AC 2010-1621: THE USE OF CONFERENCE PREPARATORY PRINCIPLES AND PRACTICES (WRITING AND PRESENTATION SKILLS) TO TEACH INTERDISCIPLINARY LABORATORY COURSES

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The Use Of Conference Preparatory Principles And Practices (Writing And Presentation Skills) To Teach Interdisciplinary Laboratory Courses

Abstract

This paper examines the application of conference preparatory principles and practices to teach materials science through the incorporation of ‘conference style writing’ as a teaching tool into an introductory multidisciplinary (Bioengineering and Materials Science) laboratory course. The goal of this work was to evaluate the use of “conference style” abstracts, oral presentations and poster presentations to teach undergraduate laboratories, and evaluate the students perceived value of these tools and skills in their future engineering careers. A 1 credit (3 hours per week for 16 weeks) materials science laboratory was used to instruct 7 materials science laboratories using pre-lab conference skills tutorials, pre-lab content quizzes, individual student 1 page abstract submissions, team conference presentations and final team poster presentations. The results of this work show that students can adopt and improve their conference abstract writing skills, and by the end of the course the students recognized that this new ‘format’ for this inquiry based class was beneficial for their engineering career. A positive feedback from the students suggests the transformative power of this writing style in not only learning how to effectively summarize a laboratory experiment, its results, and discussion, but it has also allowed them to develop material selection (based on their mechanical properties) skills for a specific bioengineering applications. The positive feedback goes hand in hand with the statistical analysis of the evaluations of the students’ writing at the beginning and at the end of the course. Statistical analysis demonstrated that 44% of the students increased 10% in a letter grade or more from the start till the end of the course. Overall, the re-design of a traditional laboratory course has proven to be beneficial for students in both majors not only for their academic development but also to prepare them for future professional opportunities.

Introduction

Background

Materials Science has been defined as a discipline that combines the relationships between the structure, properties, processing and performance of materials combined with engineering theory, laboratory practice and societal awareness. Therefore, there is a need to correlate the theoretical concepts learned an introductory undergraduate course with the actual use of these materials in laboratories and in real-world engineering applications. Introduction to Materials Science (CME210, and its associated laboratory, CME241L) are core sophomore courses in the curriculum of Bioengineering, Materials Science and Chemical Engineering undergraduates. As a multi-disciplinary class, these courses are often taught to large numbers of students, with different majors, and many cases, the associated laboratory sections are composed of truly
“multi-disciplinary” teams of undergraduates. These large class sizes and differing educational perspectives make the teaching and engaging of these students challenging, and poses unique educational challenges to instructors of these students. This paper examines the application of conference preparatory principles and practices to teach materials science through the incorporation of ‘conference style writing’ as a teaching tool into an introductory multidisciplinary (Bioengineering and Materials Science) laboratory course. The goal of this work was to enhance the academic and professional development of students during mentored laboratory activities.

At Clemson University, the materials science laboratory course (CME241L, Metrics Laboratory) was designed to introduce sophomore engineering students to the use of equipment, instruments, and procedures required to formulate, prepare, and characterize ceramic, metal, and polymer materials. Skills practiced by students include the use of proper experimental methodologies, analysis of results, evaluation of alternative procedures, and written/oral presentation techniques. This course is unique as it is a core requirement for both ceramic and materials engineering (CME) majors as well as bioengineering (BioE) majors. This course is usually taught by faculty from the School of Materials Science and Engineering, with the vast majority of students being CME students. In 2004, a new undergraduate Bioengineering major was introduced, and the composition of the class shifted rapidly to a majority of BioE students. A rising drop rate (approaching 50% among the new BioE students) warranted a re-examination of the course content and teaching style for this new multi-disciplinary student body. Approval for revision of the course was received from both the BioE and CME departments, and a commitment of teaching assistants, instructors, and laboratory space was secured from both departments.

The authors then worked to develop a new model and structure for the course that could leverage the new multi-disciplinary student body, and developed an inquiry based program where teams of students were challenged to evaluate the results of basic materials characterization laboratory data and determine the most appropriate bioengineering application for that material. For the semester discussed in this work, a new ‘abstract’ format was implemented in order to incorporate a writing style and inquiry-based approach that will help the student in their engineering careers.

In designing the course, the authors used of the S.T.A.R. legacy cycle approach to group management and experiential learning based curriculum. The S.T.A.R. legacy cycle has been suggested as a solution for teaching many different learning styles. The cycle begins with the initial “challenge,” in which a particular problem must be solved. For our purposes, this was an initial challenge for the students to determine which material out of the five given (2 metals, 3 polymers, 1 ceramic and 1 glass) was most appropriate for their given application. Next, in the “Generate Ideas” section students determine the needed background information to solve their problem and to answer any additional questions. Mainly, this required the students to assess the design criteria for the given biomedical application (or in other words, “What tests and experiments would be necessary for the student to solve the initial problem?”). Students met weekly with teaching assistants to perform a different set of experiments each week. During and following lab students met with the teaching assistant to discuss the interpretation of the data. In the “Multiple Perspectives” section, other faculty members in the two departments were often
utilized as outside “experts” and were able to provide appropriate guidance to students regarding their experimental work and materials selection. In writing their individual abstracts, students were required to conduct background literature reviews on how these problems have been previously addressed. For the “Test Your Mettle” phase, students provided a written abstract of their findings and proposed future experiments that might better test their proposed solutions. The “Go Public” phase involved presenting the team presentation of their work via oral and poster presentations at the end of the semester. These presentations were evaluated by faculty outside the department.

