AC 2008-93: "THINKING OUTSIDE THE BOOK" OR "WHY MY STUDENTS WANT TO BE CALLED BIG DRIPS"

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Abstract

An often-ignored sector of engineering and engineering technology education is the application of "book learning" to "real life" situations. The practice of engineering often requires insight, assumptions, and a merger of disciplines, three things difficult to teach in a classroom. Traditionally, while an instructor may do a wonderful job of teaching course material, it is difficult and time consuming to provide students with an understanding of the challenges of practical application.

Sometime around a student's sophomore or junior year, they realize that engineering is not an exact science. Conditions surrounding the choice of theories and/or equations are often the most difficult to judge. During their academic studies, they are helped in the decision-making by the sectioning of material but once they begin their professional career they suffer from doubt, uncertainty and the loss of the answers in the back of the book. The challenge then for engineering and engineering technology professors is in preparing students to apply classroom material to "real life" situations while still supplying them with the essential fundamentals.

This paper discusses a class assignment that inspires students to think outside the book. Students are asked to find real life examples of the theories and equations learned throughout the course and to present them to the class. For junior level courses, the topics are broad and often something of personal interest. For senior level classes, the students are to talk to practicing engineers to find actual case studies. In all instances, the topics presented, utilize course theories and/or equations. Working in teams students prepare reports and "fun" presentations to be given to their peers. In a class wide competition, the winners are awarded a trophy and given the auspicious title of "The Big Drip" for Fluid Mechanics and "The Great Gear Head" for Machine Design.

Introduction

Upon graduation, young engineers are faced with the challenge of applying classroom lessons to real-life applications. The challenges faced in industry can involve problem identification, equation selection, and mixed subject material. To an employer who hires a young engineer, there persists a learning curve. This, accompanied by a common lack of confidence, can delay the transition period from student-engineer to practicing–engineer. The sooner the new hire can overcome the aforementioned obstacles the sooner they become an asset to their company. It is a challenging task of the professor to guide students and encourage them to applying scholastic material by thinking outside of the textbooks.

Problem Development

A goal of Engineering and Engineering Technology professors should be to prepare the students for a smooth transition into industry. Employers' often communicate the need for graduates to have a thorough understanding of how to integrate technologies and solve real-world problems. Practicing engineers rely on knowledge, experience, and research to lead them through a project. A young engineer, at the beginning of his/her career, is faced with many adjustments. A lack of insight reduces the confidence of the young engineer leading to the need for greater supervision. While companies that hire new graduates have a general expectation that additional supervision will initially be required, it is advantageous to all concerned if steps can be taken to reduce the lag time.

Several obstacles exist that can lead to uncertainty and a longer transition into industry. First, students can no longer determine the type of problem they are facing or which equations apply simply by recognition of the section of the text they are studying. While in school, material is broadly segmented into courses that are refined into chapters and topics. The proper problem approach is easily recognized and their success verified by the answers in the back of the book. When initially given a project the young practicing engineer may feel insecure and unsure of the approach that should be taken. They feel lost without the safety net of the course leading the way. Try as they may they will not find the answer in the back of the book.

Another drawback encountered by young engineers is the inclination to apply equations incorrectly. Once again when asked to do work from a broad spectrum their choice of the appropriate equation can be wrong. Due to various simplifications, many engineering equations are not applicable to all cases. Often circumstances and assumptions dictate the appropriate equations. While references disclose related assumptions, a young eager engineer may overlook their importance and apply the wrong equations. It is important to give students exposure to the process of equation/theory selection out side of a textbook.

An inherent difficulty with the education of engineering students in a traditional setting is the lack of exposure to problem solving which may entail more than one course topic. Often the only exposure that students have to cross-course problems is during capstone projects. It is felt that there is a "disconnect" between theory in the course and the reality of implementing class material. Due to this disconnect, students are often struggle to implementing the knowledge in follow-on design courses such as capstone courses[1]. In reality, the practicing engineer cannot count on the compartmentalization of material. Projects or designs may require a mixture of information learned from multiple courses. Professors can aid in the preparation of students by assigning projects that expose students to mixed content.

