The Term (Project) Paper: A Viable Instructional Tool for Undergraduate Engineering and Technological Education

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Abstract

There is a growing consensus in academia and in the industry about the need for graduates of engineering and technological programs to fortify their technical skills with effective communication skills. The term paper concept at the undergraduate level addresses this need; it has been proven to be a viable instructional medium for the reinforcement, development and acquisition of technical and communication skills. The term paper concept is based on the principles of ideation and implementation, the key elements of creativity and critical thinking. The development of ideas based on the students' subject area(s) of interest serves as a driving force for implementation of the ideas. Implementation takes the students through the process of literature search for acquisition and development of knowledge base, design of experiment to validate and verify idea(s), performance of experiment for data acquisition, analyses and interpretation of acquired data, and the ultimate report writing and presentation. Report writing teaches the students how to write and is an additional medium for learning the subject material. Presentation introduces and initiates the students to life in the industry, and inculcates in them the ability to effectively convey their ideas to their peers, colleagues and superiors.

I. Introduction

The term paper concept is a non-traditional, innovative approach to teaching and learning at the undergraduate level. It is based on the principles of ideation and implementation, the key elements of creativity and critical thinking. Traditionally, undergraduate education has revolved around a "class lecture" format. The students participate, actively or passively depending on the students' disposition, in a series of class lectures, and they are periodically tested for their level of retention and understanding of course content. In this scenario, creativity is a very silent component of learning. There is not a conscious effort to acquire or develop creativity. This lack of awareness or consciousness minimizes the need for or role of creativity in engineering and technological education. With the term paper, the concept of creativity is entrenched in the process of ideation and implementation.

The process involved in carrying out the term project inculcates in the students the awareness of the need for creativity, how to develop it and its role in productivity. Productivity is the main-stay of industry; it is the source of employees' salaries and company's profit. The adage, "Practice Makes Perfect" comes to mind and is more succinctly put by the motto of the School of Technology at Pittsburg State University, Pittsburg, Kansas, "By Doing Learn". Exposure of the students to the concept and process involved in the term project facilitates their ability to learn and to be creative. It prepares students for the industry (and for graduate school for those who so

desire). Most companies are problem solving and project-oriented. The term project initiates or introduces students to life in the industry; the elements of report writing and presentation are commonly used as effective communication media. Communication facilitates logistics and operations in the industry, key elements in industry productivity and profitability. Essentially, the term paper process is comprised of nine sequential quasi-units, topic selection, literature search, design of experiment(s), experiment(s) performance, data acquisition, data analyses, report writing, report presentation and consultation with instructor. Consultation with instructor is non-sequential and can happen at any point in the process.

The objective of this paper is to explore the use of the term paper as a viable instructional medium for undergraduate engineering and technological education.

II. Relevant Literature

Of recent, there has been considerable attention and debate on the state of undergraduate engineering and technological education. Top on industry'' wish list is that undergraduate curricula include elements of critical thinking, teamwork and leadership. This trend in the industry appears to be the focus of changes in undergraduate curricula. Some of the notable discussions and efforts in this area are presented under this section.

Braham, J., "Where are the Leaders?" Machine Design, October 10, 1991, Page 58-62. Jennifer Chalsma, Staff Editor at Machine Design, after interviewing some practicing engineers from Fortune 500 companies, concludes that "Readers call for more practical, "real world" courses and less theory." Suggestions for improving engineering and technological curricula include: the use of Co-ops and Internships, and increasing the number of laboratory courses and projects.

Hiles, K. E., "A Project-Based Freshman Engineering Design Experience-FIRST," ASEE Annual Conference Proceedings, Milwaukee, Wisconsin, June 15-18, 1997. Kirk E. Hiles, an assistant professor at the U.S. Coast Guard Academy, introduced his 1997 spring semester freshman engineering class to engineering design process. The students designed and constructed a robot to compete in the FIRST (For Inspiration and Recognition of Science and Technology) competition. The students worked side by side with faculty, engineers and high school students to produce a 3'x3'x4', 120 pound robot while applying a nine step design process. "Based on the students feedback, this hands-on application of the engineering design process was much more effective (and more fun) than the traditional lecture style course."