Similarly, Enderle et al. also has demonstrated that there is a direct correlation between real world problem solving in the undergraduate curriculum and the ability to promote critical thinking, teamwork, interpersonal skills, analytical, problem solving and communication skills. Therefore, this course matches these desired technical abilities to the idea of being able to interpret the calculated material properties and effectively use this data to propose a specific material for a bioengineering application. Considering that this is the first engineering laboratory in the curriculum, several authors have emphasized that these ‘first’ laboratory experiences must generate enthusiasm, moving away from the traditional laboratory designed as ‘food recipe’. The idea of an ‘open ended hypothesis’ laboratory experience can allow the student to explore a wide range of possibilities, especially considering that each laboratory provided another piece of the puzzle, another material property. Therefore, the course structure allowed the student to pick the material that is more suitable for that application just based on that experiment. Therefore, at the end of the course, this ‘open ended hypothesis testing’ becomes more like a ‘funnel’ which filters all the data gathered from the laboratories. The funnel opens up the possibility for proper material selection for a specific application, with the complete solved puzzle giving the student the complete ‘big picture’ which then its bioengineering application relies on several supporting arguments and data.

For the semester discussed in this work, a new ‘abstract’ format was implemented in order to incorporate a writing style and inquiry-based approach that will help the student in their engineering careers. The design and planning of this course was based to meet the ABET EC2000 criteria. The foundation for the use of this criteria was to correlate and promote the undergraduate experience to be similar to other courses that have a similar set-up of a laboratory class that is mainly used to strengthen the concepts and principles learned in the lecture. Among the criteria met, this course included: the application of knowledge of math, science and engineering; the design and execution of experiments and measurements, analysis, and interpretation of data from living systems; the ability to contribute in a multidisciplinary team; ability to communicate effectively and to make the student aware of contemporary issues.

Course Description

The Metrics Laboratory (CME241L) was a 1 credit course that met once weekly for 3 hours for 16 weeks. The course was co-instructed by one faculty from Bioengineering (BioE) and one faculty from Materials Science and Engineering (MSE). For the semester of interest in this paper, there were 3 sections of students with a total of 66 students. The students were required to take this course as part of their curriculum in both BioE and MSE.
With oversight, guidance and assessment from the instructors, one teaching assistant was dedicated to teach each of the 7 laboratories for the entire semester. Each TA was responsible for developing the laboratory procedures, administering a pre-laboratory quiz, providing the pre-laboratory instructions and monitoring the progress of the students during the laboratory. The instructors and the TA’s all had office hours during the week to assist the students with questions. All materials for all labs were available via a dedicated BlackBoard internet site, and students were able to use this online site to communicate with labmates, instructors and TA’s, check their grades, and upload their assignments.

All students within a section met as a class each week prior to the start of the laboratories. Each time the class met, the first thirty minutes was dedicated to a mini-tutorial, class assessment, or class presentation activity. The tutorials were either taught by the instructors or senior teaching assistants and included the topics of conference abstract writing, oral presentation skills, poster presentations, statistics, laboratory safety. Students were then dismissed and led by the TA’s to individual laboratory locations. Once there, the students were required to take a ‘pre’ lab quiz to check their understanding of the material that will be covered in the laboratory of that day. This pre lab quiz also provided feedback to the teaching assistant and instructors in order to fully cover and reevaluate what are the student’s weaknesses and strengths for the specific laboratory.

One of the main objectives of the course was to encourage the idea of teamwork not only during the laboratory session but as well as for the actual writing of the abstract (for example the materials and methods section and results) in order to encourage discussion of how to calculate the mechanical properties. Similarly, the team discussion could shed light to evaluate whether the expected material did or did not perform for that bioengineering application, and which material will be most suitable for that specific application. Teamwork also encouraged task delegation and sharing of knowledge, eventually leading to the distinction of a natural group leader that will take charge and led the team for successful completion of the weekly abstract. Most of the teams had between 4 and 5 students, and they were referenced with their own team name.

This laboratory course covered a wide range of tests and characterization techniques that could contribute to the student’s engineering career down the road. The outcome of this course was to prepare and guide the students to be able to present the ‘best’ application with the proper material that fits it best. The team presented the application with its proper background information as well as introduced at least four tests that they used to learn more about the material they selected. Considering that this was an introductory course for both disciplines, each laboratory was designed to cover each technique in depth so the student learned the principles of the content to be applied later in their career.

The pre-requisite lecture course to this laboratory was the Introduction to Materials Science (CME210). This course included a survey of the whole of materials science (metals, ceramics, polymers, composites) and materials selection to fully understanding the relationship between synthesis, microstructure and material properties. In this course, there is an emphasis to allow further understanding of the relationship between physical and mechanical properties of materials and bonding strength. The introductory laboratory course shows the application of these important concepts through the demonstration of techniques. As an example, the effect of heat treatment and cooling on the mechanical properties of steel is covered in the lecture course,
and then the use of three point bending laboratory is used to determine changes in mechanical properties (ductility, strength and hardness) as a result of heat treatments that the students perform.

