Introducing Technical Articles to Graduate Students Through Active Learning

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Abstract

In their undergraduate studies, students obtain most of their information from textbooks and handbooks. Yet for graduate students, it is often necessary to obtain more current information that is only available in technical articles. Many entering graduate students are unaware of the role of journal articles in research and are not informed about the article submission process. Although this knowledge is important to their careers, it is rarely included in coursework. To correct this, students are required to read assigned technical articles and be prepared to discuss them in class. In addition to the traditional discussions addressing the technical points in the articles, the role of articles in research is discussed. The goal of these discussions is to prepare students for research by teaching the students how to read technical articles and by teaching them about the article submission process. Since studies have shown that students retain more information through active learning than through passive learning, class discussion is used to encourage reading and active participation. This in-class discussion of technical articles has been implemented in a graduate level thermodynamics course in chemical engineering. Since thermodynamics is one of the required core courses for the first-year graduate students, it provides an opportunity to prepare entering graduate students for research. This approach was assessed using an initial survey at the beginning of the semester and a final survey at the end of the semester. Results of the assessment are presented.

Introduction

Traditionally, technical articles are assigned in courses in order to convey technical information. While this is often the main reason to have students study journal articles, educators have used articles to meet other teaching objectives as well. One such objective is to improve critical thinking by having the students review a journal article and summarize the main points, as well as evaluate the value of the research (1, 2). Another objective is to use journal articles to improve writing skills. This was implemented in a general chemistry laboratory (3) where students listed the sections of a journal article. In the process, they learned how journal articles were organized. Journal articles were also used for improving both critical thinking and writing skills in a chemical process safety course (4). To develop critical thinking, students were asked to evaluate the paper to determine the main results and whether the assumptions were realistic. Other educators emphasize that it is necessary to teach students how to do research. One research skill that needs to be taught is to learn how to locate previously done work on a topic and then critically evaluate the previous work (5). One approach to this was to ask students to write summaries of selected journal articles and comment on any flaws in the reasoning. A similar approach was used in a graduate level chemical engineering kinetics class (6) where the students present the summaries in class and discuss the papers.

To be successful at the graduate level, students need to become familiar with the current technical literature to keep up to date (5). The primary goal of this effort is to prepare students for research by expanding their information sources to technical journals and by helping them understand the role of technical articles in research. Since studies have shown that students retain more information through active learning than through passive learning (7, 8), class discussion is used to encourage reading and active participation.

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Implementation

During the semester 10 papers are distributed to the class for reading. At the beginning of the semester, the class is told that technical articles will be assigned for reading and that they should come to class prepared to discuss each paper. The active learning is included by having a 15 minute class discussion on each paper during class time. The instructor facilitates participation by giving the students guidelines as to what types of information they should look for in the articles, by asking questions during the discussion, and by moderating the discussion to encourage all of the students to express their ideas. At the end of the discussion, the instructor may comment on any major points that did not get mentioned during the discussion. Although all of the papers relate to the course being taught, they are also chosen to provide students with a sample of various types of papers. They range from classic papers on fundamental concepts to papers on recent developments. As shown in Table 1, the assigned articles were published between 1914 and 2004.

To facilitate discussion, students are instructed to read each paper to determine:

- fundamental issue addressed (What concerns are the authors addressing?)
- motivation, perspective (Why are the authors writing this paper? How does this paper fit into other work done in the area?)
- main ideas (What are the key points? e.g. assumptions, methods used, limitations, and applications)
- relation to course (How does this paper fit into the course?)

For these articles, students do not need to read the paper for every detail unless instructed to do so for a particular paper. The main idea is to give students practice in reading the technical articles.

This approach was implemented in a graduate level thermodynamics course in chemical engineering. During the fall semester of 2003, there were 10 students. Generally, the graduate student class is small enough to allow all of the students to participate in the discussion.

Instructional Objectives

There are several primary objectives to be met in reading journal articles. These include:

- Help students realize that papers are an important source of current information
- Give students a better understanding of the role of technical articles in research
- Aid students in developing the ability to understand main points in technical articles outside their research area
- Introduce students to the paper submission and review process.

These objectives contribute to the overall goals of preparing students for research and encouraging life-long learning.

Class Discussions

At the beginning of the semester, the instructor explains that graduate students should become more familiar with journal articles. Students usually agree that during their undergraduate work they relied heavily on textbooks and handbooks and rarely searched journal articles for information. The purpose of the explanation is to help students understand the reason for the reading assignments.