Lopez, D.A., "Project-based Instruction in Manufacturing: A New Approach," ASEE Annual Conference Proceedings, Milwaukee, Wisconsin, June 15-18, 1997. David Lopez, a professor a Central Michigan University, vividly describes the instruction methodology that he uses in his undergraduate manufacturing engineering technology class. His approach favors a "hands-on" project format over the previously used lecture format. His classes are divided into teams of students, and each team analyzes an entire product by dissecting it into its component parts. Each student team writes and submits an engineering report that is evaluated. He concludes that while the projects emphasize concepts such as design for assembly, design for manufacturability, concurrent engineering overall product quality, the success of the projects depend on communication, teamwork, leadership, integrative thinking, and cooperative learning.

III. State of Undergraduate Engineering and Technological Education

It is apparent that industry's concern about the level of preparedness of today's engineering graduates with respect to design, teamwork and leadership skills is the focus of academia-industry debate. Academia appears to be taking industry's concern into consideration in undergraduate engineering and technological curricula design. The use of projects and increasing the number of undergraduate laboratory courses are viable routes for implementing curricula changes that will grant industry its wish. The students who experience project-based learning or courses that integrate "hands-on" type instructions are satisfied that it is an effective method. Paulsen et al cite students' satisfaction as an indication of higher level of teaching and learning. This paper describes one approach that incorporates the term project in undergraduate courses, and explores the role of the term project concept in critical thinking, creativity, performance, communication, and teamwork skills.

IV. The Term (Project) Paper Process

The term paper process begins on the first class meeting of the semester. Each student receives a current copy of the course syllabus with the lecture and laboratory sections contents and requirements. The first page of the syllabus has the course evaluation (Table I). The students are apprised of the term paper as a requirement for a grade in the course, and that the term paper is 10% of the final grade. The importance of the term paper in terms of grade is only strategic;

CATEGORY	% OF FINAL GRADE
Assignments	15
Quizzes	5
Term Paper (Class Project)	10
Three Exams (15% each)	45
Final Exam	20
Attitude, Attendance, & Class Participation	5
Total	100

Table I: Course Evaluation Format

an A student would truly be an all-round excellent performer whereas a student can also make a decent grade B or C without doing very well in the term paper category.

Officially, work on the term paper does not begin till about one month into the semester or after the first examination when the term paper topics are made available to the students. The term paper start date is so scheduled to allow the students time to understand the theme, fundamentals and concepts of the course; these they would need to effectively and authentically carry out the tasks involved in the term paper process. Moreover, it helps the students prioritize and balance their efforts among the other categories of the course evaluation.

The lecture period of the day the term paper topics is distributed is devoted to discussions during which the instructor gives the students background information on all the subject materials covered by the topics available to the students. This exercise is carried out with a lot of enthusiasm by the instructor with special emphasis on the possible areas of application of the chosen topics. The instructor's level and areas of experience come in handy as marketing tools. The topics selected by the students depend in part on the instructor's ability to market the importance of the topics.

**********TABLE II**********

Thermoplastic Resins – ETECH 387 Dr. C. Ibeh

**********Fall Semester, 1996; Date: 9/25/96**********

**********Topics For Term Paper**********

1) Innovations in Casting of Transparent Thermoplastics
2) Experimental Determination of Molecular Weight by Viscosity Methods
3) Cost-effective Recycling of Plastic Materials
4) Compatibility of Thermoplastics in Blends
5) Conductive Plastics
6) Plastics in Fuel Cell Applications
7) Plastics in medical Applications
8) Biodegradable Plastics
9) Thermoplastics in Composite
10) Mctallocene-based Thermoplastics
11) Thermoplastics in Automotive Applications
12) Thermoplastics in Construction Applications
13) Crosslinking Thermoplastics and Their Applications
14) Liquid Crystalline Polymers (LCP's)

****Choose any three specific topics that are of interest to you and list them in the order of preference. (You can include topics that are not listed above). One of the topics will be assigned to you for your term paper.

