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# Writing Across the Chemical Engineering Curriculum at the University of North Dakota

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## ABSTRACT

In order to prepare engineering graduates with the written and oral communication skills needed in their professional careers a coordinated writing across the curriculum (WAC) program has developed in the chemical engineering department at the University of North Dakota. The students practice and develop their skills with writing assignments in both lecture and laboratory courses from the first-year level through the fourth-year capstone design course. The coordinated approach, especially in the four-semester laboratory sequence, allows the students to develop their skills by building on communication experiences in previous courses. The WAC program at UND including writing and public speaking assignments is described.

## I. INTRODUCTION

The ability to communicate clearly and concisely, both orally and in writing, is an important skill that all engineers need to obtain to become truly successful in their professional career. However, this has not always been a clear pedagogical concern in chemical engineering curricula, where writing has been looked upon as a secondary part of engineering education. Indeed, the public's stereotypical image of an engineer is often someone who drones on monotonously using excessive jargon.<sup>1</sup> However, with the increasing competitiveness in the work place, engineering and science programs are seeking to focus on the education of the entire individual.<sup>2,3</sup> A recent article concerning undergraduate chemical engineering education<sup>4</sup> stated "Massive changes in curriculum, courses, etc., are not needed; what is needed is a change in the way the material is presented." Using more writing in engineering content areas is definitely one way to change the way material is presented. Griskey<sup>4</sup> went on to say, "We must move from an over-balance and dependence on theory, mathematics, and the computer, to a new approach that not only recognizes and maintains those gains but also clearly links them to engineering practice." The utility of incorporating writing in engineering content courses is that it introduces the students to the reality of the profes-

sion; they will spend a large portion of their professional time writing. Be it memos, internal reports, or journal articles, most professional engineers find themselves writing almost every working day.<sup>5</sup>

Many universities in the United States, including the University of North Dakota (UND), are incorporating more writing and communication skills into the content areas of the curriculum using formalized (and funded) "Writing Across the Curriculum" (WAC) programs. However, this emphasis on writing is not new within the Department of Chemical Engineering at UND. Certain of the pedagogical aspects for incorporating writing into the chemical engineering curriculum have been used for nearly three decades. Recently, there has been a reformation of the pedagogy and philosophy of incorporating writing within the chemical engineering curriculum. This paper will describe the current methods used at UND.

### A. Former "Myths"

Besides the myth that all engineers speak in a monotonous drone, there are other myths that have been perpetrated. One myth is that you don't need to be a good writer to be an engineer. This myth is often attributed to the students themselves, who feel that if they were good writers they would have majored in English or Pre-Law. This myth is amplified by the structure of many engineering courses that tend to stress graphical, numerical or computer solutions to problems. Most of the homework and tests consist of the numerical solution of some proposed problem, with minimal writing required.

Another myth is that writing should have been taught in high school and by the English Composition teachers.<sup>6</sup> Associated with this myth is the perception by professors in the professional and content programs that they aren't responsible to teach writing skills and they only need to demand "good writing" from the students, while complaining about the deterioration of the secondary school system.

As engineers in higher education, we may not be able to address these myths, nor solve the problems associated with the student's prior preparation before entering in our engineering programs, but we can do something about how students perceive the importance of writing. Most importantly, we can help students develop the necessary skills to be able to communicate clearly in their writing.

### B. Realities Of Writing By Professionals

Studies have shown that engineers may spend up to 50% of their time writing.<sup>5</sup> In a recent survey of UND chemical engineering alumni, several responses mentioned that the emphasis

on writing had served them well as they began their careers as practicing engineers. Others mentioned that even though it had been emphasized, they were still surprised at the amount and frequency of their professional writing. Practicing engineers do write! But more importantly, because of increasing competition, they are finding that to be successful as engineers they not only have to write, but they have to write well. No matter how brilliant or technically competent an engineer is, unless they can effectively communicate their ideas to a supervisor, a client, or to the public, they will have only limited success.