**Grading**

Student’s grades were determined from the following distribution:

- Abstracts (7% for each of 7 abstracts) 49%
- Pre-Lab Quizzes (3% for each of 7 quizzes) 21%
- Team Mid-Term Presentation 15%
- Team Final Poster Presentation 15%

The grading scale was as follows: A: 90-100%, B: 80-89%, C: 70-79%, D: 60-69%, F: 0-59%.

The course grading was designed to be highly dependent on individual work submitted (70%) where as the rest 30% was based on the team submitted material (which included the poster and oral presentation). Although the laboratories were conducted in teams, each student submitted their own abstract for grading. The use of abstracts facilitated this grading format because each student could reasonably produce a 1 page report each week, without dependence on others in the team. The classical laboratory format of having a team submit a multi-page report is often criticized by students who cite difficulty in finding common out-of-class team meeting times to complete these reports, and frustration with teammates that do not pull their weight. By linking 70% of the course grade to individual work that was linked to initial team laboratory work, all teammates were encouraged to show an interest in the laboratory activity, were rewarded for individual excellence in completion of the abstracts, and could be held accountable to the team based exercises that required public presentation.

Pre-lab quizzes were graded by the TA’s of that particular laboratory, and abstracts were graded with a rubric by the available TA’s that were not assigned a laboratory for that week. Oral presentations and poster presentations were graded by the instructors using a grading rubric. All rubrics were distributed to the students at the start of the semester and discussed in class.

**Pre-Lab Tutorials**

Each time the class met, the first thirty minutes were dedicated to a mini-tutorial or class assessment activities. These tutorials were either taught by the instructors or senior teaching assistants and included the topics of conference abstract writing, oral presentation skills, poster presentations, statistics, laboratory safety.

The abstract writing session covered what are the key parts of an abstract and how to elaborate on the key ideas that the reader should grasp. The sections of the abstract were the same as the ones discussed in the poster session. The abstract format followed typical conferences abstracts. Each student was responsible for writing seven abstracts. At the end of the semester, the team selected the ‘best’ application and the proper material that fitted that application and this became the topic to be presented at the Conference Poster Presentation.
The presentation skills session introduced the students to what is considered a traditional ‘conference style’ presentation. This session covered the essential topics that must be covered in a typical presentation which includes a background section, materials and methods, discussion and conclusion. This session emphasized in teaching the students about the importance of the ‘elevator’ speech, is vital for a poster presentation. This 30 to 60 sec speech must summarize the key points and outcomes of the study trying to capture the attention of the ‘reviewer’ and get him engaged to key looking at the poster. The importance of this is to make the student comfortable with the material when presenting it. In this session, a ‘pre’ designed poster was provided for the student’s reference. This poster format was used by all the students at the ‘conference’ style poster session at the end of the semester. (Refer to Section 2.)

The statistics sessions were held by one of the teaching assistants who covered an in-depth review of statistical analysis tools with a proper training of the software used for this purposes (e.g. Microsoft Excel). Within the statistical tools, the emphasis was to review with the calculation of the mean and standard deviation, as well as traditional statistical hypothesis testing (such as t-test, the use of a p-value and q-tests) in order to evaluate the quality and significance of the data gathered in each laboratory. Considering that some of the students have covered this material in one of their previous courses, it was very important to emphasize that this is the type of scenario in which statistical analysis is put to place.

The safety review session was offered in order to explain traditional safety rules with respect to the handling of instruments and safety guidelines (which include attire, physical and chemical accidents among other subjects). The departmental safety officer gave a small lecture to the students, especially considering they are responsible to wear goggles at each laboratory session.

End of semester “Student Assessment of Instructor” (SAoI) evaluations were voluntarily completed by each student, as part of the university-wide course assessment program, and the results of this assessment were used to determine the effectiveness of the instructors and course in educational effectiveness and outcomes. (These questions are included with their results in the results section). As part of this assessment, students were also allowed to offer opinions on possible improvements in the course, strengths and weaknesses of the content, grading and instructors, and overall merits of this conference-style learning technique used in engineering laboratories.

**Laboratory Content**
The course consisted of seven laboratories:

- Thermal analysis
  - The main goal of this laboratory was to calculate the thermal conductivity and the heat capacity for a wide range of biomaterials. The methodology used involved the transfer of the samples – exposed to boiled water- into room temperature water beakers. The measurement of the change in temperature in the room temperature beaker allowed for the calculation of the thermal properties; the size and type of material were taken into consideration. For all calculations, it was assumed that the total heat loss by the material was the total heat gained by the water.

- Friction and wear analysis
The main goal was to calculate the tribological properties of four biomaterials: carbon steel, aluminum 6061, Teflon, and nylon. An inclined bench set up was used for the determination of the coefficients of friction (static and dynamic). For the evaluation of wear, gravimetric measurements were performed before and after rubbing each material against silica carbide paper in increments of 10 meters up to a total sliding distance of 50 m. Students were able to understand the effect of roughness in wear.

- **Hardness/density/contact angle**
  - In this laboratory, the students determined the density, the contact angle (with respect to water) and the hardness of each of the biomaterials. Density was determined using direct measurement and the Archimedes’ method. To evaluate the wettability of each material and surface properties, a contact angle goniometer and light source were used. The Vickers hardness was determined for all of the materials.

