

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. To help students realize that there is a wealth of information in articles that may not be in their textbook, students are required to read assigned technical articles and be prepared to discuss them in class. In addition to discussing the technical points in the articles, the role of articles in research is discussed. This includes discussing the perspective of the author(s), the types of papers and journals, and the article submission process. 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 gives students an early start on making the transition from the undergraduate approach of only considering books for information.

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). Yet many students entering graduate school are not accustomed to getting technical information from technical articles. 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 2003.

Table 1. Assigned Reading for Fall 2003

Reference	Articles	Comments
9	"Separation Process Design and Synthesis Based on Thermodynamic Insights," <i>Chem. Eng. Sci.</i> (1995)	Explains the use of thermodynamics in separation process design. Helps students understand why they should study thermodynamics.
10	"A Complete Collection of Thermodynamic Formulas," <i>Phys. Rev.</i> (1914)	Classic paper showing mathematical development of property relations.
11	"Volumetric and Phase Behavior in the Ethane-Propene System," <i>Ind. Eng. Chem.</i> (1951)	Primarily presents experimental data.
12	"The Fluid Phases of Matter," <i>Sci. Am.</i> (1981)	This is a scientific journal for laymen.
13	"Molecular thermodynamics for some applications in biotechnology," <i>Pure Appl. Chem.</i> (2003)	Recent paper from a plenary lecture. Explains how thermodynamics applies to biotechnology.
14	"A Generalized Method for Predicting Second Virial Coefficients," <i>Ind. Eng. Chem. Proc. Des. Dev.</i> (1975)	Paper explaining the development of a generalized method for predicting second virial coefficients.
15	"Volumetric and Thermodynamic Properties of Fluids -- Enthalpy, Free Energy, and Entropy," <i>Ind. Eng. Chem.</i> (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," <i>Fluid Phase Equil.</i> (2003)	Recent paper from that discusses the role of data banks and group contribution methods in process synthesis.
17	"Estimation of Pure-Component Properties from Group Contributions," <i>Chem. Eng. Comm.</i> (1987)	Paper explaining the development of new group contribution methods.
18	"How to measure supersaturation," <i>Chem. Eng. Sci.</i> (2002)	Novel technique for measuring supersaturation.

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.

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 request 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.

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 main method of assessment of the students' comprehension of the concepts was 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, many of the concepts were new to them. Some examples of this are as follows.

Current Information: At least one of the students was surprised to learn that technical articles (except for review articles) are supposed to provide information on new developments. They did not realize that the articles are used for the communication of new technical ideas.

Role of Technical Articles in Research: On one of the assigned readings students commented that the authors had a long review of previous work and the students asked why this was done. This provided an opportunity to explain that researchers need to be aware of similar research so that they can explain in their papers what is unique about their research and how their work fits into the existing body of knowledge. Sometimes this requires a longer description of previous work.

Paper Submission and Publication Process: 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.

Reading Technical Articles: The last paper assigned (18) helped students realize that there is more than one type of experimental paper. While everyone was familiar with the idea of presenting experimental data, few realized that some articles present new devices for taking measurements. Overall, the students did become more proficient in reading technical articles and had a better understanding of their role in research.

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. However, these results are very subjective. To test this method, it is necessary to perform a formal assessment.

Future Work

The second time the class is taught a formal assessment will be performed. Specifically, this will consist of two surveys – an initial survey at the beginning of the semester followed by a survey at the end of the semester. The purpose of the first survey is to determine the students' level of knowledge entering the class, while the second survey is to determine how much the students learned from the class discussions.

The goal of the initial survey at the beginning of the semester is to determine the background knowledge and any preconceptions or misconceptions that the students may have about technical articles. This will include the purpose of technical articles as well as the procedure for publication. A questionnaire will be given the first week of class. It will require little time for the students to fill out and will require short answers. The general form will follow the suggestions of Angelo and Cross (19) for a background knowledge probe and for a misconception/preconception check. Some of the survey questions will be drawn from misconceptions that were expressed during the first time this was taught. The results are expected to provide guidance as to what topics should be emphasized in class. This survey will also provide a baseline for comparison with the second survey.

The survey will be repeated at the end of the semester to determine what the students learned during the semester. Survey questions will include the following concepts: reasons for reading technical articles, types of journals, types of papers, the process for submitting a paper to a journal, and the timeline for article publication. In addition to short questions, the final questionnaire will use the technique of directed paraphrasing (19) to assess the students understanding of the concepts.

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