did not recognize that the basic heuristics for writing workplace correspondence are the same. Regardless of whether it is a letter of request or a recommendation letter, the writer must analyze the audience, purpose, and context for the document in order to determine the focus, content, organization, style and format of the document. Rather than focusing on the similarities in the procedural knowledge required to complete the task, the engineers focused on the differences between the purposes for the letters and the conventions of the two subgenres.

Another problem with analogical transfer is that many people have a tendency to generalize a procedure; they want to use it for many similar tasks without realizing that critical aspects of these tasks are not analogous. Much of the writing engineering students do in college is related to lab reports. The conventional organizational structure for a lab report requires that events be recorded in chronological order. Because engineers are familiar with using this organizational pattern, they often apply it to any document they write, without recognizing that in some situations the structure is inappropriate.

Engineers at a nuclear utility plant managed by the Tennessee Valley Authority misapplied this chronological structure to a letter to the Nuclear Regulatory Commission requesting a reduction in a fine that had been levied against the utility for failing to fix a problem in 'a timely manner'. Guidelines indicated that for a utility to obtain a reduction, it needed to prove that it had done all it could to solve the problem for which it was being fined. However, instead of beginning the letter with a list of the utility's efforts to solve the problem, the engineers at TVA began with a chronological narrative of everything that had gone wrong, thus reinforcing readers' perceptions of the utility's inefficiency in solving the problems. In this case, the engineers were applying backward-reaching transfer, but the analogies were not valid; they had failed to recognize that the purpose of the document was not analogous to that of a lab report and that therefore a different organizational structure was needed.

The ability to recognize conditional differences in relatively similar problems and to understand that these differences may require different procedures for finding a solution or to recognize similarities in what appear to be dissimilar tasks and to determine the appropriateness of using previous procedures for completing these tasks successfully is called cognitive flexibility [16]. Students need to recognize that a direct correlation does not always exist between a strategy and a solution. Rather real-world situations are 'messy' and a strategy they used to solve one problem may not solve the next because the context for the new one differs from that of the previous one. By reflecting on the reason a strategy that worked on a previous project is inappropriate for a new one, students can begin to develop criteria for determining valid analogies.

To help students develop cognitive flexibility we need to design assignments that involve a wide variety of tasks so that they can build a repertoire of strategies for solving problems that are similar in some aspects and different in others. By sequencing the assignments so that students can use some but not all of the procedural and conditional knowledge they acquire in the first task to engage in the next task and by explicitly discussing this situation with our classes, we can help them develop cognitive flexibility.

These methods for helping students learn to transfer information are not limited to courses in technical communication. Rather these transfer methodologies can be adapted to many engineering courses in which a series of problem-solving assignments that follow a developmental sequence can be designed.

DESIGNING A SEQUENCE OF DEVELOPMENTAL ASSIGNMENTS

A series of assignments in my class, Writing in Engineering Fields, revolves around a proposal for change. The assignment involves four documents—a memo of request, a progress report, a proposal, and a recommendation report. These documents are designed along a continuum, allowing students to build on the strategies they learn while writing one document to write the next. Students learn to transfer the strategies they learn in writing the first document to writing each of the succeeding documents. Students not only learn the rhetorical strategies for writing the documents, but they also acquire the procedural and conditional knowledge necessary for learning to write new texts. Furthermore, by using reflection and metacognition throughout the lessons, students learn forward- and backward-reaching transfer, analogical reasoning, and cognitive flexibility. This series of assignments could easily be integrated into an engineering design course in which students are assigned to develop a design in response to an RFP.

The prompt for the assignment involves responding to a Request for a Proposal (RFP) for funding an improvement or change to some physical aspect of the university campus that would require knowledge in the field of engineering. According to the scenario, the RFP has been issued by the Director of the Physical Facilities Department. However, final approval of the project has to be made by the COO (Chief Operating Officer) and the University President.