- **Three point bending**
  - This laboratory introduced the 3 point bending test to evaluate mechanical properties such as yield strength, flexural strength and Young’s modulus of the previously stated biomaterials. This laboratory also allowed for the understanding of the effects of heat treatment and quenching on the mechanical properties of steel (hypereutectoid plain carbon steel). Different quenching media was used, and the students were able to identify the effect of the microstructure on the mechanical behavior as well as on the fracture surfaces.

- **X-ray biomaterials imaging**
  - This laboratory allowed the students to take an X-ray image with materials of unknown thicknesses inside a buffalo skull. Using the traditional grayscale table used for X-ray analysis, the students not only identified each material but also calculated the thicknesses of each material. The effects of the material composition in relation to the intensities revealed on the X-ray were understood. The students were able to compare and contrast each material and identify the benefits of X-ray imaging for certain materials.

- **Porosity/etching/grain size analysis**
  - This laboratory provided the student a solid hands-on experience of how to prepare a sample to be characterized using optical microscopy. Sample preparation included the following: cutting, mounting, grinding, polishing (up to 1 μm finish) and etching. The materials were also characterized in terms of percentage porosity (using a dot-grid method). Grain size was evaluated using the traditional ASTM standard in order to calculate the grain size number as well as the average number of grains per mm².

- **Charpy impact testing**
  - This laboratory introduced Charpy impact tests in order to evaluate the ability of the material to resist fracture based on the measured notch impact energy. The students were able to differentiate the fracture surfaces of each of the materials to determine if the material exhibits brittle or ductile failure and identify whether the material is hard or tough. The students compared the fracture surfaces of both the
3 point bend tests and the Charpy tests to truly understand the effect of strain rate in certain materials.

Across all the laboratories, the same materials were used: ceramic tile, Aluminum 6061, Plain Carbon Steel 1095, Nylon, Teflon, Pyrex glass, polyethylene. The selected laboratories were intended to result in materials characterization data that could be used to objectively assess the potential performance of these materials in an proposed biomedical application. Depending on the laboratory, each team tested a reasonable number of samples in order for them to have a sample size big enough (n>3) to be able to calculate the standard deviation in order to evaluate variability.

All laboratories were conducted within the context of applying the results towards the selection of one or more of the materials for use in a bioengineering application. This exercise was intended to prepare the students to be able to conduct the laboratory with a more hands-on approach which would allow them at the end to evaluate which material would suit their application. Experimental results that included material parameters such as elastic modulus, yield strength, hardness, contact angle, coefficient of friction among other material properties. The specific applications involved current bioengineering examples that could use similar materials that were used in this course. Specific examples of bioengineering applications given for the students to choose from included:

- Cranial defect repair
- Hip joint replacement
- External fixation
- Intramedullary rod
- Suture material
- Cardiovascular stent
- Catheter
- Bone filler
- Achilles tendon graft
- Prosthetic finger
- Eye ball replacement
- Toe nail replacement
- Ear cartilage replacement
- Denture materials.

This wide range of applications allowed each student to be able to research and investigate which material would be suitable based on the results they obtained and to compare the results to values found in literature. In addition, the use of external resources allowed the student to investigate and learn further about the application chosen for that specific laboratory.

**Abstracts**

The students were responsible for producing a one page ‘conference style’ abstract which covered the main sections: title and author information, introduction, materials and methods, results, discussion, conclusions and references. The students were expected to have at least two references (not including the laboratory manual). The format of the references followed the format of a typical Journal publication. For example, citing a journal article should be in this format: Authors, **Journal Title. Year, Journal Number, Pages.** In addition, the course also included a ‘Reference Session’ in which two teaching assistants showed the students how to access the library website. The main goal was to demonstrate how to have access (in and off campus) to main journal databases such as Science Direct, Web of Knowledge and PubMed.

During the course of the semester, students were asked to prepare an abstract based upon the performed research experiment performed the week prior. Abstracts were expected to contain an introduction, and experimental section, results, discussion, conclusion, and references. The highest priority in grading was given to a clear understanding of the lab and its purpose, and how
this lab applied to the overall research question at hand. Many examples of peer reviewed professional biomedical engineering society 1 page abstracts were provided to the students as part of the introductory workshop on abstract writing. In addition, an abstract template was provided to assist the students in formatting and section descriptions. Refer to the Appendix to review this abstract template.

To remain consistent as possible with the evaluation of the writing of the students, abstracts were judged based on the rubric below. Upon evaluation, students were given assistance and suggestions on areas which they could improve. The rubric also allowed students to self-evaluate efforts before submitting a completed assignment.

The abstracts were graded using a 115 point scale with the following rubric that was provided to the students at the beginning of the semester, and reviewed as the semester proceeded.

- 10 points for formatting standards (Title, Authors, margins, fonts, spelling)
  - 1 point deduction for each offense

- 10 points for Introduction
  - The introduction should clearly characterize the scientific question investigated. Background information should be provided to the extent that it introduces the current study and documents its importance to the literature.

- 30 Points for Experimental
  - 10 points: Specimen details given (number, size/shape, composition, interface with test)
  - 10 points: Experimental hardware (model, maker, location), and experimental procedure detailed and accuracy of measurements.
  - 10 points: Statement of statistical analysis, and variables to be measured, assessed and correlated.