The latest ABET criteria suggests the need for colleges and universities to instill in students the desire for lifelong learning[2]. To the curious and inquisitive, learning is fun however; the logistics of finding needed information is, at times, tedious and frustrating. By guiding the students through the process of searching technical documents, instructors can break down barriers that may otherwise prevent lifelong learning. Literature suggests that shifting some of the responsibility for education to students, through active learning, can yield significant benefits. As presented by Umble, Umble and Artz, proper implementation of active learning involves the students in the learning process, increases motivation to learn, leads to a greater retention of knowledge, yields a deeper understanding of course material, fosters critical thinking skills, and creates positive attitude toward the subject being taught[3]. In short, students are armed with a desire and the tools needed to seek lifetime of learning.

Concept Development

The strategy presented in this paper is an active learning exercise that can be utilized to address all three of the concerns stated above. According to Karl Wirth, author of *Teaching for Deeper Understanding and Lifelong Learning*, "A growing body of research confirms that active approaches to learning offer many advantages over traditional instructional methods, including improved retention of information, conceptual understanding and problem-solving skills"[4]. By assigning a project that challenges students to actively "think outside the book", they have at least a cursory exposure to their future. The approach presented is one that, with minor refinement, can be applied to nearly any engineering course.

The purpose of the assigned project is for students to relate the text material to a real life situation. Thereby the students are exposed to the selection process used when applying equations and theories in industry. It is suggested that while the project be introduced early in the term the due date should be at the end of the term to allow for a broader range of topic choices. Intermediate work may be required to hold students to task. While students can utilize resources such as howthingswork.com to gain a general understanding of the topic, their references should include scholarly papers and journals. By exposing students to the scholarly resources available, they will be more apt to utilize the resources in the future.

Based in on the old adage that two heads are better than one, it is recommended that students work in small teams of two or three. Active learning through team-based (or cooperative) learning allows students to learn from each other. Multiple research studies have shown that team projects can increase learning and understanding, encourage the development of problem-solving skills, engender deeper and more critical thinking, provide opportunities to incorporate prior knowledge and experience, increase confidence, provide a context for the relevance of the subject matter, and prepare students for further work and live experiences[3, 5, 6, 7]. It has been shown that discussion and sharing within a team are productive learning strategies[3, 8, 9].

The course being taught will dictate the task assigned however, in most cases the students should be expected to report on any assumptions that were used in theory or equation selection. It should also be emphasized that, should the project topic require material and equations from multiple engineering courses, all material should be discussed not just the class specific items.

The overall objective can be geared appropriately to the scholastic status of the students. For example, a sophomore level static's class may be expected to research and discuss how trusses are used in bridge structures following a general class discussion of trusses. For a junior level class the student could be assigned the task of independently studying a related topic that is not specifically presented in class. In this case, the student is expected to not only learn and explain the topic but also to "boil down" a more sophisticated research topic and show its relevance to the class material. Seniors can be further challenged with the task of meeting with a practicing engineer to write a case study based in an industry project all the while discussing its relevance to course material. In all cases, the students are not expected to perform experimentation or derive equations but rather to study what has already been accomplished and report on the findings.

The instructor has the option of assigning one of several different deliverables. For example, sophomores may be expected to write a scholastic paper, juniors may be expected to present their findings in a format typical to journal articles, and seniors can be expected to present case studies. In each, instruction on the report should be specifically stated by the professor. As a secondary objective, students should be given a platform to share their findings. Presentations allow the entire class to be exposed to, and learn from each other's research. Additionally, the importance of promoting strong communication skills in students cannot be understated.

Finally, yet importantly, is the need for the assignment to be memorable. If, as stated earlier, the objective is to aid students in their transition to industry it needs to be memorable. The author has found several ways to accomplish this task. First, it is possible to gain a student's interest through topic selection or a lack thereof. For example, in a junior level class, students may be given the assignment to find an application of course material that interests them. Many students have interests and hobbies that relate to engineering topics. By allowing them the freedom of topic choice, they are often excited by the opportunity to research and deepen their knowledge and to share what they have learned with the class. It is suggested that the students' topic be approved, for depth and appropriateness, prior to the compilation of material.