You are encouraged to choose an experimentation-based topic for your term paper.

Schedule for Term Paper

Wednesday, September 25, 1996: Distribution of Topics
Wednesday, October 01, 1996: List of Three Specific Topics Due
Wednesday, October 08, 1996: Assignment of Topics
Wednesday, October 22, 1996: Topic Outline Due
Wednesday, November 20, 1996: Term Paper Report Due

Pre-presentation and final presentation of term paper report will be scheduled after October **********22 and November 20, respectively**********

Table II: List of Topics and Schedule for the Term Paper

The term paper topics (Table II) given to the students are typically general in nature, and the students are required to select three specific topics based on their subject area(s) of interest. Students may include their own topics for consideration and assignment as their term paper topic. One of the three selected topics is assigned to the student. The purpose of requiring the

students to come up with specific topics is to encourage them to develop their own ideas (ideation) and to narrow down the scope of their work. Ideation implies authenticity, ownership and the pride of ownership. The pride of ownership is the key element in the term paper process. Acceptance of ownership by the student serves as the driving force for implementation of the project. The term (project) paper is done over a period of only two months and the report is limited to ten pages (give and take a few pages). Specificity of topic promotes ideation and results in an overall manageable process for the student and for the instructor as well. Typical examples of specific topics are some of those based on "Thermoplastics in Automotive Applications" (Table II). Some of these examples are:
* "Thermoplastics in Automotive Dashboard Applications",
* "Thermoplastic Materials Used for Automotive Bumpers", and
* "Thermoplastic Polyurethanes for Automotive Engine Block Prototype."
The students are especially encouraged to choose topics that include experimentation.

Accompanying the list of suggested term paper topics is the schedule showing the various deadlines for the term paper process. The students are instructed to keep to the deadlines and avoid procrastination. This inculcates in the students the need for planning and scheduling. Planning and scheduling are elements of good leadership.

IV Literature Search

Literature search is a pivotal part of the term paper process. It facilitates the students' ability to develop ideas (ideation) and enhanced knowledge base. It is almost impractical to do a term paper without a literature search, and this is not necessarily true for the experimentation. While it is true that inclusion of experimentation makes a paper authentic and original, one can do a very good paper without doing experiments. This is especially so when there is un-availability of equipment to carry out experiments on a particular subject matter. Literature search uncovers the trend in a subject area and the potential for further work. It prevents the prospects for "re-inventing the wheel" and plagiarism, and makes the work more useful and applicable to the needs of industry and society.

It is a standing policy of my undergraduate courses that any written report, class assignments, laboratory reports, term papers etc. must include at least five cited references. This encourages the need for literature search in students' written work. To facilitate this process, library personnel are invited to make 15-25 minute presentations on how to locate and use library resources. The library also has mini-workshops on this subject matter. The students are advised to make use of these avenues and the instructor's office hours on how to use the internet and world wide web for information retrieval. The plastics industry is a very dynamic one and "company contacts" is an essential part of most research projects. Access to PLASTICSNET makes the internet search very easy especially in the areas of company products and availability of materials. Also available to the students are materials softwares such as MOLDFLOW, CAMPUS, GE materials database etc. for information on materials properties and characteristics. For the non-plastics students (all students), extensive searches can be conducted using Engineering Information village (www.EI.org). Engineering information village search can access very many notable internet search resources such as EICOMPENDEX*WEB (www.ei.org), an engineering database of summaries of journal articles, STNINTERNATIONAL

(Science & Technology Network; http://info.cas.org/ONLINE/online.html), with access to more than two hundred, multi-disciplinary, scientific and technical databases. Worthington has a very good discussion of these valuable literature search sources (www.ei.org/lecture/shari.htm).

