Effective Strategies to Motivate Engineering Students to Develop Their Technical Writing Skills

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Abstract

Many engineering students have a real aversion to writing-intensive assignments. This paper discusses several curriculum changes incorporated in a mechanical engineering program to demonstrate just how vital communication skills are in an engineering environment and to improve those skills. The primary motivational technique is the use of student interviews with practicing engineers, allowing students to personally "discover" this real world phenomena by interacting with professionals in their field and gaining first-hand understanding of the importance of good technical writing skills. To help give a sophomore-level technical writing course immediate relevance, it is linked to a class/laboratory that was reformulated to include a large writing component. The laboratory includes team written prelabs, draft reports that are peer reviewed, and final reports that use both a memo and formal report formats. The time management plan and grading procedure that are used to effectively compact the technical material plus all the above writing components into a one-hour class/laboratory are discussed. An assessment of this interdisciplinary venue is also given.

I. Introduction

An ability to communicate effectively is expected of all college graduates. Nurturing this expertise in an engineering curriculum is especially difficult, in spite of the fact that entering engineering students at the University of Wyoming (UW) have above average English and Reading ACT scores and the College of Engineering's average composite ACT score is the highest of any college[1]. A primary obstacle is the students' perspective of the engineering profession only in terms of its technical and problem-solving aspects - the basic attributes of engineering that many wish to study. Engineering students therefore often have a real aversion to writing-intensive assignments and view them as just time-consuming nuisances, even when related to engineering subject matter. The typical engineering freshman/sophomore curriculum somewhat reinforces this notion by burying the only required writing course - the traditional freshman level composition course - in a maze of math, science and engineering courses. It is difficult to easily remedy this problem because all the engineering curricula are highly structured and rely on a full complement of basic technical courses being taught during the first two years.

Providing students with the necessary technical writing practice is further exacerbated by the national trend of the compression of curriculum over time. The prescribed hours in a Bachelor's degree have decreased from 137 credit hours in the seventies down to a current value of 128. Despite this contraction, industry and Accreditation Board for Engineering and Technology[2] (ABET) expect universities to adequately prepare their graduates to enter a profession whose sophistication and technological knowledge base are rapidly accelerating. Growing industrial competition also demands that new employees require minimal on-the-job training before they become productive engineers. This prompts the universal challenge of how one fits the explosion of essential extras into a shrinking curriculum.

To help meet the technical writing challenge, the Mechanical Engineering (ME) Department at the University of Wyoming (UW) has increased the technical writing component throughout its curriculum. Typical industrial-styled laboratory memorandum and formal report formats, including example reports, are presented and utilized in the introductory one-hour, sophomore level ME dynamics laboratory. These same formats are then used in the successive ME laboratories. The laboratory's writing/grading process has also been modified to efficiently present a representative "real world" technical analysis and writing experience. The intentional structuring of the class to simulate and require realistic professional activities responds to Bartholomae's criticism of teachers' and curriculum designers' failure to involve students in scholary projects "that would allow them to act as though they were colleagues." [3] He notes that "much of the written work students do is test-taking, report or summary…" The class requires the students to utilize the services provided by the University's Writing Center for the first experiment; students that demonstrate a real writing deficiency are sent there more oftenIn an effort to produce professional quality reports, students are required to use the word processing, graphical presentation, and spreadsheet skills developed in a prerequisite course. Even though they have obtained the necessary theoretical, computational, and presentational tools from previous courses, this is the first time they are asked to logically assemble all these skills to produce a professional report. This venue turns out to overwhelm many of them and the increased emphasis on report writing truly annoys some. The techniques used to motivate students to work on their writing and teamwork skills and then practice those skills are discussed in this paper along with their perceived success.

II. Motivating the Reluctant Student via Student Interviews with Practicing Engineers

It is well documented that communication skills are one of key assets that employers want new graduates to bring to the workplace. For instance, in a survey of 200 people with 55% identifying themselves in professional and technical occupations, Faigley and Miller found that the average reported over 29% of their total work time was spent writing[4]. The median wrote approximately 8 memos per week (both to persons inside and outside their company or agency). Seventy-four percent of those surveyed reported collaborating at times, and 25% of the material written by this set of people were collaborative efforts.