To society, engineers are often regarded as stiff, analytical and lacking in creativity. To the typical engineering student their studies may seem just that. Most engineering presentations are expected to be formal and professional. The second technique to ensure the material is memorable utilizes the presentation of the paper. When the project is introduced to the class, an emphasis should be placed on an assignment that includes a professional paper and a fun presentation. Students are referred to the style of "Bill Nye the Science Guy" or "Myth Busters". They are encouraged to utilize visual aids and demonstrations. The grading rubric includes points for "fun" and "memorable". According to Wilbert J. McKeachie author of *Teaching Tips a Guidebook for the Beginning College Teacher*, student learning and memory are closely tied to motivation[10]. He states that, "too often teachers think of learning only in terms of formal instruction." By incorporating the exercise presented in this paper, students are self-motivated by the topic that they choose and the challenge to be creative with the presentation.

For students performing case studies the "fun" presentation style is not applicable. A case study by definition steps through a process of discovery chronologically[11]. This is true of design cases or a failure analysis, for example. Students are encouraged to present the information in the order in which it was used or discovered by the engineer and to challenge the class at decision branches. Only after class discussion are they to divulge the path taken by the engineer and the result thereof.

With both presentation styles, mentioned above, the interest of many students is heightened by a competition. The top teams in each class are awarded a trophy. Announcement of the awards early in the term can spark friendly competition among teams that drive the students to heightened excellence.

Discussion of Application and Feedback

The above exercise has been successfully used at the University of Pittsburgh at Johnstown for the past six years (2003-2008). It has been applied each year in multiple sections of a junior level Fluid Mechanics course and for two years (2003, 2004) in a senior level Machine Design course. The author no longer teaches the Machine Design course. While several modifications and improvements have been made through the years, the objectives have remained the same.

Each year, students are first introduced to the project through the syllabus. Initial details are presented in the third week of classes. A copy of the handout is attached at the end of the paper. In the Fluid Mechanics class, in order to promote enthusiasm the students are challenged to “be the big drip”. One team in each class is awarded the annual “Big Drip” award and presented with a trophy. See picture below in Figure 1. The team earning the highest grade for the project and presentation combined are crowned the winners. Classmates contribute to the presentation grade.

Figure 1: “Big Drip” Award and the “Great Gear Factor” Award

Each year the instructor’s expectations have been exceeded. Students have contacted the engineer in charge of the fountain located in the three rivers in Pittsburgh, visited and reported on the pump house. They have researched and reported on supercavitation and sonoluminescense. Researched and reported on the aerodynamics of dimples on golf balls and the baseball curveball. Many students choose to construct demonstrations, which are at times elaborate, and even though it is not a requirement, students have performed their own testing or designs to enhance what they have researched. An example of a design/demonstration occurred recently when a team, who researched the design and flight of hang gliders, chose to build and test their own hang glider using heavy gage plastic tarps and pvc conduit. Students' eagerly jump at the challenge to compete for the "Big Drip" and often devote a great deal of time and resources to present a wonderful project.

The exercise presented in this paper has been a success as evidenced by the fact that, each year students become increasing motivated to go beyond the requirements. They genuinely enjoy the creative aspect of the presentations. For example, students presenting their study of flight dressed as flight attendants', and along with knowledge shared packs of peanuts with the class. Students have presented their own versions of "the Mythbusters" and the "Tooltime". Students have given their presentations dressed as Bernoulli and Euler, two founding fathers of fluid mechanics. In addition, the audience has been soaked on multiple occasions by supersoakers, the class was treated to a demolition demonstration by a student that is a military expert, and the professor has been propelled around the room on a homemade hovercraft. The presentations have become well known on campus with students outside of the engineering technology program asking to sit in on the presentations.

Student Feedback

During last week of class for each of the past three years, students answer a questionnaire about the course. Three questions pertaining to the Big Drip project are asked. The first is, "Was the final paper/presentation a worthwhile endeavor?" Students are overwhelmingly positive as can be seen in Figure 2 below. In 2005, 47 students were surveyed. Thirty-nine students responded that the project was worthwhile which represents 83 percent of the class. In 2006, 72 students were surveyed and 62 responded positively for a class percentage of 86. Forty-four students were surveyed in 2007, 42 felt the project was worthwhile which represents 95 percent of the class.