Practicing engineers are sensing the need to improve their communication skills. A brief review of some of the journals commonly read by practicing engineers reveals several "self help" articles that deal with improving their communication skills.<sup>1,7-9</sup>

For the practicing professional, the reality that "clear writing indicates clear thinking"<sup>10</sup> is being recognized not only by their immediate supervisors, but also by customers, clients and by the public at large. Engineers can no longer just let their "facts speak for themselves, ... 'cause no one expects me to be a great speaker.'" They need to be clear and effective communicators if they don't want their facts misinterpreted, or their entire oral or written communication dismissed as being incomprehensible.

## II. CURRENT PHILOSOPHY

Writing assignments are often used in academic course work for the following three reasons<sup>11</sup>: 1) writing as a tool for learning, 2) instructor feedback, and 3) the production of polished, final draft written material. The philosophy concerning written and oral communication in the UND Department of Chemical Engineering can be summarized in two concepts. First, we believe that clear writing (or oral presentation) indicates clear thinking.<sup>10,12</sup> Second, we believe that written and oral communication is a necessary skill for good engineering. Throughout the curriculum, beginning in the first-year course "Introduction to Chemical Engineering," the idea of clear writing indicating clear thinking is stressed. Our approach is that writing is a skill that can be developed<sup>13,14</sup>, and it is a skill that most practicing engineers will use each day just like mathematical or computational skills. Opportunities to practice and develop oral and written communication skills are interspersed throughout the curriculum. However, the department feels that our four-semester laboratory sequence is an especially appropriate place for our students to practice and improve their analytical, mathematical, statistical, computational and *writing* skills. The students understand that we think writing is important if for no other reason than we give them lots of practice. The importance of written and oral communication is also stressed by the level of feedback they receive, the opportunities for improvement, and the emphasis on grading of their written work.

## III. CURRENT PROGRAM

The emphasis of good writing reinforced with lots of practice throughout the curriculum has been a tradition in the

UND Department of Chemical Engineering for at least 30 years. As students progress through the program they are given different opportunities to practice and apply communication skills. The students encounter writing assignments in lecture and laboratory courses and the capstone design course. The writing varies in each type of course.

### A. Lecture Courses

The writing assignments in the lecture courses are given from the first year to fourth year. In the first-year chemical engineering course the students are introduced to the department's oral and written communication philosophy. The students are "walked through" the preparation of a term paper. Many of the students are concurrently enrolled in the first-year composition course taught by the English Department. Every few weeks the students are required to complete some milestone towards their final project, which is the production of a paper that deals with one of the technological or research frontiers in chemical engineering.<sup>15</sup> The milestones include choosing a topic which is approved by the professor, preparing an initial bibliography, and preparing a detailed outline. At the end of the ninth week of the semester the students turn in a typed first draft of their term papers. These papers are read and graded by the professor using a checklist which assigns points according to organization, depth, breadth, completeness, neatness and mechanics (grammar and spelling). The graded papers, with suggestions on how to improve the paper, are returned to the students, and they have an additional two or three weeks to produce a final polished draft. During this time some class time is devoted to tips for good oral presentations.<sup>1,16</sup> The last few weeks of the course are reserved for student presentations; each student gives a 15 minute oral presentation (mini-lecture) to inform the class about their topic. The oral presentation is graded by both the professor and members of the class using the checklist shown in Figure 1. This checklist is used for all oral presentations throughout the curriculum and places emphasis both on technical content and presentation style. The checklist is used to give students constructive criticism on their speaking style. The combined scores on written and oral assignments accounts for approximately one third of the course grade.

Other lecture courses that use writing assignments with an emphasis on producing a polished draft are the third-year Unit Operations and Mass Transfer courses. In the Unit Operations course, the writing assignment is associated with a project to develop a computational package (using either a spreadsheet, equation solver, or compiled programming code) that solves piping network problems using Bernoulli's equation and friction loss correlations. The writing assignment consists of preparing a detailed "operation manual" to accompany the software package. The grade on the project is not only based on the functioning of the software package and its ability to give correct answers, but on the written presentation given in the operations manual.