Our own alumni immediately recognize this need when they enter the workplace, and often find themselves wishing they had been better prepared. For instance, UW's College of Engineering surveyed their alumni in 1992 to determine their perception of the quality of their education in terms of competing with their colleagues from other schools[5]. Their concerns involved "real world engineering tasks" preparation - notably the opportunity to practice oral and written communication and teamwork. This desire was found throughout all disciplines and was therefore endemic to undergraduate engineering education.

Consequently, it was eventually decided to completely reorganize the required upper-level writing components of the ME curriculum. The first step taken in the reorganization of the ME curriculum was to drop the three-hour, senior level technical writing course because many of the writing intensive aspects of this course are included in a five-hour, capstone design sequence (a proposal, an interim report, and final written and oral reports). To better serve the upper division ME laboratories and courses, the English Department developed a sophomore level, two-hour technical writing course, *Writing in A Technical Field*, in collaboration with the ME department. This course is directly linked to the one-hour ME introductory laboratory, and the combined courses satisfy the University's requirement for a mid-level writing intensive course. More importantly, this interdisciplinary approach provides a mechanism for students to immediately recognize the key role that technical writing plays in advancing the logical thought process that is necessary in an engineering environment.

To encourage students to seriously try to develop their technical writing skills, the laboratory instructors would present the results from the 1992 UW engineering alumni survey and some of their personal insights. However, this appeared to have very little impact on classes. To truly convince the students that they must be proficient in technical communication, it was decided to replace the ineffective lecture format with one in which the class *discovers* this fact for themselves. To accomplish this, the Chinese proverb, *"To know the road ahead, ask those coming back*," is emulated by having the class conduct its own interview-based survey. Its aim is to give students an opportunity to interact with professionals in their field and gain a first-hand understanding of the many ways writing is used and the importance of good technical writing skills.

During the first minutes of the first class meeting, a two question survey is given, with no leading information, to ascertain student perceptions of the role of technical writing in the workplace. The students are asked "As a practicing engineer, what types of writing do you expect to do in your job" and "How much time do you expect will be devoted to writing tasks." Representative results, based on AY 1998-99 class data are shown in Figures 1 and 2. Prior to the linked ME lab/technical writing class experience, students (n = 44) on average believe engineers spend approximately 34% of their time performing technical writing tasks. Next, each student selects a person from the regional list of members of American Society of Mechanical Engineers (ASME) to interview. Since the list is fairly large, the students have the opportunity to interact with someone that is in a field, with a company and/or at a location that excites the pupil. Each student then prepares an appropriate interview by consulting reference material on interviewing techniques and styles. The goals of the interviews are set by the particular instructor, but basically all the students ascertain what writing formats are utilized, the percentage of time involved in technical communication, and the importance of collaborative writing. Each student then writes a one- to two-page informal report and some, if not all, of the students give a brief oral presentation on their findings to the entire class.