- 40 Points for Results (including graphing and table content)
  - 10 Points: Display of data clear and complete (Graphs and/or tables)
  - 10 Points: Text of results clear with numerical references to data. No re-iteration of methods statements or premature use of discussion statements.
  - 10 Points: statistical correlations and/or comparisons of datasets or values given for clarification of meaningful data.
  - 10 Points: Presented data accurate (units, values) and true to experimental method.

- 20 Points for Discussion and Conclusion
  - 10 Points: Meaningful discussion of trends, experimental findings and/or insights given.
  - 10 Points: Concise summary of experimental findings, importance and future possibilities.

- 5 Points for References, Acknowledgement
  - Proper reference formatting, and professional standards.

**Oral Presentations**

At the mid-term of the course and following the completion of 3 or 4 laboratories, all teams were required to present a 15 minute “conference style” presentation that combined their laboratory results to date and apply them towards the selection of a material for one specific bioengineering application. These presentations were formatted according to standard scientific
presentations and included a title, introduction and background, materials and methods, results, discussion and conclusion. These presentations were conducted in front of student peers, instructors and TA, and were followed by a 5 minutes questions and answer period. Students were graded on the oral presentation in three main areas: organization, content, and delivery. A grading rubric was used by each instructor and a final grade was determined by consensus. Their goal was to present the most useful information to their research project in a clear, concise, well delivered manner.

**Poster Presentations**

The final assignment given to the students and the most important to the goal of this class was to prepare a poster of their research for the end of the semester poster presentation. Since one of the overarching goals of this class was to prepare students for a conference style presentation, preparing a poster and presenting it in front of their peers was meant to provide invaluable experience that will help the students prepare for a conference. The poster had six main areas: research objective, introduction, experimental, results, discussion, and references. These areas will be discussed in further detail below. The poster session was graded on several key areas. The design and layout of the poster was to be well organized, logical, and easy to follow with consistent style. The content of the poster was to be adequate to address the research question at hand, along with proper use of terminology with well justified conclusions. Any graphs presented on the poster were to be clearly labeled with their purpose clearly understood to have great importance and impact on addressing the research question. Furthermore, students were asked to be able to provide a brief explanation of their poster what addressed the question, the conclusion the group came too, and what methods they used to reach this conclusion. A grading rubric was used by each instructor and a final grade for each team was determined by consensus.
Common Presentation Content

The abstracts, oral presentations, and poster presentations all contained sections that were common to most experimental reports, and were broken up into six sections:

- **Introduction**
- **Experimental (Materials and Methods)**
- **Results**
- **Discussion**
- **Conclusion**
- **References and Acknowledgement**

In the introduction section, students were asked to give a brief overview of the question at hand. They were to state the purpose of their research and why it was important to understand. They were asked to include a brief history of the application and any other applicable background information. They finished the introduction by stating what their end use was and what material properties would be vital for this use. For the oral presentation and the poster presentation, students were asked to give a brief overview of who they were, what they hoped to accomplish with their research, and what steps they took to accomplish this.

In the experimental section the students were asked to list all of the materials and equipment they used for the four most beneficial labs to validate their material for their end use. For the abstracts, the lab performed that week was outlined and described therefore highlighting how the experiment was performed and what useful information it provided. For the oral and poster presentation, four labs were chosen that gave the students the most relevant information to the question at hand as well as the most useful data and information. Each lab was described in brief
detail, describing what they did and what properties were measured. Furthermore, any statistics the students used to analyze the data received we mentioned here.

In the results section students were asked to summarize the data received from the lab performed. This included all useful graphs and data that helped to analyze the problem at hand. For the oral and poster presentation, they included a graph of the most relevant data that most directly supported their conclusion to the question at hand. Also, for the poster, all results of all materials tested were presented in a chart based on the end use chosen. This chart was simply a list of all materials tested compared to their properties. In the body of the chart a labeling system was used, usually positive or negative, to indicate whether the materials property that was quantified was useful for their specific end use. This further allowed students to identify how they came to the conclusion that their specific material chosen was most well suited for their particular application.

In the discussion and conclusion sections the students were asked to explain the overarching impact of their research. They were to explain the importance of experiment and why it was important for them to perform and what data could be extracted. These sections were of the upmost importance in the poster and oral presentation, as here students had a chance to really explain the overarching goal of their research and how they reached their conclusion. Furthermore, they were also to discuss any novel information they discovered. The students also addressed what future research could be done to further identify the ideal material and material properties for their specific end use.

In the references and acknowledgements section students were asked to provide information on any help they received performing research as well to cite all the outside sources used to support the background section of the bioengineering application describe in the poster. Great importance was applied to referencing any external material used using traditional referencing style. The use of external sources allowed the students to support their arguments for the chosen material for that application considering whether it has been used or is currently used for similar applications. This is critical as this allows the students to understand the need to compare their data to literature values as well as to guide them to critically evaluate what sources are reliable to use.