In the Mass Transfer course the writing assignment is associated with a day-long design project.<sup>17</sup> Here the students work in groups and are given a design problem and have 10 hours to make the necessary calculations, complete the design and turn

## ORAL PRESENTATION EVALUATION

Name of Speaker: \_\_\_\_\_

Date: \_\_\_\_\_

Topic: \_\_\_\_\_

Report: \_\_\_\_\_

Content Introduction (grab attention, orient audience) \_\_\_\_\_

Body (relevance, important points covered, completeness) \_\_\_\_\_ X 2 = \_\_\_\_\_

Summary (conclusions, recommendations) \_\_\_\_\_

Comments: \_\_\_\_\_  
\_\_\_\_\_

Delivery Speaking style/manner (enthusiasm, distracting mannerisms, eye contact,  
reading from notes, appropriate attire, etc.) \_\_\_\_\_

Voice (loudness, clarity, speed, etc.) \_\_\_\_\_

Visual Aids (appropriate, neat, etc.) \_\_\_\_\_

Comments: \_\_\_\_\_  
\_\_\_\_\_

Questions: Ability to answer \_\_\_\_\_

Comments: \_\_\_\_\_  
\_\_\_\_\_

Length of presentation: \_\_\_\_\_ minutes. Deduct 2 points for each full minute overtime \_\_\_\_\_

Total Points \_\_\_\_\_

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Name of Evaluator: \_\_\_\_\_

Grading Scale: 10 - outstanding; 9 - excellent; 8 - very good; 7 - good; 6 - fair; 5 - poor;  
4 through 1 - unacceptable

*Figure 1. Oral presentation evaluation form used throughout chemical engineering curriculum. Form allows for constructive criticism and is used by both faculty and students. Confidentiality of the student evaluators is maintained by the removable portion at the bottom.*

in a polished report. Again the grade is not only on the approach and calculations for the design, but on the final written presentation.

The writing assignments in the other departmental lecture courses emphasize the writing-to-learn and instructor-feedback concepts. Two examples of assignments used are journals and microthemes.<sup>11,18</sup> These types of assignments allow a student to compare and synthesize the material being covered and also to give the instructor feedback on how well the students are learning. Evaluation of the assignments is based on effort and depth of observation and not on writing mechanics. The journal assignments consist of the students being required to maintain a journal to summarize the important points of a reading assignment and to write down any questions they have. These can often be used as the beginning points for the lecture. Microthemes are given occasionally at the end or beginning of a class lecture in much the same way that a quiz would be given. The students are given about five minutes to respond to some question such as "what was the most important concept covered today." The microthemes are written on standard 3x5 note cards. The small space forces the students to summarize their thought concisely. Microthemes are conveniently used even in large lecture classes.<sup>19</sup>

### *B. Laboratory Courses*

Most of the writing practice in our program occurs during the four-semester laboratory sequence. The laboratories are coordinated so that as the students progress through the series of courses their experimental tasks become more complex and their writing assignments vary. Table 1 summarizes the various experiences provided in the laboratories and is the basis for the following discussion.

During the first few weeks of the second-year laboratory course, the students have assignments that ensure that they are competent in working with a word processor, a spread sheet, an equation solver and developing graphs from a spread sheet. After the first few weeks working individually on their assignments, the class divides into three member groups to work on laboratory projects. The second-year laboratory experiments deal primarily with various measurements common in chemical engineering practice and consist of collecting and reporting data. During the third-year laboratories the projects deal with measurements of chemical and physical properties of materials. These experiments require the student not only to collect the data but also to perform some sort of data manipulation or analysis. Many of the projects consist of fitting the data to a physical or chemical model and require the students to perform some statistical analysis. At least one of the experiments in the second semester involves determining optimum operating conditions using a Box-Behnken experimental design.<sup>20</sup> The projects in the fourth-year laboratory deal with various unit operations and process control and are more involved than those in previous semesters. Several of the experiments involve optimizing of the operating conditions of process equipment using some sort of statistical experimental design.<sup>21</sup>

As the students progress through the laboratory sequence they experience different working environments and experience dealing with group dynamics. In the second-year class the stu-

dents collect data as a group and can even perform preliminary analyses as a group, but they are graded on their individual written reports. During the third-year laboratories (ChE 331 and ChE 332) the students work as individuals and are graded on individual reports. At the fourth-year (ChE 431) level the students work in self-assigned groups of three students and submit a single report for the entire group which is graded.