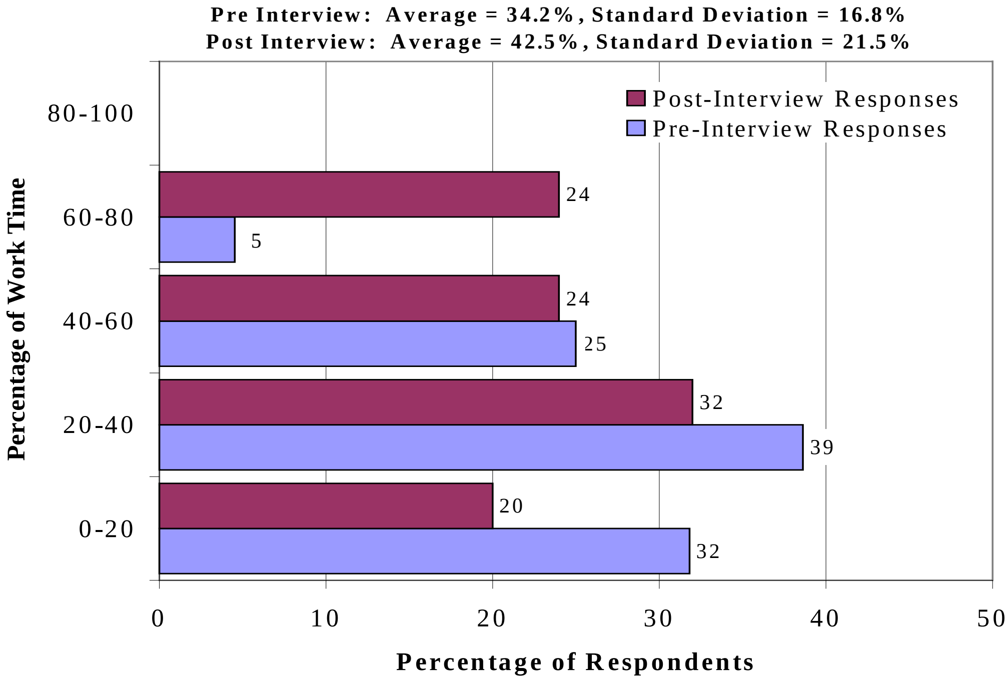

Figure 1. Pre-and Post- Interview Responses to “Expected Percentage of Professional Work Time Spent Performing Technical Writing Tasks”

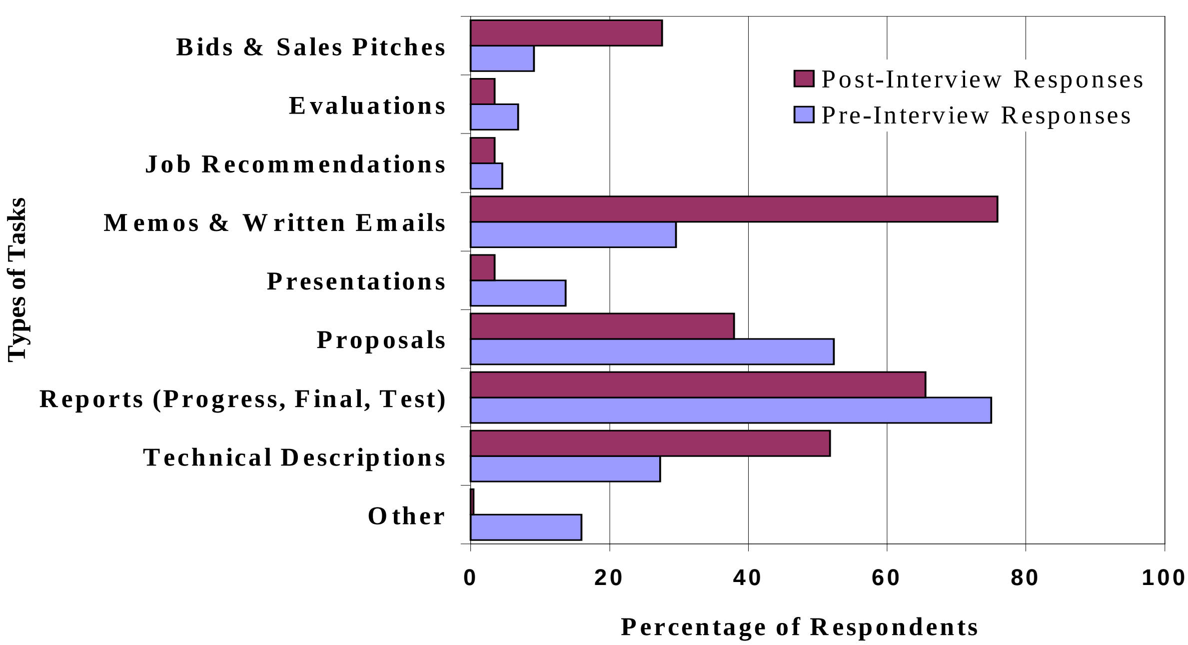

Figure 2. Pre-and Post- Interview Responses to “Expected Types of Professional Technical Writing Tasks”