Table 1. Assigned Reading for Fall 2004

Reference	Articles	Comments
9	"Separation Process Design and Synthesis Based on Thermodynamic Insights," *Chem. Eng. Sci*. (1995)	Motivates students to study thermodynamics.
10	"A Complete Collection of Thermodynamic Formulas," *Phys. Rev*.. (1914)	Classic paper showing mathematical development of property relations.
11	"Phase equilibria in the system nitrogen-ethane and their prediction using cubic equations of state with different types of mixing rules," *Fluid Phase Equil*., (2004)	Paper from a specialist journal discussing the effect of mixing rules.
12	"Reliable computation of binary homogeneous azeotropes of multi-component mixtures at higher pressures through equations of state," *Chem. Eng. Sci.*, (2004)	Article from a more general journal showing that research in equations of state is continuing.
13	"The Fluid Phases of Matter," *Sci. Am.* (1981)	This is a scientific journal for laymen.
14	"Molecular thermodynamics for some applications in biotechnology," *Pure Appl. Chem.* (2003)	Recent paper from a plenary lecture. Explains how thermodynamics applies to biotechnology.
15	"Volumetric and Thermodynamic Properties of Fluids -- Enthalpy, Free Energy, and Entropy," *Ind. Eng. Chem*. (1958)	Article showing the development of generalized correlations.
16	"Potential of Thermodynamic Tools (Group Contribution Methods, Factual Data Banks) for the Development of Chemical Processes," *Fluid Phase Equil*. (2003)	Recent paper from that discusses the role of data banks and group contribution methods in process synthesis.
17	"Distribution of isomorphic amino acids between a crystal phase and an aqueous solution," Ind. Eng. Chem. Res., (2002)	Paper discussing solid liquid equilibrium and the need for further research in this area.
18	"How to measure supersaturation," Chem. Eng. Sci. (2002)	Novel technique for measuring supersaturation.

The discussion is conducted so that volunteer responses are elicited. Since part of the grade depends on the discussion, a record is kept of who participated in the discussion. If some students are more reticent, the instructor can requests responses from someone who hasn't spoken yet or can call on a specific person. The discussion is largely guided by the questions given in the implementation section.

To aid students in understanding the role of technical papers, there are many concepts that can be discussed. A selected list of topics may include why researchers read articles, why the articles exist, the different types of articles and journals, and the criteria for publications. Each of these concerns is addressed during class as discussed below.

Why read papers?

The primary reason people read technical articles is to obtain new information that is not yet available in books. This is essential in research. For example, publication of research results requires that the paper present new material. Therefore, it is necessary to become familiar with recent research to avoid duplication.

The students may ask why books do not contain the latest developments. At this point, the instructor can explain that most researchers do not perform enough research on the same topic in a year to produce a book. If people waited until the results were collected in a book, some of the results in the book would be several years old. The purpose of technical papers is to disseminate research results in a timely manner. Also, technical papers are the first step towards incorporating research results in a book. Often books contain the information from many technical papers. Students are encouraged to look at their textbooks to see that many authors are referenced.

Why do they exist?

As discussed, technical articles are used to disseminate recent developments in research. As such, they are a method of communication in the technical community. Depending on the type of paper, they may also be used to bring attention to research needs or to encourage research in certain areas. One example of this is the paper on applying thermodynamics to biotechnology (13).

Types of journals

There are several considerations when reading a research article. One of these is the intended audience for the article. For example, *Chemical Engineering Progress* is expected to be of interest for the practicing chemical engineer, while other journals (e. g. *AICHE J., Chem. Eng. Sci., Ind. Eng. Chem*.) are primarily written for the chemical engineering researcher. Other scientific periodicals such as *Scientific American* are written more for the scientific layman. The audience may also be primarily of one discipline. For example, *Chemical Engineering Science* is primarily written for chemical engineers while *Pure and Applied Chemistry* is primarily written for chemists. However, both of these journals may have articles that would be of interest to both chemists and chemical engineers.

Another attribute of the journal is the range of research areas that it accepts. Some journals are highly specialized while others have a wider range of topics. For example, journals that cover a wide range of topics often group the papers by areas such as reaction engineering, separations, or process control. Other journals such as *Fluid Phase Equilibria* are more specialized. Journals may also vary by whether they mainly report one type of research such as experimental data (*Journal of Chemical and Engineering Data*), or whether they report a combination of theoretical, experimental, and simulation developments.