In the fourth-year laboratory the emphasis is placed on learning to produce a group report. Since the possibility exists of unequal contributions by the various group members, we have devised a method to modify the grade on the group report according to effort/contribution. With each report, the students are required to turn in an evaluation of the efforts of the other group members. Each group member must distribute 100 points between the other group members based on their contributions. The total points that each group member receives is then used to either amplify or diminish the individual grade relative to the grade received on the group's report. This method has been used for years and seems to work well. The students hesitate to evaluate the contribution of their group members. We stress that as their engineering careers progress and they move into supervisory positions, evaluations of others work will be part of their jobs. The students respond well to the assignment and seem to honestly assess the relative contributions of group members.

The written assignments vary in each laboratory course. Initially the students are given a very structured format and eventually they have a free format. The concept of writing for different audiences is also stressed. This is based on the idea that if a reader or audience is to grasp what the writer means, then the writer must understand what the reader needs.<sup>22</sup> The second-year reports have a prescribed format (even a template) and the narrative cannot exceed one page. Sections include objective, procedure, results, and conclusions/discussion. There are 10 laboratory projects and reports during the semester, and it is expected that all reports are word processed and that all graphs are computer generated. The emphasis of the written reports is to create a short, clear and concise report that mimics a weekly project or progress report. The reports are graded by the professor and returned weekly with comments on the technical content and written presentation. The grade is based on technical content, analysis and writing.

During the third year emphasis is placing on learning to write for different audiences, and different types of reports are prepared. The students are given an outline which indicates the format for each type of report. These outlines are used to help structure the reports. For two projects each semester a memo to a customer format is used.<sup>23</sup> The scenario is that they have been asked by a customer to perform the analysis. The customer is technically knowledgeable and is familiar with how the requested information is to be used, but not necessarily with the techniques used to obtain it. This report format is very similar to that used during the second year, but they have more freedom with format and style. In addition, now the audience is someone besides the professor. The second type of report format used for two of the projects is an abstract such as would be sent for a technical presentation. This by necessity has to be very short and concise and convey the results of their project. During the course of the semester the students have

<b>Course</b>	<b>ChE 232 Laboratory I 2nd Year, 2nd Sem.</b>	<b>ChE 331 Laboratory II 3rd Year, 1st Sem.</b>	<b>ChE 332 Laboratory III 3rd Year, 2nd Sem.</b>	<b>ChE 431 Laboratory IV 4th Year, 1st Sem.</b>
<b>Credit hours</b>	<b>2</b>	<b>2</b>	<b>2</b>	<b>4</b>
<b>Laboratory time</b>	<b>3 hrs/week</b>	<b>6 hrs/week</b>	<b>6 hrs/week</b>	<b>8 hrs/week</b>
<b>Types of experiments</b>	<b>Various measurements common in chemical engineering practice</b>	<b>Chemical and physical properties of materials</b>	<b>Chemical and physical properties of materials Statistical analysis and optimization</b>	<b>Unit operations Process control Optimization of operating conditions using statistical methods</b>
<b>Working environment</b>	<b>3 member group</b>	<b>Individual</b>	<b>Individual</b>	<b>3 member group</b>
<b>Report authorship</b>	<b>Individual</b>	<b>Individual</b>	<b>Individual</b>	<b>Group report</b>
<b># of projects</b>	<b>ten</b>	<b>six</b>	<b>six</b>	<b>six</b>
<b>Report format/ audience</b>	<b>One page summary to professor</b>	<b>1) Memorandum to customer 2) Abstract for presentation 3) Note for technical journal 4) Operations manual</b>		<b>1) Memo to file 2) Report to supervisor 3) Technical note 4) Letter to parents</b>
<b>Oral reports</b>	<b>None</b>	<b>Individual presentation at class symposium</b>		<b>Group presentation of final project</b>