Assignment #1

Students write a memo to me in the role of their supervisor, requesting permission to work on the response. Once I've approved their request, they spend the next five weeks developing the proposal as both a written report and as a five minute oral presentation. At the end of the second week, they are required to submit a progress report so I, once again in the role of their supervisor, know whether they are on target and will complete the assignment by the deadline. During the sixth week, they present their ideas in a PowerPoint slide presentation to a small group of their peers who assume the roles of the Director of Physical Facilities, a budget manager in the Fiscal Affairs Office, and the Executive Assistant to the University President. At the end of their presentation they provide each member of the group with a written copy of their proposal. Each member must then write a recommendation report, indicating whether or not the proposal should be accepted. This process closely resembles that used by industry and is relatively realistic as the students are examining an actual aspect of the university.

Despite the fact that the first assignment appears to be a fairly simple one, it involves all of the basic concepts students must acquire to write effective documents. From the beginning of the class, I help students perceive their assignment as a series of problems to be solved by asking them to list the questions they need to answer to write this document.

The list always includes the following six questions.

1. What content should be included?
2. What style of language (technical or lay) and what grammar (imperative, active voice as in instructions, or declarative, passive voice, as in a report) should be used?
3. What voice (1st, 2nd, or 3rd person, formal or informal) should be used?
4. How should the information be organized and sequenced?
5. How should the document be formatted?
6. How should the document look?

I help them discover the heuristics for answering these questions by asking them to consider the major decisions they make whenever they write a paper. Thus, by asking them to engage in backward-reaching transfer, they discover they must answer the following set of questions before they can find the answers to the previous ones

1. What is the information that the audience needs to know?
2. What is the information the audience already knows, including the technical terminology?
3. What is the information that will be most important for the audience to know based on the audience's purpose and biases?
4. How do I obtain the information for the content?
5. What are the conventions in terms of style, grammar, voice, organization and format for that type of document?
6. How are graphics and visual text, such as headings, typography, and page layout used in this type of document?

Students then consider the procedures they have used previously in solving these questions. By using forward- and backward-reaching transfer, they determine the following.

- To solve questions about audience, they should either make a guesstimate by referring to their previous knowledge of the people who read these documents, or they should conduct an audience analysis through interviews, surveys, or focus groups,
- To solve questions about the presentation of information, they should refer to documents discussed or used as models in textbooks or to similar documents that were written previously.
- To solve questions about gathering information for the content, they should consult other persons with knowledge of the subject, investigate written and electronic sources, observe a situation, or reflect on their own work.

As a class activity, we then go about guesstimating the audience's knowledge, purpose and context and from the results of this analysis determine the content, style and voice, and sequence of information for the memo they will write. They are then assigned to read the section on request memoranda in their textbooks in order to determine the conventions and the way in which the content should be presented. In addition they study copies of several model memoranda from local industries. I use the latter activity to help students learn to 'read like a writer' [17]. By examining the model, not in terms of its content, but in terms of its rhetorical aspects, students can discover the organizational pattern for the information, the language that is used, the writer's voice, the type of visual text, whether graphics are included, and the general layout of the document. To obtain the actual information they need to write this memo, students must either recall a problem on the campus, tour the university to observe a situation that needs to be remedied, or interview people about such a problem. At the conclusion of the activity, the class engages in metacognition to review the heuristics and procedural strategies used to determine how to write the document. Then, to engage them in forward-reaching transfer, I ask them to consider how they might use these strategies in future assignments.

Assignment #2

This assignment is a progress report. While students write it for the same audience, that is their supervisor, their purpose—to provide the reader with information about what they have been doing—is different as are the conventions for this document. I begin with a class activity involving backward-reaching transfer. I review the strategies and conventions that were used in the last project, listing the various aspects on the board. Then in an exercise in analogical reasoning, I ask students to consider which of the procedures they've previously listed might be relevant for the new document. These are asterisked. The exercise permits students to discover that all of the procedures appear to be relevant.