The ideas and knowledge base developed during literature search culminate in a project theme or question that evolve into the paper's objective(s). One paper entitled: "Thermoplastic Materials Used for Automotive Bumpers" asked the question, "What is (are) the best material(s) for automotive bumpers?" Another paper entitled: "Compatibility of ABS/PC in Blends," asked the question, "What is the role of compatibilizers in ABS/PC blends?" The project question sets the pace for the experimental section and design of experiments. Having asked the question, the student's objective would be to satisfactorily answer the question(s).

V. Experimentation

Noted previously, is the fact that while experimentation is not necessary for a good term paper, it is necessary for authenticity and originality. Experimentation is generally carried out to verify and validate the ideas developed during the ideation stage. Experimentation consists of design of experiment, performance of experiment, data acquisition and data analyses. In design of experiment, one is concerned with choosing the right type of test that will yield the right type of data about the subject matter; data, which upon analyses and interpretation would answer the project question. The ASTM (American Society for Testing and Materials) manuals come in handy and can ensure the accuracy of methodology being used in the experiment(s). The term paper entitled: "Thermoplastic Materials Used for Automotive Bumpers" chose to test the impact strength of selected sample materials from different automotive companies. The tests were based on ASTM D-256 methodology for Izod Impact testing. The performance of experiment(s) is very important with respect to the element of precision and replicability of obtained result(s). It is customary to measure accuracy via error analysis and precision via standard deviation.

The instructor guides the students as to the appropriateness of their design of experiments. This is done by making use of the "Topic Outline" portion of the term paper schedule (Table II). The students are required to submit a term paper outline based on the outcome of their literature search, indicating how they hope to write the paper. A big part of the outline is the experimentation; the students indicate what experiments they would perform, how they would perform the experiments and the type of data they hope to generate. The instructor reviews the outline before approval or recommends changes and modifications before approval. The approved outline must be part of the finished paper and appears in the appendix.

One innovative use of experimentation is that of teamwork and cooperative learning. The students are assigned to work in teams on the experimental portion of the term paper. It is easier on the students when they can perform the experiment with their peers and they get to learn more on the same subject because each member of the team is working on a different perspective of the subject. A team of three students assigned to the general topic, "Plastics in Fuel Cell Applications," could actually be working on three related but different topics such as:
(1) "Polyethylene Binder in Molten Carbonate Fuel Cell Electrolyte Matrix,"
(2) "Polybutylene Binder in Molten Carbonate Fuel Cell Electrolyte Matrix", and
(3) "Polypropylene Binder in Molten Carbonate Fuel Cell Electrolyte Matrix."

Their experimentation is the same but their expected results are different; they work together to formulate and fabricate their matrix products using plastics equipment like the two-roll mill and compression molding machine, and they also work together to determine the electrical resistivity of their products using a two-point probe electrical resistivity analyzer. The student(s) who is(are) good in calculations and chemistry help those who are not in the composition formulation portion of their experiments. The students help each other in using the equipment correctly. Data analyses and report writing are done individually. Johnson and Johnson cite individual accountability as one of the basic elements of cooperative learning.

VI. Report Writing

Ideation, literature search, outline and experimentation are preludes to report writing. Report writing is the basis of assessment of the students work on the term paper, and the students are encouraged to follow the guidelines stipulated for good technical writing. Attached to the

**********TABLE III**********

*****FORMAL REPORT FORMAT*****	*****MEMO REPORT FORMAT*****
Letter of Transmittal	Not Applicable
Title Page	Not Applicable
Table of Contents	Not Applicable
Summary	Summary
Introduction	Introduction
Literature Review	Not Applicable
Main Body of Paper	Main Body of Paper
Experimental Section	Experimental Section
Results	Results
Discussion of Results	Discussion of Results
Conclusions/Recommendations	Conclusions/Recommendations
Bibliography	Bibliography
Appendix	Appendix