*Table 1. Writing Assignments in Laboratory Sequence*

one of their two abstracts "accepted" and they then prepare a 10 to 15 minute oral presentation about their project. During the final week of the semester, the laboratory class holds a symposium where each student gives their oral presentation. A third type of report format, which is used for only one project, is a manuscript for a technical note to a research journal. This report is more involved and includes an abstract, an introduction and background, a section describing the experimental methods and techniques, a presentation of the results, an analysis and discussion of the results, a conclusion and cited references. The final type of project report format used at the third-year level is that of an operations manual with an accom-

panying cover letter. Here the scenario is that the student is to prepare an operations manual for a high school chemistry laboratory so that a high school student can perform the analysis. Emphasis is placed on communicating to the high school student the safe and correct procedure for performing the experiment. The operation manual must contain information concerning any hazards associated with either the equipment or the chemicals used (including Material Safety Data Sheets information). In addition, the manual must clearly describe the data reduction procedures and analyses.

During the fourth-year laboratory emphasis is placed on learning to produce a group report. Again, various audiences

for the reports are assigned; these include a note to a research journal, a memorandum to file, a report to a supervisor or even a letter to their parents.<sup>24</sup> The grade is based on the methodology, the analysis and the presentation given in the group report. The professor grades the reports and they are expected to be in a polished draft condition. Reports that are not up to standard are required to be rewritten. At this level we no longer tell them what to write nor give them a specified format. They are only required to respond according to the given audience. In the fourth-year laboratory the students are also required to give oral presentations. The oral presentations are evaluated and graded by both the professor and the other students.

The different report formats help the students to realize the differences between audiences and the need to tailor the writing to the appropriate audience. The grades in the laboratories are not only based on their laboratory skills, the data collection and analysis, but also on how well the students have communicated the results and their analysis in a given format style and to a given audience.

### *C. Writing Consultant*

During the third year the students have access to a writing consultant who is available to help students with any writing mechanics or style. The writing consultant is an English instructor who is employed by the department to be available for student consultation for 10 hours a week. In addition, the consultant reads all of the student papers, makes comments (in a different colored pen), and grades the readability. The final report grade is a composite (80% Professor, 20% Consultant) of the two grades given. The consultant has an office in the department that is near the undergraduate laboratories. The students are required to meet with the consultant at least twice each semester. Most students find the consultant to be helpful and make several visits beyond those required.

The idea of a writing consultant is a long time tradition at UND (about 15 years), however the job description and emphasis has changed over time from being an "English grader" to a "writing consultant." This change in emphasis is motivated by the argument that split grading of the "technical content" by the professor and the "writing mechanics" by the English grader emphasizes and acknowledges that learning in the course is somehow distinct from writing in it.<sup>6</sup> Since this is contrary to the departmental philosophy that clear writing is an indication of clear thinking (and hence good learning), the emphasis has been placed on being a writing consultant more than just an English grader. Both the professor and the writing consultant grade the entire paper for readability and clarity. By necessity the professor checks the calculations and technical arguments, but also grades the presentation of the material. Another advantage of using a writing consultant is that it gives the students additional contact with a professional who is interested in helping them improve their writing skills beyond (but not replacing) the time given by the professor.

The use of the writing consultant has been studied as part of a graduate thesis in the English Department.<sup>25</sup> The results of the study found the interaction between the students, the writing consultant and the professor to lead to a good learning

environment for the students. The concept of a writing consultant has been successfully used elsewhere.<sup>26</sup>

### *D. Student Newsletter*

During the third year the students also participate in producing a newsletter published by the student chapter of the American Institute of Chemical Engineers. The student organization has an elected officer who is the editor of the newsletter. As part of the third-year laboratories the class is divided into three groups. Each group is responsible for submitting articles for one of three issues of the newsletter each semester. The student editor prepares a list of possible topics for the newsletter and each student chooses their own topic and writes an article for the newsletter. The newsletter is printed and distributed to all the chemical engineering students and sent to their parents. The students seem to enjoy the project because it allows them creative freedom in format and style, and both the students and parents enjoy hearing about the department.