At this point, I begin to move students toward accepting more responsibility for their learning by requiring that they work individually rather than as a class to solve questions about gathering and presenting the information. After students have arrived at their own conclusions, we discuss their findings as a class activity. One of the things they realize is that the conventions differ from those in the previous document and they conclude that the reason for this deviation is the differences in purpose. Thus, in addition to helping students learn the domain-specific heuristics for writing a technical document by engaging in metacognition, I help them develop analogical reasoning and acquire cognitive flexibility. They then go on to write their progress reports.

After they submit their documents, I ask them to review the procedures they used to determine how they should write the new document. Although most of the items are the same as those listed previously, students discover that referring to their previous experience is a new strategy, and they add the following procedure to their list: 'Consider the procedures that have been used previously and select those that can be used to determine how to write a new document.' In addition to reviewing their strategies and in an effort to help them understand how conditional knowledge affects the decisions they make in relation to their texts, I ask them to consider the reason some of the conventions deviated from the previous document. After some discussion, they recognize that the change in the conventions related to the context in which the document would be read, and so they add this item to their list: 'Consider the context in which the document will be written and read.'

Once again engaging them in forward-reaching transfer, I ask them to consider how they might use this knowledge in future assignments. Recognizing that they could begin to figure out how to write the new document by selecting from the procedures they used previously those that were applicable to the new document, they added the following item to their list: 'Consider previous strategies and select those that are applicable to the new project.'

Assignment #3

To reinforce the need for cognitive flexibility, I engage the students in the same activities for writing the third document as I did for the second, but this time I not only assign a different type of document, that is, a proposal for a change in the workplace, but a different audience—those who will be involved in deciding whether to fund the proposal. I also move the students further along the continuum for assuming individual responsibility for their own learning by replacing class activities, except for the opening and closing review sessions, with individual activities.

Assignment #4

This final document is a report recommending one of the proposals submitted by the students for funding. Not only are there no class activities but students do not receive step-by-step instructions on what they should do. They simply receive the prompt for the assignment and are then left to work on their own. Most of the students have learned what to do. They do not ask 'How long should the report be?' or 'Should we include graphics?' They know how to find the answers to these questions. For those few students who still want the teacher to provide the answers, I simply respond to their questions by asking them a question in return. For example, in response to 'How long should the paper be?' I ask, 'What are the basic criteria for determining that?' By responding 'the audience,' students recognize that they can answer this question themselves. 'Long enough to include all of the information the audience needs to understand the message.' And they also know that this is a 'messy' answer, that it is a judgment call.

MINI-LESSONS

Throughout the course I provide mini lessons of approximately 20 minutes in various aspects of technical writing. These include reading to write, writing for an audience, the revision process, organizing information, use of graphics, document layout and format, and learning from failure.

Reading to write

Students cannot write documents that they have never seen or read and many students are unfamiliar with technical documents. Therefore, before students write an assignment, I provide them with models of documents from industry that are in the same genre (memos, progress reports, proposals for change) as those they are assigned to write. The class studies these documents, not in terms of their content, but rather in terms of the following rhetorical aspects.

- *Content*—The amount and kinds of information, e.g. background information, detail, statistics, etc.
- *Organization*—The organizational pattern, e.g. cause/effect, comparison/contrast, chronological, etc.
- *Style/voice*—The way a document sounds, e.g. formal or informal, personal or impersonal, subjective or objective; use of first, second or third person; technical or lay vocabulary.
- *Text grammar*—The grammatical forms used, e.g. active or passive voice, imperative or indicative mood.
- *Graphics*—The visuals, e.g. diagrams, photographs, charts, etc.
- *Layout*—The way a document looks, e.g. headings and subheadings, columns, boxes, etc.

After examining several models in a specific genre, students develop the story schema for that genre and are able to reproduce it better than if they are simply lectured about it.

Writing for an audience

Engineers write for three types of audiences: experts in their field; generalists, such as marketing people who know something about their field; and novices who know very little about their field. Students need to learn to write differently for different readers, for example, they should not use technical terminology if readers are unfamiliar with their topic.

