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Implementing Entrepreneurial Assignments in a Multidisciplinary, Sophomore-Level Design Course

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ABSTRACT

Many engineering programs stress the importance of technological innovation by offering entrepreneurship electives and programs. Integration of entrepreneurship into the required engineering curriculum has predominantly focused on senior capstone design courses. This paper describes a strategy for integrating entrepreneurship into a multidisciplinary sophomore-level design course. This early introduction provides an opportunity for students to further pursue their entrepreneurial ideas through a junior/senior level, project-based course.

The Rowan Sophomore Engineering Clinics are integrated courses in which engineering design is taught concurrently with technical communication. This paper describes two entrepreneurial assignments that have been integrated into the Sophomore Clinics: a white paper, and an open-ended semester long design experience in which students propose their own entrepreneurial projects. The projects appear to lead to increased interest in entrepreneurship among students, as indicated by survey results and by an increase in students choosing to pursue entrepreneurial projects as juniors and seniors. While the Sophomore Clinic structure is unique to Rowan University, the entrepreneurial assignments themselves are readily adaptable to other engineering programs.

Keywords: entrepreneurship, design, multidisciplinary

I. BACKGROUND

There is a significant and growing interest in strategies for fostering entrepreneurial skills in engineering students. Many engineering programs have created a course in entrepreneurship [1–3], and such courses often involve collaborations between engineering and business students [4–7]. In one such course, Raviv, et al., [8] showed that the generation of ideas is a skill that can be learned. The authors further demonstrated that their one-semester course led to a marked improvement in engineering students' ability to generate ideas.

There are also an increasing number of more extensive entrepreneurial programs for engineering students. Shartrand, et al. conducted a summary review [9] that identified 47 technology entrepreneurship credentials that are available at United States colleges and universities, and stated "the vast majority of programs were labeled as minors, concentrations or certificates." Several of these programs have been described in the literature [10–13]. Michigan Tech and North Carolina State offer vertically integrated programs that give underclass through senior engineering students the opportunity to collaborate on entrepreneurial problems in a multi-disciplinary setting that is intended to model a business [14,15]. The University of Maryland's Hinman CEO's program [16] is a co-curricular program that also includes a residential, live-learn component. Standish-Kuon and Rice [17] presented an overview of the entrepreneurship programs at six universities, and summarized relevant needs, assets and obstacles for creating them.

Most of the aforementioned authors cite the importance of technological innovation and entrepreneurship in economic development as a key factor that motivated the development of entrepreneurial courses and programs. However, there also exist strong rationales for integrating entrepreneurship into engineering education, beyond the obvious desire to promote entrepreneurial behavior in graduates. Coyle, et al. [18] call attention to the linkages between entrepreneurial skills, global/societal issues and service learning. Ochs, et al. [19] point out synergies between entrepreneurship and the ABET criteria [20], which among other things require that students understand engineering solutions in a global/societal context and that students have an appreciation of the need for lifelong learning. In *The Engineer of 2020* [21], a case is made that engineers in the near future must be prepared to function in a world where the rate of technological change, the effect of technology on individuals, and the effects of social, cultural, political and economic forces on technology will all be increasing. This report identifies several characteristics as being essential for engineers of 2020, such as: practical ingenuity, dynamism, agility, resilience, flexibility, and strong communication, business and management skills. The authors of this paper submit that these characteristics and skills are closely linked to entrepreneurship.

There is also evidence that exposure to entrepreneurship can have a positive impact on student attitude and retention. Ohland, et al., showed that freshmen who participated in an entrepreneurship course were more likely to persist in engineering, and had higher GPAs on average, than students who were not exposed to entrepreneurship [22]. Dabbagh and Menasce [23] describe a first year course in which some students did an entrepreneurial project and others a more traditional design project. In this study, both groups of students perceived their projects as having "real-world usefulness" [23]. However, the entrepreneurial project had a larger impact on student perception of the engineering profession and on the importance of professional and business management skills.