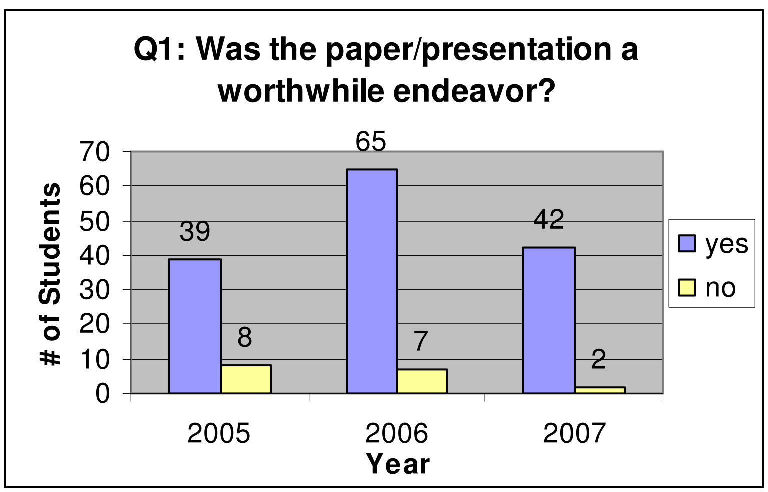

Figure 2: Question 1 Results

The second questions asked was, "Did it help you to "think outside the book" in seeing how theories and equations apply to real life situations?" As can be seen in Figure 3 below the responses were again overwhelmingly positive. In 2005, 89% of the students felt the project helped with the application of theory to real life situations. Seventy-two students answered the survey in 2006. Of the total 66 answered that it did help their understanding, which accounts for 92% of the class. In 2007, of the 44 students responding 42 felt that it did help them to think outside the book, which is a class percentage of 95%.

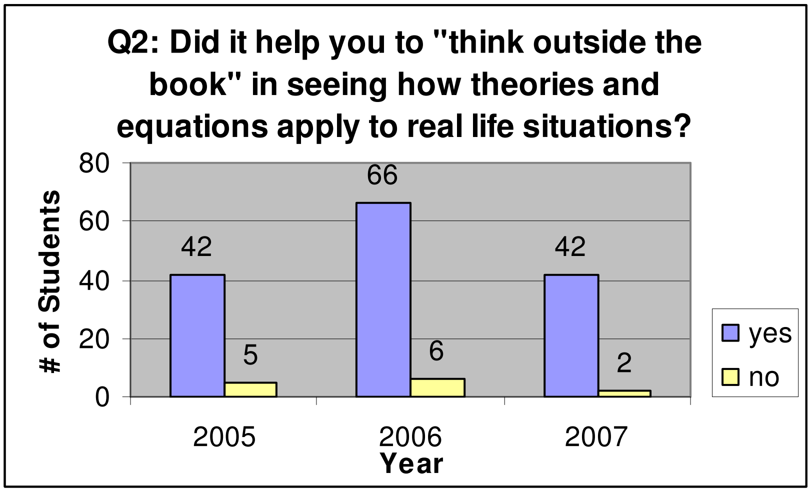

Figure 3: Question 2 Results

When asked the third question was asked, “Should the exercise be repeated in future Fluid Mechanics classes?” the students again responded positively as can be seen in Figure 4 below. The 83 % of the students enrolled in 2005 felt that it should be repeated. In 2006, 67 of the 72 students felt that the exercise should be repeated which accounts for 93% of the class. In 2007, only one student voted against the exercise, which meant that 98 % of the class was for repeating the project in the future.