Hearing first hand from their interviewees and then from their peers leaves the students with a powerful impression of just how necessary effective communication skills will be in their professional careers. Based on the interview assignment, students find the amount of time engineers spend writing may vary from writing just one memo a week to almost full time for project engineers and managers. But, on the average, students (n=29) can expect as professionals to spend approximately 43% of their time dealing with writing. The fairly large distribution of the data is not unexpected or unreasonable considering the diversity of the interviewed engineers' jobs and companies. The survey's data of students' preconceptions are probably somewhat biased as the students' anticipate the importance of technical writing when taking a survey in a linked ME/technical writing sequence. Conducting the survey in a freshman engineering class may show a larger difference when comparing anticipated versus actual time spent on technical writing tasks. The class survey also gives the students an appreciation for the large variety of types of documents that are used in the profession. The survey results emphasize the obvious need to be able to write reports and proposals, but it also conveys how memos, transmittal letters, collaboratively written documents, multiple drafts, the review hierarchy, writing to the audience (instruction manuals, technical and non-technical papers, etc.), applications, and E-mail, etc. are all used on-the-job. Interviewees have also commented that they wished that they had been exposed to a similar technical writing course. Although the information cannot be precisely quantified, and certainly doesn't apply in all situations, results from the interviews strongly suggest a direct link between career advancement and the amount of professional time spent in writing. Some project managers, division managers, CEOs and company presidents spend 80-90% of their time engaged with writing. Furthermore, this writing is directed more toward a client/business-related audience and less for an engineering/technical readership. Other high-level managers reported while a minimal amount of time is spent actually writing, the bulk of their time is spent in verbal communication, including phone conversations, teleconferences, and presentations. The class reports also provide an excellent introduction to many of the topics and formats used in the linked English class/ME laboratory.

In terms of the interviews' motivational value, many students have concluded their report with comments such as: "this interview has changed my thoughts about engineering and writing;" "writing is not only important but mandatory in an engineering field;" and "the reasons for having a technical writing class are obvious and abundant." Confirmation of the students' aversion and then conversion to writing are reflected in the following student's remarks:

> "This interview confirmed the worst. Engineers have to write a lot. I had realized before there was a certain amount of writing involved in engineering, but I never grasped the full extent of it. Writing is a very significant part for the engineering profession and something that must be taught to insure the success of an engineering student in the real world."

III. Paradigm for Writing in the Linked Laboratory

The 1992 UW Engineering College alumni survey indicated that they were very pleased with their education in terms of their ability to compete but there were some common deficiencies that they had encountered once on-the-job. Besides communication, these included teamwork, computer, and statistical skills. Also there were comments like "The real world requires more flexible skills. College is not the real world!"

The old ME introductory laboratory fell in the classical demonstration mode where weekly experiments were performed, the experimental procedure and theory were essentially given in the assignments, and the students submitted minimal experimental write-ups. It was decided to reformulate this laboratory to address all the common alumni concerns and thereby give the students the opportunity to start practicing these skills at the sophomore level in a more realistic scenario. The literature shows the retention of students and content matter improves with discovery-based learning when compared to traditional lecture/demonstrations format[6-14]. Since the inclusion of these components in an experiment greatly increases the time investment required from both the students and the instructor, a class/laboratory mix was adopted, and the number of experiments was cut to only five. The writing/grading process that evolved to make effective use of the limited available time in this one-hour laboratory class is explained below.

The class/laboratory sequence begins with a class, when the pertinent apparatus and experimental objectives are presented to the students, one week before a laboratory session. The assignment's goals are contained in a typical client to consultant memo that does not include an experimental procedure. This exposes the students to a realistic request for engineering services via a memo. An explicit experimental procedure is supplied to the class for only the first experiment to use as a guide in subsequent experiments. For the next three experiments, two- or three-person teams are assigned to formulate and write up experimental plans that include computer-generated spreadsheets to record all pertinent data prior to the lab. Copies of these plans or 'prelabs' with the recorded data are submitted when the student completes the laboratory. Other instructors have also found prelabs to be helpful in having students arrive prepared for a class or laboratory[15]. The prelab is graded (the teamwork & team grade component) and returned within two days to the team member that has been assigned to author the experimental report (see Figure 3). The report author writes a draft report in the form of a memo with supporting attachments and submits it in the following week's class. The required report format is detailed in a lab manual that also includes a similar example memo report. The required report components as well as the point allotments are delineated in a checklist (see Figure 4). As Mathes points out, this type of checklist supplies a convenient tool for self-evaluation and self-teaching[16].