### *E. Capstone Design Course*

The final course of the chemical engineering curriculum, taught during the second semester of the fourth year, also has a significant writing component. The course is coordinated by one faculty member, but every member of the chemical engineering faculty participates and acts as an advisor for the individual groups. The grade in the six-credit capstone design course is based entirely on the evaluation of written and oral presentations. The students work in groups of three to four, but in this case the groups are assigned by the faculty. The idea is that in practice they will often be assigned to work with people whom they don't initially know very well.

During the semester each group conceives, synthesizes, designs and makes an economic evaluation of a chemical process facility. To help the students progress to the final goal of the analysis of the process, there are four interim "milestone" reports (scope, process, equipment, economic analysis) that are due besides the final comprehensive report. The group submits one report for the entire group.

Each group must decide who their audience is and who their group represents. The audience is chosen to be appropriate for their project. For instance, if their project consists of modifying a process or adding a new process stream in an existing facility then their audience might be a plant manager and they are a group of plant engineers or possibly consultants. If the project is an entirely new facility, then their audience might be a board of directors or a consortium of investors. The decision of the audience is left entirely to the students.

Each report is expected to be in a polished form and is graded by their group's advisor. Each interim report is also read and evaluated by a second faculty member. The second reader is rotated among the various faculty members in the department. The final comprehensive report is evaluated by all faculty members. The students are again required to evaluate the performance of their fellow group members, and each individual's grade is either diminished or amplified depending on their assessed contributions.

With each interim report the group gives a 15 minute oral

presentation to the class and faculty with a five minute question period. Each member of the group must give one of the interim oral presentations. They are evaluated and graded by both the faculty and their classmates. For the final comprehensive report, each student makes a 20 minute oral presentation with a 10 minute question period to the faculty.

#### IV. CONCLUSIONS

Students progressing through the UND chemical engineering curriculum are exposed to a coordinated sequence of writing experiences that help reinforce the philosophy that clear writing is an indication of clear thinking. As the student's writing experience increases, the assignments vary from the heavily prescribed format and style in the first- and second-year courses to complete freedom in style at the fourth year.

The students practice writing for various audiences. During the first and second year they write to the very tangible audience of the professor. As their experience increases they write for audiences that they may encounter as a practicing engineer. Their format varies from a formal note to a research journal or a report to a supervisor to the informal letter to a parent or student newsletter. From journals and microtheme assignments they learn that writing can help them organize their thoughts and improve their learning. From the variety and quantity of written assignments the students learn that writing is going to be an important aspect of their professional careers. A recent alumni survey shows that the alumni are finding that writing is an important component in their professional careers and that the emphasis they received in the program has been beneficial. Interaction with various corporate recruiters who visit the campus also indicates that they value the level of writing prowess in the students.

Besides experiencing the importance of written communication, the students are exposed to the importance of developing oral communication skills. Their experiences vary from teaching a mini-lecture at the first year to presenting technical results at the third- and fourth-year level and finally to describing and "selling" their project in the capstone design course. The practice they receive allows them to overcome fears of public speaking and the constructive criticism they receive from the professor and their peers helps them improve.

Feedback from alumni indicates that they found the experience of working in groups to be very valuable for their initial industrial assignments. From the overall feedback received in the alumni surveys and from return visits by alumni it seems one of the reasons the emphasis of written and oral communication has worked so well is that it is throughout the curriculum and that the writing assignments, especially in the laboratory sequence, are coordinated and the students build on their previous experiences. The students sense the departmental philosophy about the importance of writing and are aware that there is an unified approach and not just a haphazard smattering of writing assignments. The emphasis by every faculty member and the presence of the writing consultant (with an office in the department) tells the students very early in their "careers" that we take writing seriously. In this UND has the advantage that the faculty is relatively small and that for years the program has had enrollment management so there are rea-

sonable class sizes. The consistent and manageable class sizes has fostered the development of a coordinated approach to writing across the chemical engineering curriculum.

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