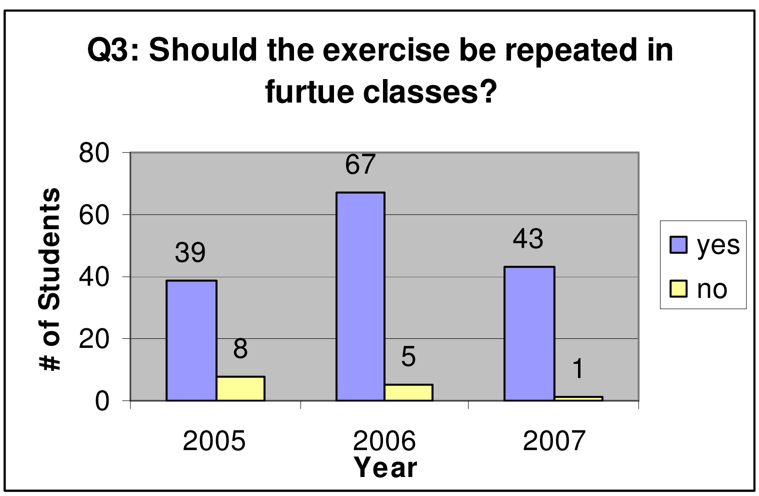

Figure 4: Question 3 Results

Recently, past fluid mechanics students were given a more in-depth survey about their experience with this exercise. Thirty-one Civil Engineering Technology (CET) students and 16 Mechanical Engineering Technology (MET) students responded. The first questions asked, “Did the Big Drip assignment aid in your general understanding of Fluid Mechanics?” Students were now responding to a Likert scale, with an answer of one representing "not at all" and a response of five meaning "very much so". As can be seen below in Figure 5, the vast majority of the class responded positively. In fact, 81% of all students surveyed responded with a 3, 4, or 5.

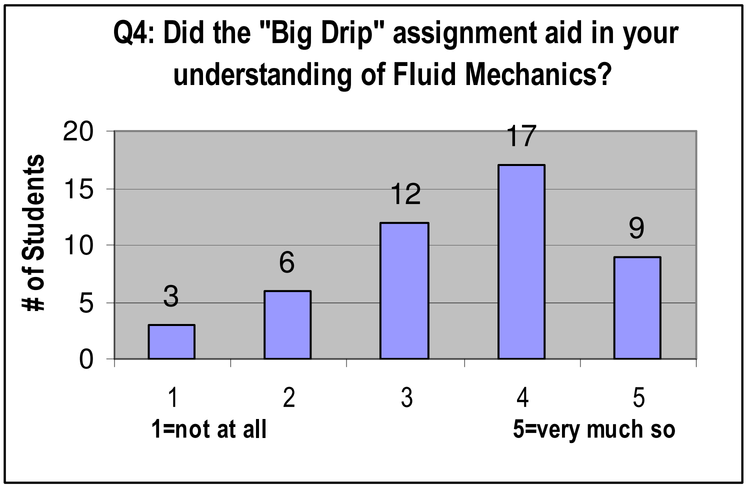

Figure 5: Question 4 Results

The next question asked was, "Did the Big Drip assignment help you to look outside the book to see the practical application of learned principles?" Figure 6 indicates that students overwhelmingly felt that the assignment was an aid to their understanding of the application of learned principles.

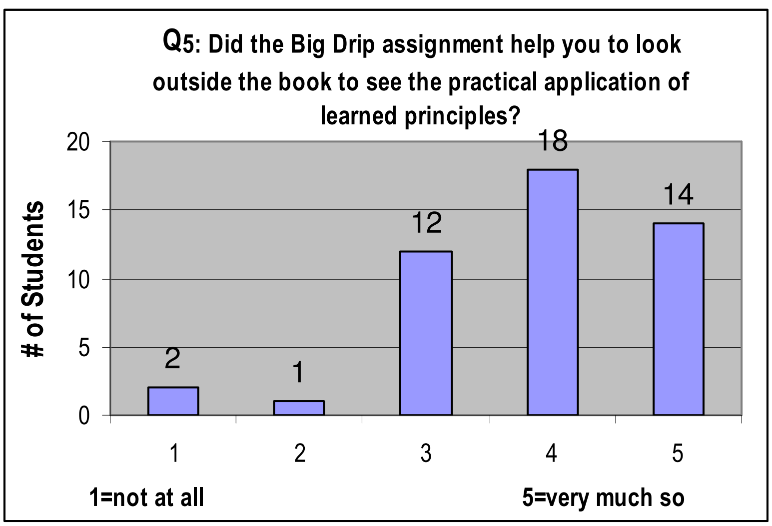

Figure 6: Question 5 Results

Question 3 was repeated with a Likert scale. The results are shown below as Question 6. It is evidence that again students feel strongly that the practice of this exercise should be continued.