**Results**

Statistical analysis was performed in order to evaluate the performance of the class as whole as well as individual writing performance at the beginning and at the end of the course. The beginning of the course is considered as Week 1 (January 5th) and the end of the course was Week 16 (April 20th). The seven laboratories were conducted weekly between Week 6 (February 9th) and Week 13 (April 13th). Figure 2 was calculated by extrapolating each student’s final grades based upon the linear trend of their abstract grades. The change from their initial grades to their final extrapolated grades were calculated and given below. The data from figure 4 and 5 was calculated by simply comparing the grade distributions from the start of the class to the final extrapolated grades.
Figure 2. Percentage of students whose abstract grades improved throughout the semester.

Figure 3. Initial abstract grade distribution of Students for the CME 241 class.
Unlike the standard laboratory reports that are typical of most engineering laboratory write-ups, the use of the 1 page abstract format was seen by many students as a clearer task in which to complete an assignment, and a more concise medium to effectively communicate the material learned in each laboratory. This led to the student perception that the expectations of the course content were more clearly communicated, that the course was overall more relevant, and that it was well organized. Student feedback from the end of semester course evaluations gave a score of 4.23±0.61 (n=65, scale of 1 to 5) in response to question G1, “The instructor clearly communicated what I was expected to learn.”, a score of 4.43±0.64 (n=65, scale of 1 to 5) in response to question G2, “The instructor made the relevance of the course material clear.”, and a score of 4.42±0.66 (n=65, scale of 1 to 5) in response to question G3, “The course was well organized.”. These basic questions are asked at the college level in all engineering and science courses, with the results of this class exceeding the “Same Discipline” average scores for all of these measures.

The authors attribute many other aspects of the course content for these high assessment scores. In response to G1, the authors attribute the use of the pre-laboratory mini-topic lectures, abstract writing tutorials and examples, and individual TA pre-laboratory overviews to the satisfaction of students need to understand what was expected of them. In response to G2, the authors attribute the clear guiding theme of the course, in which professional style conference abstracts would be used as a medium to explore the application of laboratory methods to biomaterials applications, as the basis for high marks by the students. At the sophomore level, the ability to communicate the “relevance” of basic engineering content is difficult, as students often fail to absorb the abstract discussion of “applications”. This can be seen as a both a lack of interest on the part of the student, but also a lack of sufficient grasp of the academic content to be able to effectively translate that knowledge to the larger “big picture”. The use of abstract writing was seen as a way to engage the student, both in terms of a writing medium in which the student was producing a document that holds professional peer-reviewed merit, and as a method to translate their laboratory knowledge to a topic of relevance to their biomedical educational objectives.

Figure 4. Final abstract grade distribution of students of the CME 241 class at the end of the semester.
Students were overwhelmingly supportive of the class, with 95% of students responding that as a result of this course, they felt that they became a “better student/engineer” (Question I1: Have you become a better student/engineer as a result of this course?, Yes=60, No=3). Over 90% of students thought that their technical writing skills were significantly improved (4 or better) as a result of this course (Question I2: My technical writing skills have improved as a result of this course.”, 4.4±0.71 (n=64, scale of 1 to 5). And finally, student feedback on the relevance of the course was overwhelmingly positive, with over 90% of students stating that they had a greater understanding (4 or better) of materials selection criteria for use in biomedical applications as a result of this course (I5: My understanding of the materials criteria and selection for use in bio-medical applications has improved as a result of this course.”, 4.52±0.90, n=65, scale of 1 to 5).

Discussion

It can be easily seen from the data that over the course of the semester, most student’s grades improved significantly. 86.36% of students showed some improvement in abstract grades over the course of the semester. This can be attributed to a better fundamental understanding of what is required in an abstract and what was to be expected. It was also determined that not only did student grades improve, but the amount of students creating superior level work doubled. The percentage of students whose final grade was an A was 68.18% as compared to 34.85% initially. The percentage of students who performed poorly (C or F) went from 25.76% initially to 4.55%
Based on the course evaluations, the students commented on the variability of the grading of the abstracts considering it ‘inconsistent’ from week to week. This variability was mainly dependant on the scheduling of the laboratories, as the teaching assistants taught for 4 weeks straight, and the other four weeks they were responsible to grade. Because of this, the teaching assistants did not always grade their own abstracts. Even though they followed the rubric, there was some inconsistency in grading. Therefore, in the coming semesters the authors will suggest that teaching assistants grade their own laboratories abstracts in order to keep a continuous grading format. The students did note that the materials used in the laboratory course could not be directly applied to current bioengineering applications. Among the materials used these included ceramic tile, aluminum 6061, Nylon, Teflon, and high carbon steel. The decision to use these materials relied mostly on cost and actual processing into proper sample dimensions and shared for each laboratory. The use of ‘medical grade’ materials was out of the budget of this course. The decision to use these materials relied on the fact that students learned what desired properties (within a range) are needed for each specific bioengineering application. The students were to research about the traditional material used for their application and then compare it to the most suitable material tested in the laboratory. It is because of these reasons that the materials supported the inquiry-based approach intended for this course, which is highly emphasized by NSF report for undergraduate engineering education. As one student stated, “actually doing the experiments and seeing the materials act the way they did made the concepts easier to learn, seeing a beam rebound from the 3 point bending laboratory reinforced the difference between elastic/plastic deformation.” etc. The emphasis of this course was more of a hands-on approach which was appreciated by the students, as one stated “this course helped me to realize what it would be like to be a bioengineer in the real world.”