**********For more detailed information see:**********
******* "An Anatomy of a Technical Report" by Dr. Adam E. Darn" **********
*** "Report Writing for Engineers" by Savage, Baasel, Baloun, Dinos, Kentall, and Collier****
******* "Principles of Good Technical Report Writing" by Dr. Christopher C. Ibeh**********

Table III: Contents of Formal and Memo Report Formats

Course syllabus given to the students on the first day of class are the "Laboratory Report Writing Guide" and "The Principles of Good Technical Report Writing." The Laboratory Report Writing Guide discusses the three types of technical reports, briefings, memo and formal, that are customarily used in the industry. The Principles of Good Technical Report Writing provide hints on good technical writing skills. These documents are discussed in detail on the first day of the meeting of the laboratory section and the instructor's office hours are used for further clarification and explanation. The students are apprised of the differences and similarities

between the formal and memo formats for technical writing (Table III), and that the term paper reports will be done using the formal report format.

The formal report format is chosen for the term paper report because it has most of the elements of a good technical report and provides good writing practice. With knowledge of how to do the different sections of the formal report format, one can easily adapt to any writing format that is encountered in the work place. Of all the formal report format sections, literature review generates the most interest and questions from the students. Literature review is part of literature search; it discusses the three or four most relevant work that has been done in the area of interest as can be seen from the relevant literature of this paper. Literature review shows the trend(s) in a subject area and focuses attention on the need for more work.

The Principles of Good Technical Writing handout aforementioned, has a section on the logical order of doing a technical report:

1) Report outline
2) Data generation and calculations
3) Tables and figures
4) Write introduction
5) Write the procedure (experimental section)
6) Write the discussion of results
7) Write the conclusions and recommendations
8) Write the summary

The handout concludes by reminding the students that report writing can be demanding and one should not be overwhelmed. Students should always consult their instructor; they would be "surprised that some apparently difficult situation has a relatively simple solution."

VII. Report Grading Format

The grading format may be considered generous because the deductions do not add up to 100%. The reasoning being that the term paper report is just a portion of the work that goes into the term paper process. Ideation, literature search, experimentation are some of the other components of the process. The point distribution for the term paper is as follows: 5% automatic deduction for any omitted section (10% for the main body); 5% for organization and presentation (grammar, spelling, neatness, coherence); technical content (complete, independent and concise summary 5%; complete test procedure and equipment 5%; main body of paper under appropriate headings and subheadings, and with correctness of theory and concepts 10%; adequate data presentation 5%; correct sample calculations 5%; logical data analyses and discussions 5%; appropriate conclusions and recommendations 5%) 40%. The deductions total only 60%, leaving a 40 points buffer; only the very bad papers make failing grade.

VIII. Report Presentation

Report presentation occurs in two stages, pre-presentation and final presentation. Pre-presentation is scheduled the week after the Topic Outline is due and is worth the equivalent of one class assignment. Final presentation is scheduled after the submission date of the term paper and is worth two class assignments. This compensates for the infringement on assignment time.

Both presentations are video taped. Use is made of the school's instructional media's video taping facilities. Both presentations have the same format except that the pre-presentation has a shorter duration of three minutes whereas the final presentation lasts for about ten minutes. Grading of the presentations is done jointly by the instructor and the students on a 60:40 basis. The criteria for assessment of the presentations are: knowledge of subject, preparedness, communication, quality of work, and others. The "others" criterion takes into account any perspective of the grader that is not covered by the four criteria. The presentation videos are available to the instructor and students for self improvement purposes. The students tend to do better in the final presentations overall, probably due to the better level of preparedness generated from the pre-presentation.