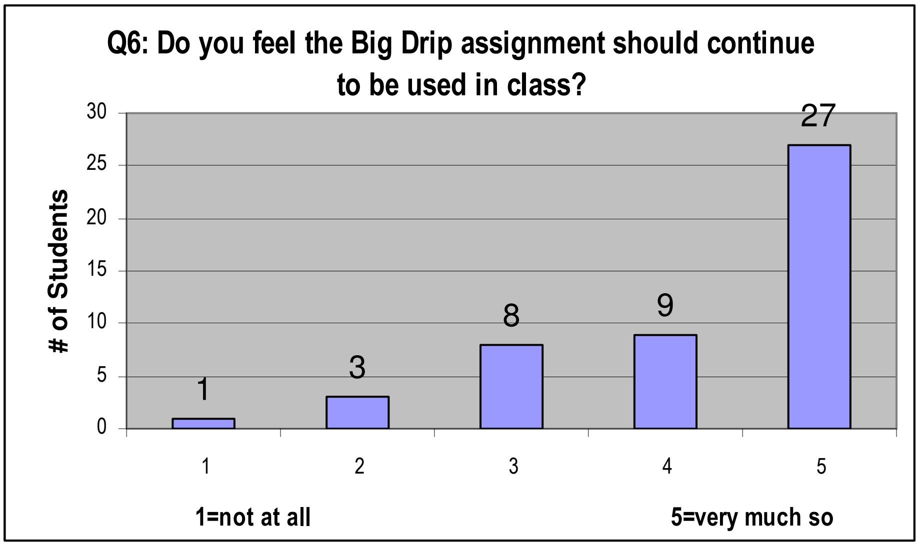

Figure 7: Question 6 Results

It is noteworthy to mention that the MET students had a higher impression of the assignment than of the CET students. In each of the Likert scale questions the Mechanical Engineering Technology, students ranked items higher than did Civil students as can be evidenced by Figure 8 below. The explanation of the differences between CET and MET student perceptions is beyond the scope of this paper.

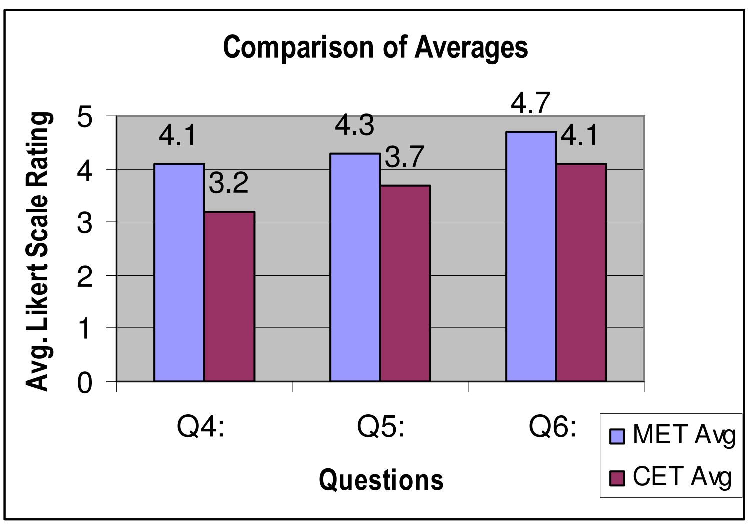

Figure 8: Comparison of MET and CET Responses

Some students provided written feedback about the assignment. Several of their comments can be seen below:

- *It improved my understanding on basic fluid mechanics. I used my project in a real life situation.*
- *I was able to apply class lessons to an actual system.*
- *I had so much fun doing the Big Drip even though we didn't win it was exciting to do something my way.*

- *It was educational and enjoyable*
- *I felt it helped link fluid mechanics from the classroom to real life.*
- *A lot of work but worth it if you put some effort into it.*

Conclusions and Comments

In summary, an often-ignored task of the engineering educator is to prepare students for the application of theories and equations "outside the book". This requires challenging students to identify problems outside of the context of the section they are studying, they must carefully choose equations based on the applicable assumptions, and at times, they must solve problems where material from more that one class at a time is needed.

The exercise presented can be modified for use in nearly any engineering or engineering course. Depending on the academic maturity of the students, the professor can adjust the work required.

One aspect that has lead to the overwhelming success of the project came about due to the desire for the presentations to be memorable to the entire class. It has been found that when asked to present a creative and fun project they are highly enthusiastic and often exceed the expectation of the assignment.