The revision process

Students need to learn to revise by recognizing problems and errors in their own texts. I help them improve their proficiency in doing so by requiring them to maintain a chart of their errors each time I return a set of papers to them (See Fig. 1). Prior to their submitting their next paper, I tell them to use their chart as a check list to make certain that they have not repeated those errors.

The revision process involves three phases: macrorevision (determining if the document as a whole makes sense), microrevision (checking paragraphs, sentences, and vocabulary), and proofreading (eliminating grammar, usage, punctuation and spelling errors). Using peer response groups, I lead students through these three phases during their first assignment. After that I expect them to engage in the process, including obtaining peer response, on their own.

LEARNING FROM FAILURE

List the errors from your returned paper in the respective column. Then indicate what you need to do to correct the error. When you are ready to proofread your new paper, go through the list of errors on each previous paper. Look through your new paper to make certain you have not made the same errors. If you have done so, correct them.

My Errors Paper #1 Letter of Application and Resume	**My Errors Paper #2** Progress Report	**My Errors Paper #3** Proposal	**My Errors Paper #4** Recommendation Report	**My Errors Paper #5**
1. Incorrect capitalization. Don't capitalize the words "major" or "minor" when talking about your courses. 2. Misuse of semicolon. Use a comma, not a semicolon after the word "however." 3. Missing details. Specify names of places if they haven't been mentioned previously. 4. Use the transition "In addition" when additing an item to a list.	1.Comma placement. Commas should be placed after an introductory clause or phrase. 2. Word usage. Don't need to use word "quantified" in analysis. Use "between" instead of "from-to." 3. Word tense. Should be "supporting information **for** the proposal," not "**of** the proposal." 4. Missing details. Specify topic of research, types of information gotten.	1.Don't use "we" in a proposal. 2. Misplaced comma. Commas should be used before an (ing) phrase. 3. Verb tense. Don't use will if not referring to future. Use "would."		

Fig. 1. Chart of errors and corrections.

RUBRICS FOR GRADES

Grade	Audience Awareness	Content/Focus	Organization	Style/Voice/ Text Grammar	Graphics	Format	Basic writing: Syntax, Vocabulary, Mechanics
A Students must achieve at this level on all of criteria	Recognizes audience and writes appropriately.	Focuses on appropriate topic. Provides information audience needs and wants to know. Sufficient detail for audience to understand message. No unnecessary information.	Uses conventional organizational pattern, sequences information logically and chunks related information.	Uses vocabulary/voice appropriate to audience, uses text grammar appropriate to convention.	Uses graphics appropriately and where needed. Provides appropriate titles, captions, etc.	Uses conventional format, uses headings and subheadings appropriately and according to convention. Document appears readable.	Writing is easy to read, no errors in vocabulary, syntax, grammar, usage, spelling.
B Students must achieve at least at this level on all criteria	Recognizes audience and writes appropriately.	Focuses on appropriate topic. Provides most of the information readers need/ want to know. Sufficient detail for audience to understand message. Almost no unnecessary information.	Uses conventional organizational pattern, sequences information logically and chunks related information.	Uses vocabulary/voice appropriate to audience most of the time, uses text grammar appropriate to convention.	Uses graphics appropriately and where needed. Provides appropriate titles, captions, etc.	Uses conventional format, uses headings and subheadings appropriately and according to convention. Document appears readable.	Writing is easy to read, only one or two errors in vocabulary, syntax, grammar, usage, spelling.
C Students must achieve at least at this level on all criteria	Recognizes audience and mainly writes appropriately.	Focuses on appropriate topic most of the time. Provides most of the information readers need and want to know and most of the detail audience needs to understand message. Almost no unnecessary information.	Uses conventional organizational pattern, most information is sequenced logically and most related information is chunked.	Uses vocabulary/voice appropriate to audience most of the time, uses most of the text grammar appropriate to convention.	Uses graphics appropriately and where needed most of the time. Provides in the main appropriate titles, captions, etc.	Uses conventional format, uses headings and subheadings appropriately and according to convention most of the time. Document appears readable.	Writing is fairly easy to read, several errors in vocabulary, syntax, grammar, usage, spelling.
F Students receive a failing grade if their document meets any of these criteria	Does not write appropriately for audience.	Does not focus on topic. Fails to provide most of the information audience needs and wants to know. Omits many details audience needs to understand message and/or includes much unnecessary information.	Fails to use conventional organizational pattern, information is not sequenced logically. Related information is not chunked.	Does not use vocabulary/voice appropriate to audience much of the time, does not use text grammar appropriate to convention.	Uses graphics inappropriately. Does not include graphics when needed most of the time. Fails to provide appropriate titles, captions, etc. most of the time.	Often does not use conventional format, fails to use headings and subheadings appropriately and according to convention much of the time. Document is difficult to read.	Writing is difficult to read, numerous errors in vocabulary, syntax, grammar, usage, spelling.