- **Statement of Purpose (/5)** *Does this section give a concise statement of the principal or hypothesis to be tested?*
- **Derivations of Required Relationships (/15)** *Does this section, much of which may be a handwritten attachment, give an adequate development of the pertinent equations, coefficients, and theoretical relations?*
- **Experimental Procedure (/10)** *Does this section give the reader a good visual sense of the step-by-step testing procedure that is proposed?*
- **Spreadsheet (/20)** *Is this a comprehensive and well organized spreadsheet or is it missing major components?*

- **Grade (/50)**
- **NOTE:** *A copy of your group's prelab along with this grade sheet must be submitted at the beginning of the lab or you will not be allowed to start the lab. A copy of the filled-out spreadsheet must also be submitted at the end of the lab.*

Figure 3. Prelab Checklist with Sample Grading Distribution

- **Heading/Salutation/Sign-Off (/5)** *Have the audiences, source, subject, and relevant reference information been identified so that the recipient(s) immediately know the significance of the letter? Is there a proper salutation and closing? Is the memo signed?*
- **Purpose Statement (/5)** *Is a concise statement of the client's request and/or the problem and the objective of the test provided?*
- **Summary (/10)** *Are the important conclusions and your recommendations briefly stated so that the reader will not have to read further into the report?*
- **Sample Description (/5)** *Does the reader have a good visual sense of the sample that was tested?*
- **Test Procedure (/10)** *Are the analyses and the tests that were performed briefly explained?*
- **Results of Testing (/10)** *Are the bottom-line results of your analysis given?*
- **Conclusions (/10)** *Have you presented your interpretation of the results in the form of major conclusions? Are the actions, goals, and any recommendations listed in decreasing order of importance?*
- **Attachments (/25)** *Are the documents necessary to support your results, analyses, and conclusions included in the report?*
- **Paragraph and Single Sentence Editing (/10)** *Does the text of the report reflect careful revision and editing?*
- **Format and Visuals (/10)** *Does the report embody effective document design principles? Are visuals (graphs, charts) and tables used appropriately?*
- **Grade (/100)**

Figure 4. Memo Report Checklist with Sample Grading Distribution

Each draft report is given to a non-author member from a different team to essentially grade the draft report in the same manner that the instructor eventually will. The peer reviewers make analytical, spelling, grammar and presentation corrections right on the draft copy and submit constructive criticisms and a numerical grade for each of the components on the report checklist. This reviewed draft must be returned to the instructor within two or three days. A cursory check of the reviewed document by the instructor ensures the author receives valid and reasonable amounts of feedback. The peer reviewed draft and completed checksheet are returned to the author who resubmits these documents with a revised report. This permits the instructor to grade the final report and the reviewer's contributions at the same time. Identifying author and reviewer information is stripped from the work to maintain anonymity throughout the process. The roles of the author and peer reviewers are reversed for each of the first four experiments. Draft reports that are not handed in on time do not receive the benefit of a review.

This draft/peer review process has proven to be very effective. It reduces the workload on the students and the instructor since almost half the number of final reports is written. The experience of seeing and critically reviewing their colleagues' work gives the students a whole new perspective. It is much more meaningful when peers have trouble following one's work (even though they are involved in the same assignment) compared to an instructor, who is viewed to be at a totally different technical level. Most of the reviewers take this assignment quite seriously since the accuracy and thoroughness of their work is graded. The superior quality of most of the student-graded reviews is a pleasant surprise.

The final laboratory experiment in the semester involves the most complex experiment in which each student is individually responsible for all aspects of the experiment. In this case a formal report is required. The format details and an example of a formal laboratory report and associated letter of transmittal are again presented in the laboratory manual. The students are given more time on this assignment, and the instructor acts as the reviewer. Students struggle with the translation of quantitative and qualitative information into any sort of discussion of results or conclusions presented in a logical, concise, and accurate manner, but they really struggle with the concept of an abstract. To help with this problem, the laboratory manual contains abstracts taken from the papers that the ME faculty have written. Besides giving them some pertinent examples, it introduces this sophomore level class to the type of research that is being performed in the department, as well as possible future graduate research opportunities.

Several things are done to reduce the initial shock that occurs when a student is required to take so many components and integrate them into a single package for the first report, even if a person is quite familiar with each component. Several class periods are spent reviewing concepts and tools (e.g. graphing, spreadsheets, introductory statistics, propagation of error analysis, nonlinear regression analysis) that are to be utilized in the laboratory and doing related homework assignments. As previously mentioned, the prelab for the first experiment is given to the students to reduce the initial workload. The first experiment is also limited to very simple concepts, measurements, and their associated errors so that the main objectives only involve statistical concepts and the introduction of the memo report format.