The courses and programs described above are predominantly elective in nature. Efforts to integrate entrepreneurship into the core, required engineering curricula are comparatively rare, and those reported have focused primarily on the capstone design course [19,24]. Johnson, et al. [25] describes efforts to integrate entrepreneurial modules and projects throughout an entire Electrical and Computer Engineering curriculum. Condoor and McQuilling [26] describe the integration of entrepreneurship into an introductory, first-year engineering curriculum.

This paper presents the integration of entrepreneurship into a multi-disciplinary, sophomore-level course sequence on engineering design. These projects require no specific resources and are readily implemented, either singly or as a sequence, by other engineering programs. The projects were integrated into the Sophomore Engineering Clinics, which are required courses in all Rowan engineering programs. These courses are described in section II. A theoretical framework for teaching design, and its relationship to entrepreneurship, is presented in section III. The first entrepreneurial assignment, described in section IV, was required for all sophomores. The second project, described in section V, was one of two options presented to students when they chose a semester-long design project. Section VI presents assessment of the projects and a discussion of lessons learned.

II. THE ROWAN UNIVERSITY ENGINEERING CLINIC SEQUENCE

Rowan University has an eight-semester sequence of courses called the Engineering Clinics. This sequence is required for all engineering students. The sequence culminates in the Junior/Senior Engineering Clinic, in which students work on in teams of 3–4 on real engineering research and design projects. Most Junior/Senior projects are externally sponsored, either by local industry or government agencies. In 1999, Rowan created the Venture Capital Fund, which was described in detail previously [27]. It is now called the Rowan Undergraduate Venture Fund. Students can propose their own entrepreneurial Jr/Sr Clinic projects and obtain up to $2500 of funding per semester from the fund to pursue their projects. While some noteworthy successes have resulted from this fund [28], few students took advantage of this opportunity prior to 2007. One motivation for the incorporation of entrepreneurship into the sophomore year was to stimulate more interest in the Rowan Undergraduate Venture Fund.

The Freshman and Sophomore Engineering Clinics are intended to provide a foundation of engineering skills needed for Junior/Senior Engineering Clinic. The Sophomore Engineering Clinics are integrated, team-taught courses where students learn technical communication (technical writing in the fall, public speaking in the spring) concurrently with an introduction to engineering design. Each Sophomore Clinic course consists of two 75-minute lecture periods taught by Communication faculty members, and one 160-minute lab period each week, supervised by engineering faculty members. For workload purposes, the course is treated as a three-credit course for all faculty members from both colleges.

Currently, the Sophomore Engineering Clinics (SEC I and SEC II) integrate a sequence of three design projects of increasing complexity, as illustrated in Table 1:

- An introductory 4-week project. In recent years this has been a bottle rocket project, described further in Section III.
- A project which occupies the remainder of the fall semester. In recent years this has been a turbine design project that is also described in Section III.
- In the spring, students are offered a choice between two semester-long design projects, one of which is the Entrepreneurial project described in Section V.

The evolution of this three-project sequence and its rationale were described previously [29]. This paper discusses how entrepreneurial assignments were integrated into the Sophomore Engineering Clinics, through two assignments: a white paper in SEC I, and the "Create Your Own Entrepreneurial Project" design experience in SEC II. Portions of this work have been published previously in ASEE conference proceedings [30,31].

Section III further describes the strategies employed in SEC I and II for teaching engineering design, and how entrepreneurship fits naturally into those strategies.

Course	Design Project		Communications Instruction
Sophomore Engineering Clinic I	4 week design project		Technical writing
	10 week design project		
Sophomore Engineering Clinic II	14 week entrepreneurial project	Other design project option	Public Speaking

Table 1: Schematic schedule for Sophomore Engineering Clinic I and II

III. A THEORETICAL FRAMEWORK: DIXON'S TAXONOMY

Dixon's Taxonomy has long been used in SEC I and II as a tool to organize the purposes and goals of the design projects. The taxonomy, as described by Dym [32], identifies seven distinct levels of specificity at which the solution to an engineering design problem can be understood.

- **Perceived Need** is the motivation for developing a new product.
- **Function** is a broad conceptualization of the product's use or operation, indicating *what* will be done with no reference to *how*.
- **Physical Phenomena** is an identification of the fundamental principles that will be applied to carry out the function.
- **Embodiment** is a general description of the primary features and scale of the product.
- **Artifact Type** is a parameterized design; the product is fully described except that the specific values of key parameters are not yet specified
- **Artifact Instance** is a single, completely specified product.
- **Feasibility** is an assessment of whether the completed Artifact Instance is feasible according to relevant criteria, e.g., commercially competitive, environmentally friendly, safe, etc.