Typical student’s impressions with respect to the use of the conference style abstract writing reflected a positive response and they highly valued the positive effect of the learned professional writing style into their careers. Among the responses, these include, “I am really glad I have experience writing abstracts because this will help me greatly in my future career;” “I thought the abstract method was great. We learned to be concise and professional.” Many students quickly grasped the “relevance” of abstract writing as a professional tool. This relevance was initially introduced to the students through discussions of why abstracts are written, how they are used in conferences, how they are reviewed, and what professional benefits can be expected from a well written abstract. The students were most interested to learn that the acceptance of a one page written abstract to a professional conference was the launching point for multi-day professional travel to a conference. Students were even more interested to know that these benefits are often expended to undergraduates that engage in laboratory research, and that most of these conferences include opportunities for professional networking with future employers. In comparison to the discussion of why a “laboratory report” is important in your professional career, the use of conference style “abstracts” as a method to engage students, clearly communicate the relevance of the task, and offer clear opportunity for professional advancement is much more approachable. Finally, it could be expected that an “abstract” would be one of the first documents expected from a student or junior engineer, with a more comprehensive final report following this initial abstract. In professional practice, laboratory
reports are comprehensive documents (often approaching 100’s of pages), and usually encompass many weeks or months of professional work. Guidelines for these documents vary considerably from employer to employer, and it is usually the case that few outside the inner circle of confidentially will ever read the report. Abstract writing on the other hand implies that the document will be read by the public, and usually follows a universal template designed for readability by a specific professional society (ASEE or ASME for example). In addition, these abstracts stress writing for accessibility by people proficient and non-proficient in the field, which forces the writer to introduce and explain the relevance of the work being presented. Each of these tasks works to further enhance the ability of the student to apply their basic knowledge and fosters willingness for life-long learning. Refer to the Appendix for an example of one of the best abstracts written by the students in this course.

Similarly, based on the feedback, the students valued the interaction with the testing equipment and the availability of the teaching assistant to provide help and guidance. Among the student’s impressions towards the strengths of the instructors and teaching assistants, these include: “Very Organized and well communicated. Also, they are very well knowledgeable on the subjects they instruct;” “Hands on application of information we learned in CME 210, we had to think of applications for various material properties;” “Practical goal of learning how to write abstracts. The labs do a great job mirroring material learned in class. The TA’s are helpful and most labs are enjoyable;” “I like how each T.A. has his/her own lab. It allows for them to know exactly what they are talking about;” among others. The use of the ‘pre’ lab sessions such as the statistics review sessions were highly valued by the students mainly for the importance to evaluate the significance of the data and the variability in the experiment. Several students replied, “the statistics lecture beforehand was very helpful in learning how to analyze our data.” The pre lab quizzes were also widely accepted by the students considering that “I thought the quizzes before each lab was a good idea to make sure we understood the reading;” “The pre-lab quizzes were helpful so we knew what to expect in lab and had background knowledge,” among others.

Overall, based on the students’ feedback, sixty-two students will recommend this course to a friend, two will not and one did not respond. Therefore, this result not only strengthens their positive response to this new’ course’ format and layout but it also signifies that the content and development of all the laboratories has been widely accepted and enjoyed by more than the 95% of the class.

Conclusion

The inquiry based-approach in combination to the application of a conference style writing and presenting format has been successful to not only introduce sophomores of both Bioengineering and Materials Science to a wide range of laboratories but it prepare the students to be able to write and present their work the same as a traditional conference style format. The overall academic performance as well as the student’s feedback supports the success of the implementation of this course not only based on the content of the course but most importantly to the designed format and organization. More than one third of the class showed a positive trend by increasing a letter grade by the end of the course. Based on the student’s feedback, the methods of evaluation could be revised, but the format of the course will be used for upcoming
courses. Similarly, the students positively commented on the use of the conference style abstract format as well as the use of oral and poster presentations as these strengthen their skills and abilities needed for their engineering career. In addition, this course was designed based on the ABET EC2000 criteria, which emphasized the conceptual application and subsequent design and execution of experiments, measurements and data analysis in order to introduce the student to current issues with the design of medical devices/bioengineering applications. This course promoted the effective written and oral presentation of a current bioengineering application by a multidisciplinary team, therefore fulfilling and exceeding all the listed ABET criteria. The ‘open ended hypothesis’ approach was also appreciated by the students, as they did recognize how each laboratory contributed to the learning of a new material property that will at the end support their argument to pick a specific material for a bioengineering application.

Acknowledgements

The authors wish to thank both departments Materials Science and Engineering and Bioengineering for their financial support and facilities. We are also very grateful for the help of all the teaching assistants involved in this course.

References

Appendix

The abstract below represents one of the best abstracts written by a sophomore student in the CME 241 class. The abstract evaluates the use of carbon steel for the use in total hip replacements.

Assessment of Friction and Wear Properties of Carbon Steel for Use in Total Hip Joint Replacements

Student Name #1, Student #2, Student #3, Student #4, and Student #5
Team Name, Section #02 Team 1, University, State Zip Code

INTRODUCTION: Total Hip Joint Replacements (THR) typically have two main components: the femoral component and the acetabular component. Ceramics, metals, and polymers are commonly used materials for a THR. Carbon steel typically has excellent mechanical properties, such as durability and strength, for the femoral hip component, which consists of a neck, a stem, and a proximal body [1]. The analysis of static and dynamic friction for this material is of utmost importance to determine the ease at which it can move in the body, especially when in contact with the surface of the acetabular component. As the two move against each other, wear will occur. This can cause problems when debris results from the wear, so the wear factor is also an important value to determine for the materials involved [2].