Types of papers

Technical articles may fall into several categories. They may be theoretical, computational, or experimental in nature. Often they are a combination of these types. For example, the paper may compare experimental data with theoretical results. The experimental papers are not limited to reporting experimental data; they may also present new experimental techniques or devices (18). Another type of paper is a review paper. The review paper does not present any new data, but it summarizes the research in a given area.

Other papers may not be written as typical research papers. Some papers are from plenary lectures. These often summarize the state of research and discuss future directions. Other articles are written for the general scientific public to disseminate information beyond a given area of research. For example, papers in *Scientific American* generally fall under this category.

Many journals categorize papers according to the length. Some papers are considered full length papers while shorter papers are often printed in a separate category.

In the discussion on types of papers, the structure of the paper is discussed as well. This includes comments about the introduction providing the motivation for the work in most papers. However, it also discusses how different types of papers may have different sections. For example, while experimental papers have a section describing the equipment and experimental techniques, theoretical papers often do not have or need an equipment description.

Journal Acceptance Criteria

Each journal has its own review and acceptance criteria. Although these vary from journal to journal, there are some criteria that are similar. One requirement is that the material must be appropriate for the journal it is submitted to. Another requirement for the research paper is that it must present new material. If the work is too similar to work already reported in the literature, it will not be accepted for publication. A third requirement is that the paper should be well written. Specific submission guidelines are given for each publication.

In addition to the acceptance criteria, the length of time between submitting the paper and receiving the reviews was discussed as well as the time required for publication. Since the time for review and publication varies considerably between journals, students were encouraged to check the submission and acceptance dates on articles.

Assessment and Discussion

Assessment was performed by using an initial survey the first day of class and a final survey at the end of the semester. The purpose of the first survey was to determine the students' level of knowledge entering the class, while the second survey determined how much the students learned from the class discussions. Both surveys were designed to assess the students' knowledge. The final survey had additional questions to determine the students' perception of what they had learned from the reading assignment discussions. In both surveys the responses were anonymous. In addition, both surveys were designed to be brief.

The goal of the initial survey at the beginning of the semester was to determine the background knowledge and any preconceptions or misconceptions that the students may have about technical articles. This included the purpose of technical articles as well as the procedure for publication. The general form followed the suggestions of Angelo and Cross (19) for a background knowledge probe and for a misconception/preconception check. Some of the survey questions were drawn from misconceptions that were expressed the first time this was taught in 2003. This survey provided a baseline for comparison with the second survey.

As shown in Table 2, the first set of questions addressed the importance of reading technical articles. The students were instructed to answer the questions using a rating of 1 to 5 as defined in the table. The initial and final survey results are the average ratings on each question. A comparison of the final survey results with the initial survey results shows that the students became more convinced that technical articles are important for conducting research and that they are the main source for current information.

Table 2. Importance of Reading Technical Articles

Question	1	2	3	4	5	Initial Survey	Final Survey
1. What sources do you use for technical information?	books only	mainly books	books and articles	mainly articles	articles only	2.92	3.20
2. What sources do you use for current technical information?	books only	mainly books	books and articles	mainly articles	articles only	3.83	4.3
3. Rank the importance of reading technical articles for conducting research.	not necessary	slightly useful	useful	very useful	crucial	4.75	4.8

Other questions that were asked required short answers. The purpose of using the short answer format was to avoid leading the students to any particular response. Five questions were asked in this format as given in Tables 3 – 7. In some cases, more than one answer was given to a question. Therefore, the survey results are reported as the ratio of the number of times a response was given divided by the number of respondents. Since multiple responses were given, the sum of the ratios can be greater than one.

The first two questions in this section deal with why students and faculty publish and read technical articles. Table 3 shows the responses to the question regarding why graduate students and faculty read technical papers. The final three responses only appeared on the second survey. There seemed to be little difference in the responses between the initial and final surveys. This is probably due to the fact that most of the students already realized that articles are a good source current information. The responses in Table 4 show the responses regarding the purpose for publishing technical articles. While the responses show that the goal is to disseminate research results, there is a slight shift to the idea of disseminating results quickly.

Table 3. Why do graduate students and faculty read technical papers?

Responses	Initial Survey	Final Survey
Avoid repeating work	0.25	0.10
Get current information	0.67	0.50
Find out what has been done	0.17	0.60
See what direction research is headed in	0.00	0.10
Ensure the validity of theories or data	0.00	0.20
Get new ideas for proposals	0.00	0.10

Table 4. Why are technical articles published?