As an illustration of the use of Dixon's Taxonomy, since 2005, SEC I has started with a 3–4 week project on design of bottle rockets [33]. This project has relatively rigid constraints as listed below:

- The rocket body is a 2-L soda bottle
- There is a clay nose cone, molded into a rounded shape
- There are three identical, symmetrically placed wings, made of 3/8" foam board
- The bottle is partially filled with water
- The air inside the bottle is pressurized to 50 psi
- The rocket is launched at an angle of 45 degrees from the horizontal.
- The sole criterion for "success" of the design is the perpendicular distance the rocket travels from the plane of the launcher.

The students' task is to find optimal values for three parameters: mass of clay, volume of water, and one parameter (e.g., the base length of a 30–60–90 right triangle) that describes the wings. The bottle rocket project has proved to be an effective vehicle for teaching parametric design [33].

Table 2 illustrates use of the taxonomy, providing a description of a bottle rocket at each level. A similar summary is typically discussed with the students during the second week of the bottle rocket project, both to introduce the taxonomy and to provide a motivation for the bottle rocket project within the context of teaching design.

The strategy that has been adopted in SEC I and II is to present the students with a sequence of design challenges that increase in complexity. Dixon's Taxonomy provides a theoretical framework

Taxonomy Level	Sample Description of Bottle Rockets
Perceived Need	To make a small object travel a distance
Function	Flight
Physical Phenomena	Conservation of momentum
Embodiment	A rocket fashioned using 2-L soda bottle as body, filled with pressurized air and water, fins and a nose cone
Artifact Type (*Initial State*)	Rocket has a nose cone made of clay molded into a rounded shape, three identical triangular fins spaced symmetrically around circumference of bottle, and is filled with water and air pressurized to 50 PSI. Three adjustable parameters are: volume of water, mass of clay, and length of base of the right triangle.
Artifact Instance (*Final State*)	Rocket uses 700 mL of water as propellant, 120 g. of clay for nose cone, and fin base is 4" long
Feasibility	Rocket travelled 370 feet from launching device

Table 2: Descriptions of soda bottle rockets at the levels of Dixon's Taxonomy. Moving downward on the taxonomy represents moving to states of more specific knowledge.

for understanding what is meant by "complexity." Within Dixon's Taxonomy, realistic design problems can be understood as having an "initial state" and a "final state." Dym [32] notes that as the initial and final states move farther apart on the Taxonomy, the complexity of the design challenge increases.

In the case of the bottle rocket, "Artifact Type" was the initial state, and students had 3-4 weeks to conduct experiments and design the "Artifact Instance" that they believed was optimal under the given constraints. The bottle rocket project is followed by a 10-week project, which has been either a crane design project [34] or more recently a wind turbine design project [35]. In both of these projects the "final state," as in the bottle rocket project, was "Artifact Instance;" students designed, fabricated and tested an optimized crane or wind turbine. However, these projects are significantly more open-ended than the bottle rocket project. In the wind turbine project, for example, all student teams are provided with identical plastic hubs, which fit onto a test apparatus constructed by the faculty. Students then design, optimize and build turbine blades, subject to certain constraints, such as the restriction that the blades must be attached to the pre-drilled holes in the hub. The project is thus much more complex than the bottle rocket: rather than being told which three parameters to optimize, students determine their own list of parameters and devise their own strategies for optimization. In the language of Dixon's Taxonomy, the "final state" of both the bottle rocket and the wind turbine design project is "Artifact Instance;" students in both projects design and fabricate an optimized product. However, the "initial state" of the bottle rocket is "Artifact Type," while the initial state of the wind turbine project (and the crane project that preceded it) is "Embodiment."