MATERIALS AND METHODS: The static and dynamic frictions of carbon steel, aluminum 6061, Teflon, and nylon on Al 6061 and nylon were determined. The four blocks of the different materials were massed on a balance and placed on an inclined plane (friction bench) of 10° with a countersurface of Al 6061 or nylon. For static friction, weight was added to the pulley, string, and hook system until the block moved up the incline plane, and that was measured. For dynamic friction, the block was nudged while the water weight was added until the block slid up the plane steadily. This was repeated for all 8 combinations of materials and planes. Seven sets of data were acquired.

To determine the wear factor for each material, the dimensions of the material and the mass were measured. A 1 kg weight was placed on top of the block, and it was rubbed against the 320 grit silicon carbide paper. The block was massed every 10m of sliding for a total of 50m. This was repeated for the other three material blocks. Four sets of data were completed.

RESULTS: The static friction force and the normal friction force were calculated by determining the force (w) from the mass applied along the pulley ($w = mg$, where $g$ is 9.8 m/s²). The normal force was calculated by the weight force of the block multiplied by the cosine of the angle of elevation (10°). Then, the coefficients of friction ($\mu_s$ for static and $\mu_d$ for dynamic) were determined by the equation $F = \mu N$. The value was averaged across the data sets and the standard deviations were determined (Table 1). The most favorable average coefficients of static and dynamic friction were results of the steel and nylon combination (0.47±0.13, 0.39±0.022 for static and dynamic, respectively).

The wear factor ($K$) was determined by the application of the equation $K = V / (d X P)$, where $V$ is the volumetric wear rate, $d$ is the total distance, and $P$ is the applied load. For accuracy, the weight of the wood was determined from the volume of the block and the density, and it was accounted for in the calculations. The average wear factors and standard deviations were calculated for each material (Table 2). Notably, carbon steel had a wear factor of 0.004±0.002 mm²N⁻¹m⁻¹, which was the lowest among tested materials.

Table 1. The average coefficients of static and dynamic friction for material pairs

<table>
<thead>
<tr>
<th>Combination</th>
<th>$\mu_s$</th>
<th>Std Dev</th>
<th>$\mu_d$</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel vs Nylon</td>
<td>0.47</td>
<td>0.013</td>
<td>0.39</td>
<td>0.022</td>
</tr>
<tr>
<td>Al6061 vs Nylon</td>
<td>0.59</td>
<td>0.044</td>
<td>0.44</td>
<td>0.018</td>
</tr>
<tr>
<td>Teflon vs Nylon</td>
<td>0.52</td>
<td>0.021</td>
<td>0.39</td>
<td>0.027</td>
</tr>
<tr>
<td>Nylon vs Nylon</td>
<td>0.54</td>
<td>0.034</td>
<td>0.46</td>
<td>0.023</td>
</tr>
<tr>
<td>Steel vs Al</td>
<td>0.61</td>
<td>0.048</td>
<td>0.53</td>
<td>0.016</td>
</tr>
<tr>
<td>Al6061 vs Al</td>
<td>0.69</td>
<td>0.078</td>
<td>0.56</td>
<td>0.025</td>
</tr>
<tr>
<td>Teflon vs Al</td>
<td>0.66</td>
<td>0.074</td>
<td>0.50</td>
<td>0.017</td>
</tr>
<tr>
<td>Nylon vs Al</td>
<td>0.72</td>
<td>0.051</td>
<td>0.58</td>
<td>0.050</td>
</tr>
</tbody>
</table>

Table 2. The average values of wear factors ($K$) for the four materials

<table>
<thead>
<tr>
<th>Material</th>
<th>$K$ [mm²N⁻¹m⁻¹]</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Steel</td>
<td>0.004</td>
<td>0.002</td>
</tr>
<tr>
<td>Al 6061</td>
<td>0.039</td>
<td>0.016</td>
</tr>
<tr>
<td>Teflon</td>
<td>0.049</td>
<td>0.014</td>
</tr>
<tr>
<td>Nylon</td>
<td>0.038</td>
<td>0.011</td>
</tr>
</tbody>
</table>

DISCUSSION AND CONCLUSIONS: The lower the coefficient of friction, the easier it is for the two materials to slide along each other. This is extremely important with a THR because the femoral component must be able to rotate in the acetabular component smoothly and easily. Overall, the coefficients of friction were lower for the nylon countersurface than the aluminum (Table 1), which implies that a polymer like nylon should be used for the acetabular component, and the steel on polymer combination is quite reasonable. The standard deviations for these values were also quite small, meaning the measurements are fairly precise, and results can be replicated easily.

Steel showed the lowest wear factor, meaning that fewer particles were sloughed off by abrasive wear through contact with the silicon carbide paper. This is desirable because it promotes the longevity of the implantable medical device and proves the durability and resistance to wear of steel. Further analysis of carbon steel on alternative polymer bearing surfaces, such as UHMWPE, should be explored to determine the optimal material pair choice.


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