It should be noted that several of the English assignments are designed to alleviate some of the writing burden through consolidation. For instance, a piece of writing that a student is working on for the linked lab is also used in one of the English assignments. Also, the ME senior design proposal requirements and process are presented to the English class. The students can utilize the research assignment for the technical writing course to generate some background information on a possible senior design project.

As expected, individual faculty use variations of the report formats in subsequent courses but they pretty much utilize the ones introduced in this laboratory course. Since the implementation of these curriculum changes, the faculty is utilizing memos more when making assignments and now require more structured and better-written student reports. The students are therefore receiving more exposure to technical writing and more opportunities to practice it.

IV. Conclusions

Even though the class's interview-based survey determining what and how much engineers write echoes the conclusions of professional surveys, having the students conduct the survey via personal interviews themselves has proven to be an effective pedagogical technique – much like repeating a classical experiment. It gives students an opportunity to interact with professionals in their field and gain a first-hand understanding of the many ways writing is used and the importance of good technical writing skills. Further, a majority of the pupils ***discover*** on their own that they must be accomplished technical writers to succeed as engineers. Their survey also delineates most of the formats, audiences, and procedures they will encounter.

An assessment of the success that this interdisciplinary approach has had in promoting technical writing skills is very subjective. Students still complain about the amount of work for minimal credit but there appears to have been a notable improvement in their attitudes toward the emphasis on writing in this laboratory. The faculty that teach the subsequent courses report they have seen a vast improvement in the professional quality of the reports from the veterans of the linked courses. Unfortunately, some students tend to avoid the difficult logical thought process that is required to generate a professional report in favor of things that they want to do and give them immediate gratification. Inordinate amounts of time may be spent working with analysis software or producing computer generated drawings and graphs that, as Denton notes, "go well beyond the scope of the report requirement" [17].

Considering the reformed course places a strong emphasis on simulation of "real world" engineering tasks, perhaps the best judges of the effectiveness of the course are course alumni. In August 1998, a brief survey was sent to UW ME graduates (approximately 125) of the reorganized lab. Thirty-eight surveys were returned. The initial results of those indicating they were currently practicing engineers (twenty-eight) were summarized. When asked to "rate the effectiveness of the course with regards to developing technical writing skills", over 68% of the respondents responded *Good* or *Very Good*; when asked to "rate the course effectiveness in terms of developing critical thinking skills", over 79% responded *Good* or *Very Good*. (Scale was *Very Good, Good, Fair, Poor, Not Applicable.)*

In an effort to expand, enrich, and sustain the on-going pedagogical collaboration between the linked classes, the Mechanical Engineering, English, and Physics departments with the financial support of the University's Center for Teaching Excellence (CTE) will be establishing web-sites which link appropriate materials. Administrative files, homework and solutions, and laboratory assignments will be posted at the ME site. The prelab and report formats with their respective grading checklists and sample laboratory reports, currently found in the class/laboratory manual, will be transferred to the English class's web page. Discussions of analysis techniques common to both Physics and ME (e.g. statistics, propagation of errors, regression analysis) will be updated and posted. Benefits of such sites will include refinement of the delivered materials, minimization of duplication, and facilitation of the students' appreciation that they must assimilate information from many disciplines. With its direct links to other campus resources, the web site will make the emphasis on connected learning physically apparent to ME students.

Another recently implemented strategy is the adoption of a portfolio or journal in the ME class/laboratory class. While used frequently throughout the humanities to allow for personal reflection and chart progress and growth, such a tool is rarely used in engineering education. Rather than handing in individual lab assignments, students hand in *all* their work to date in a single packet. The aim is for the students, as well as the instructor, to be able to easily see the progression from rough draft to final report for a particular assignment as well as individual growth over the semester.

The restructured laboratory course exposes the students to a realistic engineering environment at an early point in their curriculum. It promotes critical thinking at every stage of the experiment: from the experimental design, to writing a valid prelab and analyzing the data, to writing the final report. The students are also exposed to teamwork, the peer review process, and the need to meet a schedule since other people depend upon their work. They have the opportunity to practice technical report writing in a germane setting with timely and meaningful feedback. The students also increase their skills in the use of productive computer software since it is an integral tool in the analysis and the production of a professional report.

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