SEC II continues this progression by offering semester-long design challenges that are still more complex. The SEC II "Create your own entrepreneurial project" was developed in part because it fit logically into the established structure for SEC II, by challenging students to move all the way up the Taxonomy to "Perceived Need." First, however, entrepreneurship is introduced in SEC I through the White Paper, a writing assignment which is *not* considered part of the design sequence described in Table 1. Sections IV and V describe these two assignments individually.

IV. SOPHOMORE ENGINEERING CLINIC I: WHITE PAPER

SEC I is a team-taught course that integrates technical writing with engineering design. Most of the graded deliverables in the course are written reports (both individual and team) stemming from the two design projects completed in lab. However, conducting and presenting literature research is an integral component of technical writing that is not usually well represented in the design projects. Consequently, the course includes one additional individual assignment, unrelated to the laboratory design projects, that emphasizes literature research. Since 2008, this assignment has been an entrepreneurial White Paper.

The White Paper assignment challenges students to identify a product that is not currently available, but could be developed in the near future. Alternatively one could propose a cheaper or more efficient version of an existing product, or a better way of making a currently available product. The students present research on currently existing technology that is related to their proposed product, and outline future steps necessary to develop the proposed product.

Examples of past White Paper topics are listed here:

- "Smart Alarm Clock." The student proposed a programmable alarm clock. Instead of setting the clock to go off at a particular time, the user would enter a window of time during which he/she wanted to wake up, and the clock would monitor the person's sleep state and wake him/her up at an optimal time during the window. The student's research revealed that people cycle through sleep stages as they sleep, and that there are advantages (improved energy level, clarity of thinking, mood etc.) to waking up from REM sleep rather than from a deeper stage of sleep. The research further demonstrated that it is possible to determine a person's sleep stage by monitoring his/her heart rate, and that inexpensive heart rate monitors are available. He concluded that a smart alarm clock could be constructed by integrating commercially available components, and that the only "new" component required is an algorithm that interprets the heart rate data and determines the optimal wake-up time.

- "Kayak Lighting." The student, an avid kayaker, noted that there are no commercially available kayaks equipped with warning lights sufficiently powerful to make the kayak visible at night to larger boats and ships. The student did research on optics and the intensity of light needed to be visible at specific distances. The student also did research on safety issues related to having active electrical circuits in a small boat, and presented a reasonable estimate of how much cost and weight would be added to a kayak if warning lights were installed.

Each white paper was graded by one writing instructor and one engineering instructor. The first time the assignment was used (fall 2008); several common shortcomings in the White Papers were observed:

- Some students presented an interesting idea but only cursory research.
- Some failed to locate readily available and clearly relevant literature or patents.
- Some presented an existing product as if it were a new product.
- Some presented notions, but not a single, clearly defined product.

The faculty believed that the issues listed above were at least partially attributable to student misunderstanding of the point of the assignment. For the second (fall 2009) offering of the project, new grading rubrics, shown in Appendix A, were introduced, along with an explicit requirement that every white paper must include at least five references. The new rubrics were intended to communicate explicitly the importance of research and of distinguishing the proposed product from existing products.

The white paper assignment requires no specific resources, and is readily integrated into any course in which literature research and/or technical writing are primary instructional objectives. The specifications for the assignment as it was presented in the Fall 2010 semester are given in Appendix B.

V. SOPHOMORE ENGINEERING CLINIC II: "THE CREATE YOUR OWN ENTREPRENEURIAL PROJECT"

Students in SEC II are allowed to choose between two different semester-long design projects. The "Create Your Own Entrepreneurial Project" was introduced in 2007 as one of the two options. In this project, each student proposes an idea for a semester-long entrepreneurial design project. The project timeline is as follows:

Week One

The structure and expectations of each of the design projects being offered are presented, and each student chooses one. For example, in the Spring 2009 and Spring 2010 semesters, the choices

Semester	Entrepreneurial Project	Alternative project
Spring 2007	46	51
Spring 2008	52	52
Spring 2009	85	38
Spring 2010	72	42

Table 3: Numbers of students in SEC II projects

were the entrepreneurial project and a wind turbine design project. Table 3 summarizes the statistics for project selection for the four years the entrepreneurial project has been offered.