Fig. 2. Matrix of rubrics for grades.

Organizing information

I provide students with exercises, using previous students' drafts, to help them learn to organize their texts by chunking related pieces of information together.

Graphics

Students learn the various types of graphics, how these graphics are used, how they are cited in text, and how to write headings and captions for them.

Document layout and format

Students learn how headings and subheadings are used; how graphics are placed within a document; when to use columns, and the kinds of ancillary material included in a long document, including Table of Contents, Glossary, Appendix, etc. Students also learn how to emphasize text using various typefaces or fonts, boxes, etc.

ASSESSMENT/EVALUATION

Students' papers are evaluated according to a set of rubrics that involve basic composition knowledge, such as grammar and punctuation, as well as the rhetorical aspects listed above. Students cannot receive a passing grade if they do not have a basic knowledge of composition. To receive an A grade, students need to have excelled in each rhetorical area. Figure 2 provides the matrix I use for grading.

The majority of students receive a grade of C or B indicating that they have acquired basic mastery of the various rhetorical areas. While their documents may not be elegant, they have at least learned to write technical documents so that their readers understand their message.

CONCLUSIONS

By the end of the term, most of the students have learned to transfer their knowledge from one task to the next as well as to take responsibility for their own learning. While they may have learned to write only four specific types of documents, they have learned to figure out how to write any type of engineering document. Although they may not have fully mastered the use of commas, or acquired a sense of how much detail they need to include in a document, they are now aware of these areas of concern and conscious that they need to check on these aspects when they write. They have learned to learn.

A number of students who have taken this course have told me how the strategies they learned in class helped them in their jobs.

David, a non-traditional student who was working in a plant that makes molds for the plastic industry, wrote a proposal to make one of the machines more efficient after noticing that it was not being used to maximum capacity. Not only was his proposal accepted by the company, but his manager was so impressed with the proposal that David was asked to work on a plan to improve another aspect of his division. By applying what he had learned to write the first proposal, i.e. using forward- and backward-reaching transfer, David was able to fulfill this assignment. 'My boss changed his view of me after I researched [my] idea and presented it effectively,' he wrote to me. It was not long after that that he received a promotion.

Cindy was another student who learned how to apply what she had learned in school to the tasks she was given in the workplace. Shortly after graduating, she was asked to compile a catalog for a training manual, a type of document that she had never learned to design. When she showed me the completed document, I was amazed at how well she had put it together. 'You told us we should look at similar documents,' she explained, 'so I found one I really liked [on automobiles] and adapted it.' Cindy had learned to read like a writer.

Mark, another non-traditional student who was working in the steel industry, commented after the class mini session on revision that he had finally become convinced that peer editing helps and he planned to use it at work.

By teaching students to learn to learn, we are not only preparing them for an unknown distant future, but we are also providing them with the skills and strategies necessary to tackle new assignments in the jobs they are doing today. It is apparent that we cannot prepare our engineering graduates of today by instructing them only in content-specific areas. What we can and must do is teach them to learn to learn.

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