IX. Viability of the Term (Project) Paper

The term paper embodies ideation and implementation, the key elements of creativity and critical thinking; it works on the premise that students actively participate in the learning process. Students develop the awareness that task(s) performance and effective communication skills are career-needed technical and leadership skills. The expectation to perform is there and one must have the preparedness to do so. The term paper does not automatically turn students into experts but it sets the process in motion, a learning process that carries on into their careers.

The term paper embodies the elements of organization, knowledge of subject, application of course materials, resourcefulness, intellectual self-discipline, focus and deductive reasoning, and meet the criteria for creativity and critical thinking as espoused by Kurfiss J.G. of Santa Clara University. The correct use of the formal report format, goal setting such as specific topic selection and plan formulation on how to tackle the project, and commitment to successfully perform the project are demonstrations of organizational skills. Knowledge of subject is displayed in the main body of the paper for example the paper entitled: "Thermoplastic Materials used for Automotive Bumpers," cites the reasoning behind the choice of plastics as the materials used in automotive bumpers as, "ease of processing, weight reduction, styling freedom, performance (corrosion resistance, weatherability, etc.) and low cost." This paper further demonstrates the ability to acquire and utilize knowledge; there is appropriate design of experiment to determine which plastic material(s) are suitable for bumper applications. The paper's ability to correctly perform experiment(s) is based on application of knowledge acquired in the laboratory section of the course. Analyses and interpretation of acquired data come from the knowledge and use of the concepts and fundamentals of the lecture section of the course. Determination of which materials are suitable for bumper applications is a display of knowledge of (plastic) materials and deductive reasoning.

The overall project implementation requires resourcefulness, intellectual self-discipline, focus, and reasoning.

X. Success of the Term Paper at Pittsburg State Univeristy (PSU)

Some of the note-worthy impacts of the term paper at Pittsburg State University are:

1) Undergraduate student publications; Birt, W.O., Waymire P., are students who have successfully published the results of their term projects.

2) PSU plastics graduates are better prepared for the industry. Ethan Barde, Vice President, Primera Plastics Inc., went into partnership to found the company shortly after graduating. The company, Primera Plastics Inc., is based on the topic of his term paper entitled: "Processes for Automotive Body Panels." In his term paper, he concluded that injection molding is the most feasible process for automotive body panels. His company now is a precision injection molding company specializing in automotive parts. Ethan recalls that when his new company was faced with the need for a business plan, he modeled one after the formal report format that he used in school.
3) The term paper prepares our students for the senior level, capstone design course.
4) PSU applied for and secured an NSF-REU (National Science Foundation, Research Experience for Undergraduates) site at PSU. The site brings in undergraduate students from neighboring colleges to perform structured and meaningful research side by side with PSU students for ten weeks during the summer. The PSU/NSF-REU program is currently in its second year of operation; the first nine students participated in the program during the summer of 1998. Detailed information on the activities of the PSU/NSF-REU program can be obtained via the URL: **http://www.pittstate.edu/services/nsfreu/.** The concepts of this program were developed from the experiences of the term paper.
5) The author served as president, executive board of the "friends of the PSU AXE library" partly due to the popularity attained form the literature search activities of the term paper students.
6) The (MCFC) fuel cell project at Pittsburg State University (Ibeh et al)(3)(11) is an off-shoot of the term paper concept.

XI. Limitations of the Tem Paper

*Some students complain that the term paper is too much work.
*The term paper is extra work for the instructor.
*The materials requirements for the term projects could have financial implications.

XII. Conclusion

This paper has demonstrated the viability of the term paper as an instructional medium for undergraduate engineering and technological education. it integrates the "hands-on," applications-oriented laboratory experimentation with the fundamentals and concepts of the class-based lectures.

XIII. Recommendations

Based on the positive impacts of the term paper, this paper recommends that:
1) The use of the term paper concept be made in as many undergraduate courses as possible.
2) Teams of students be used in laboratory experiments to facilitate cooperative learning.

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