Week Three

Each student gives an elevator pitch- a 90 second persuasive speech- describing their idea for a semester-long entrepreneurial project to their classmates; typically, an idea for a new product. Each student also submits to the faculty team a one-page summary of their proposed project. Based on the elevator pitches, the students rank the proposed projects (besides their own) in which they would be interested in participating.

Week Four

The faculty announces which proposed projects will run and assigns a team of 4–5 students to each (the next section describes how these assignments are made). A primary faculty mentor is also assigned to each project. For example, in the spring 2009 and spring 2010 semesters, a total of 18 different entrepreneurial projects were selected, and three engineering faculty members supervised six projects each. The other two engineers on the faculty team supervised the alternative projects.

Finals Week

Each student team gives a ~10 minute final presentation on their project to their classmates, and submits a written final report to faculty.

Some teams, at the discretion of the faculty mentor, were provided a small budget (<$100) for supplies to conduct experiments. However, the entrepreneurial project as described in this paper does not require a budget or any other specific resources beyond faculty time. The project can consequently be implemented in any introductory engineering design course.

The remainder of section V provides more details on specific aspects of the project.

The Elevator Pitch and Project Selection

The elevator pitch is a practical and challenging assignment for engineering students: They were given only 90 seconds to make a speech that would persuade the audience, their peers, that their product was feasible, that there was a market for their product, and that it would be an exciting project to work on. Elevator pitches were organized into "flights" of 8–10 speeches. After each flight, there was a 5-10 minute break, during which students had the opportunity to approach the presenters and discuss the proposed projects further. After all elevator pitches were completed, students submitted a selection form on which they ranked the projects, besides their own, in which they were interested in participating.

In selecting projects, faculty used the selection rankings as the primary criterion; for example projects that were chosen as "first choice" by at least 3 other students nearly always were selected. However, the faculty reserved the right to decline a project if it appeared infeasible for sophomore-level students to make substantial progress on the project in a semester, or if the project required resources that were unavailable.

Appendix C gives the grading rubric for the elevator pitch. Faculty evaluation of the presentation, as determined using the rubric, was 2/3 of the assignment grade. The other third was determined by the number of classmates requesting to work on the project. Consequently, if a popular project was declined by faculty for practical reasons, the student proposing it was still graded as one who had made a successful elevator pitch.

The students whose proposed projects did not run were assigned to other projects based upon their ranked list of preferences. Consequently, even though fewer than 25% of students had the opportunity to explore their own idea, every student had the opportunity to participate in an entrepreneurial project of their own choosing.

Framework for Progressing on Project

After teams were assigned, approximately ten weeks remained for completion of the entrepreneurial design projects. Each team was required to meet with their faculty mentor every week during the lab period. Aside from these meetings, lab time was predominantly unstructured time during which students worked on tasks specific to their projects. However, during weeks 5 and 6, a portion of the lab periods were devoted to reviewing Dixon's Taxonomy, and using it as a framework for progressing on design problems. Many students, in their elevator pitches and one-page descriptions, were essentially describing their proposed products at the "Embodiment" level of the Taxonomy; they had fairly specific preconceived notions of what the final product would look like. The first assignment given to all teams was to specify the "Perceived Need" that the elevator pitch had identified, and brainstorm possibilities for Function and Physical Phenomena that could meet this need. Faculty required teams to refer to the levels of the Taxonomy explicitly when writing progress reports, and stressed that a team should not progress to the next level of the taxonomy without a clear, preferably quantitative, basis for the decision. In some cases, teams ultimately arrived at alternative embodiments that were worth considering instead of, or in addition to, the embodiment pictured in the original elevator pitch.

Criterion for Success of Projects

The "final state" of the project, as described by Dixon's taxonomy, varied from project to project. In some cases, such as a project entitled "Invent a New Musical Instrument," a working prototype (Artifact Instance) was produced by the end of the semester. For most projects, the time frame and lack of budget made advancing to this stage unrealistic. Specific goals and expectations were determined on a case-by-case basis through consultation between the team and the project faculty mentor. However, in an effort to ensure that the expectations and level of rigor were comparable for all projects, the faculty team established a goal applicable to all projects: *by the end of the semester, the student team should be able to persuade the faculty team that the project has enough merit that it deserves to receive funding for further development and/or implementation*. Following are examples of how two specific teams met this criterion for success:

- "Rain-Catch Irrigation System." The team chose to focus on a particular village in The Gambia, populated primarily by subsistence farmers. The team's research revealed that essentially all of the annual rainfall occurs within a 4–5 month period. The team identified a community building with a corrugated metal roof suitable for a gutter system, researched costs of specific building materials available in The Gambia, and designed a rain-catch system and concrete water storage facility using available materials. They further presented research regarding the time and water required to grow pumpkins and squash, and quantified the number of acres that could be irrigated during the dry season for this length of time using the volume of water collected. The final design thus featured both a reasonable estimate of the cost of the system and a clear explanation of its benefits to village.
- "At-Home Carbonator." The team did market research demonstrating that there is demand for carbonated fruit, which is currently only available through bulk production processes. The team completed heat transfer calculations showing that a crock-pot sized device that was charged with dry ice could maintain a temperature cold enough for a time long enough to produce carbonated fruit. They also submitted a reasonable cost estimate for such a device.

Final Deliverables

Each team delivered a final presentation and submitted a final report. The full grading rubrics for these assignments are given in Appendices D and E, and these rubrics were distributed to the students at the same time project teams were announced. Because engineering design and technical communication were the primary objectives of the course, the grading rubrics emphasized effectiveness of writing and soundness of design process, while the potential of the project in an entrepreneurial sense (quality and originality of original idea, size of potential market, etc.) did not figure as prominently in the grading. Both the report rubric and the presentation rubric did include a 10 point "persuasiveness" section which directly mirrored the criterion for success: the 10 points were awarded if the faculty member was convinced the project had enough merit that he/she would support its continuation into the next semester. Teams that met this "persuasiveness" criterion were encouraged to apply for funding from the Rowan Undergraduate Venture Fund and continue their projects through the Junior/Senior Clinic, but whether the team did or did not choose to pursue the project further was irrelevant to the SEC II grade.

Specifications for the final deliverables included that the report should be a comprehensive description of the project, with detailed calculations supporting all quantitative results. Presentations, by contrast, were no more than 10 minutes long and focused on the team's most convincing evidence that the proposed product was feasible, had a market and was worth funding for further development. Thus, the project provided a realistic example of the roles of these two different forms of communication. The entrepreneurial project also offered an advantage over many previous SEC II design projects in that each presentation covered a unique problem; a more interesting and pedagogically sound situation than 15 or more teams giving oral presentations on their solutions to the same problem.

In grading the final reports, the three engineering faculty graded the report three different ways: one read the entire report, one read the report excluding the appendices, and one read only the abstract and conclusions and looked at the figures and tables. This grading scheme was meant to reflect the way real technical reports are read, and give students a strong incentive to think carefully about practical aspects of report organization: e.g., what is necessary information vs. supplemental information that can be placed in an appendix, what needs to go in an effective summary, how to write captions in sufficient detail that the figure stands on its own, etc.

VI. ASSESSMENT

The primary pedagogical goals of the Sophomore Clinics are providing instruction in engineering design principles, technical writing and public speaking. The assessment data summarized in Table 4 shows generally positive feedback from the students regarding meeting these goals. Note that while all eight questions request responses on a scale from 1–5, 3 is the "optimal" response to the first three questions while 5 is the "optimal" response to the other five questions. This survey was

Question	Scale	# Responses	Mean response
The handouts for this course were	1=too elementary 3=about right 5=too advanced	55	2.96
The pace of this course was	1=too slow 3=about right 5=too fast	56	2.93
The design projects were	1=too elementary 3=about right 5=too difficult	56	3.07
The objectives of this course were	1=not attained 5=attained	56	3.91
This course assisted me in developing teamwork skills	1=strongly disagree 5=strongly agree	56	3.96
This course assisted me in developing multidisciplinary engineering skills	1=strongly disagree 5=strongly agree	56	3.64
This course assisted me in developing project management skills	1=strongly disagree 5=strongly agree	56	3.91
This course helped me make the link between engineering design and public speaking	1=strongly disagree 5=strongly agree	56	3.94

Table 4: Overall course evaluation from Spring 2010 offering of entrepreneurial project

administered only to students who completed the Entrepreneurial project, and 56 out of 72 students (78%) responded.