Responses	Initial Survey	Final Survey
get recognized	0.08	0.00
disseminate research results	0.67	0.60
save time	0.08	0.00
to elicit peer feedback	0.08	0.10
to disseminate results quickly	0.25	0.40

The purpose of the literature review in an article is addressed in Table 5. Most students already realized that the literature review is used to provide background. In the initial survey 40% of the students stated that the purpose of the review was to give credit to previous researchers, while this response dropped to 10% in the final survey. In the final survey, there was one respondent who wrote that the literature review could show why a technical improvement was needed.

The criteria for getting a technical article accepted is addressed in Table 6. The response for the work being novel or creative increased from 17 to 50 percent during the semester. Also, while several students wrote “don’t know” on the initial survey, only one student wrote “don’t know” on the final survey.

The final question addressed the length of time it takes for an article to be reviewed. During the class discussion the instructor mentioned that many papers give the submission dates and accepted dates. The initial survey showed that 42% of the students wrote ”don’t know” for this question, but none of the students used this response on the final survey. In general, on the initial survey most of the students thought the reviews would be received in less than 6 months, while the times became longer on the second survey. Discussion in class included the fact that this varies with the journal.

Table 5. Why is a literature review included in an article?

Responses	Initial Survey	Final Survey
to give credit to previous researchers	0.33	0.10
to validate work	0.17	0.10
to show related topics	0.08	0.00
to provide background	0.50	0.60
to show what is currently known	0.08	0.00
to show why an improvement is needed	0.00	0.10
to show the author researched the topic	0.08	0.20

Table 6. What are the criteria for getting a technical article accepted?

Responses	Initial Survey	Final Survey
novel	0.17	0.50
repeatable	0.08	0.00
peer review	0.33	0.30
don't know	0.33	0.10
prove the research is being published	0.08	0.00
good preliminary data	0.08	0.00
good proposal	0.08	0.00
good writing, correct format	0.00	0.20
useful information	0.00	0.20
credible, validated	0.17	0.20

Student perception of the technical article reading assignment was assessed in the final survey using the questions shown in Table 8. For these questions, the students were asked how much they agreed with the statements by rating their agreement on a scale from 1 to 5 (1 – strongly disagree, 2 – disagree, 3 – neither agree or disagree, 4 – agree, 5 – strongly agree). In general, the students thought that the technical reading assignments and class discussions helped their understanding of how to read technical articles and how to get a journal article published. Furthermore, most of the students recommended that this exercise be repeated the next time the class is taught.

Discussion and Conclusions

Class discussion of journal articles required very little additional time to implement. Faculty members commonly use technical papers to provide more information on technical concepts. Although discussing the role of technical papers in research required some time, it provided graduate students with a better understanding of why they should read the recent literature. Having the reading assignments and class discussions account for 10 percent of the course grade motivated the students to read the assignments. In addition, class participation seemed to encourage the students to be prepared.

The survey assessment was supplemented by faculty observation during class discussion. It was clear from the students' observations and questions that they had read the papers and they were able to comprehend the main points. They commented on some of the differences in the types of articles. However, some of the concepts were new to them. For example, many of the students had not submitted a paper to a journal at this time, so they were

not aware of the review and publication timeline. Most students didn't know that papers frequently list the date the manuscript was received and the date it was accepted.

Table 7. How long does it take for a journal article to be reviewed?

Responses	Initial Survey	Final Survey
Don't know	0.42	0.00
4-7 months	0.08	0.00
6 months	0.33	0.00
few months	0.08	0.00
several months to a year	0.08	0.00
6 months to 2 years	0.00	0.30
1 year	0.00	0.30
6 months to 1 year	0.00	0.30
1 to 2 years	0.00	0.10

Table 8. Student's perception of the technical reading assignments.

Statement	Average Rating
1. During this course, my ability to read technical articles improved.	4.22
2. I have a better understanding of the role of technical articles in research.	3.89
3. As a result of the discussions, I have a better understanding of the types of journal and articles.	4.11
4. I have a better understanding of the acceptance criteria and procedure for getting a journal article published.	3.67
5. I would recommend that the professor repeat the technical article reading assignments and discussions the next time the course is taught.	4.39

Since this has only been implemented once, it is difficult to make generalized statements. The response from the students was that they liked reading the papers and discussing them in class. Many of the students regularly contributed to the discussions. Since this assessment has only been performed once with a class of 12 students, it has not been well tested. Future work will include repeating this technique and its assessment during the fall semester of 2005.

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