References

1. Jensen, D., Wood, J., Dennis, S., Wood, K., Campbell, M., *Design Implementation and Assessment of a Suite of Multimedia and Hands-on Active Learning Enhancements for Machine Design*, Proceedings of ASME International Mechanical Engineering Congress and Exposition, Orlando, FL, 2005
2. *Criteria for Accrediting Engineering Technology Programs*, ABET Board of Directors, Technology Accreditation Commission, 2007.
3. Umble, E.J., Umble, M, and Artz, K., Enhancing Undergraduates' Capabilities through Team-Based Competitions: The Edward Jones Challenge, Decision Sciences Journal of Innovative Education, Vol. 6, Number 1, January 2008.
4. Wirth, K., Teaching for Deeper Understanding and Lifelong Learning, Elements Magazine, Vol. 3 pp.107-111, April 2007.
5. Cuseo, J, *Collaborative and Cooperative Learning in Higher Education: A Proposed Taxonomy*, Cooperative Learning and College Teaching, Vol2, pp 2-5, 1992.
6. Johnson, D., and Johnson, R., *Action Research: Cooperative Learning in the Science Classroom*, Science and Children Journal, Vol. 24, pp 31-32, 1986.
7. Kurfiss, J., *Critical Thinking: Theory, Research, Practice, and Possibilities*, ASHE_ERIC Higher Education Report No. 2, Washington, DC, Magna Publications, 1988.
8. Johnson, D., Johnson, R., and Smith, K., *Cooperative Learning: Increasing College Faculty Instructional Productivity*, ASHE_ERIC Higher Education Report No. 4, Washington, DC, The George Washing University, 1991.
9. Ravenscroft, S., Buckless, F., and Hassall, T., *Cooperative Learning: A Literature Guide*, Accounting Education, Volume 8, pp 163-176, 1999.
10. McKeachie, W. J., *Teaching Tips a Guide for the Beginning College Teacher*, Seventh Edition, D. C. Heath and Company, Lexington, KY, 1978.
11. Beheler, A., Jones, W.A., *Using Case Studies to Teach Engineering Technology*, Proceeding of ASEE Annual Conference and Exposition, 2004.

The following attachment is the handout used in the junior level fluids class. Additional time is spent in the classroom discussing what constitutes a scholarly reference. They are also instructed on how to use the university's electronic library system of journal articles.

MET 1154 Fluid Mechanics
Final Paper Guidelines

General:

You are asked to choose an item that utilizes one or more of the fluids equations and concepts that we have studied throughout the semester. The final paper, together with its presentation, will count for 20% of your final grade. As such, care should be given to every aspect of the paper including spelling and grammar.

Research:

Once you have chosen a topic, begin researching the item. Your goal is to be able to obtain enough material on how it works (from a fluids point of view) to be able to easily explain it in your paper and presentation. Visuals aids always increase understanding and are helpful to keeping the attention of your audience.

Your search may require a library or internet search. It is also possible to search registered patents at www.uspto.gov. If you need help navigating around the patent web site let me know. Do not discount phoning a manufacturer and speaking to a design engineer or sales person.

You are required to state all sources. At least two scholarly references are required!

Paper:

Your paper should include an introduction/background section, a how-it-works section, a closing, and a references/sources page. Be specific about what you are trying to teach the reader assume that they have a basic level of fluid mechanics knowledge.

Introduction/Background:
Give the reader a comprehensive description of the product and its use. You can add any other general information of interest in this area.

How-It-Works
This is the meat of the report. Use diagrams, pictures and equations to explain thoroughly how the item utilizes what we have learned in class and in its operation. Be certain to state any assumptions that were made in order for the equations to apply.

Closing
You should be able to sum up what has been provided in the paper.

References
Be sure to include all web sites, persons talked to, etc. Plagiarism is reason for an automation failure.

Presentations

Speeches are to be approximately 15 minutes long. All authors are expected to participate in the speech. The presentations should provide enough of the paper that the audience will understand and benefit from the speech. You may use any tools necessary to provide a great presentation (ie: PowerPoint). Make it fun! Your audience is a part of the grading for the presentations. Be creative…*The Big Drip Award* will be presented to the team with the highest overall grade in each session.…*Go for the drip!*