As a secondary goal, the projects described here are intended to foster entrepreneurship in undergraduate students and increase student interest in the Undergraduate Venture Fund. There is some evidence that the White Paper assignment, as a first introduction to entrepreneurship, is an effective vehicle for encouraging students to pursue entrepreneurship further. The spring 2007 and spring 2008 SEC II students were able to choose between the "Create Your Own Entrepreneurial Project" or an alternative design project, but did not have the prior experience of the White Paper assignment, which was introduced in fall 2008. Table 3 shows that 49% (98 of 201) of these students selected the entrepreneurial project. By contrast, in the spring 2009 and spring 2010 cohorts, who did experience the White Paper assignment, 66% of students (157 of 237) selected the entrepreneurial project. This increase is statistically significant ($p<0.1\%$). In addition, a survey was administered to the spring 2010 SEC II class, and the results are summarized in Tables 5 and 6. These surveys were administered in class on the day project teams were announced, and all 114 students responded. Notable results include:

- 47% of SEC II students said that their experience with the White Paper made them more likely to choose the Entrepreneurial SEC II project; only 9% said that their experience with the White Paper made them less likely to select it.

Response	# Students*	% Students
More interested	49	46.7%
Less interested	9	8.6%
No effect	47	44.8%

*105 of 114 students answered this question. Transfer students who took SEC II without taking SEC I the previous semester were asked to leave it blank.

Table 5: Spring 2010 SEC II student responses to the question "Would you say your experience with the White Paper assignment made you more interested, or less interested, in doing an entrepreneurial clinic project?"

Statement (Students were instructed to "circle all statements with which they agreed.")	Number who agreed (72 total respondents)	% who agreed
I chose the entrepreneurial project because I have a specific idea I want to pursue	35	49%
I chose the entrepreneurial project because I like the idea of doing something new and unique	57	79%
I chose the entrepreneurial project because I want a change from last semester	52	72%
I chose the entrepreneurial project because the wind turbine isn't very related to my major	21	29%

Table 6a: Results of survey regarding reasons why students selected entrepreneurial project.

Statement (Students were instructed to "circle all statements with which they agreed.")	Number who agreed (42 total re-spondents)	% who agreed
I chose the wind turbine project because I am interested in renew-able energy	18	43%
I chose the wind turbine project because I became excited about the topic last semester	8	19%
I chose the wind turbine project because I don't have an idea for an elevator pitch	23	55%
I chose the wind turbine project because the entrepre-neurial project is too unclear	9	21%

Table 6b: Results of survey regarding reasons why students selected wind turbine project.

- 50% of students reported choosing the Entrepreneurship project specifically because they liked the idea of doing something new and unique.
- Despite the inherent uncertainty in the Entrepreneurship project only 9 students reported avoiding the Entrepreneurship project because it was too unclear. This is 7.9% of the respondents, and 21% of the students who opted for the wind turbine project.

The authors also investigated whether SEC II elevator pitches that stemmed directly from SEC I white papers on the same topic were more successful than those that did not. To address this, each elevator pitch was assigned a "feasibility" score and a "student interest" score, each on a scale from 1–3, with 1 being the best. Table 7 shows how student interest was defined; a project that was a "first choice" selection of at least 4 students, for example, clearly had sufficient interest to run and received a 1 on this scale.

Feasibility was assessed primarily from the one-page write-up that accompanied each elevator pitch, rather than from the pitch itself. To be considered "feasible," a project proposal should:

- Provide a compelling statement of the need for the proposed product.
- Outline a logical, effective approach to the project.
- Define a scope for the project that makes completion of a prototype plausible within 3 semesters of work by a team of 3–4 students.

Table 8 shows the rubric that was used to assign ratings of 1-3 to the "need," "approach" and "scope" of each proposed project. Since a project was considered infeasible if it was weak in any of these three respects, the "feasibility" rating of each proposed project was considered equal to the *highest* of the three individual ratings for "need," "approach" and "scope."

Tables 9a and 9b summarize the results for the spring 2010 SEC II cohort. Exactly one-third (24/72) of the students gave an elevator pitch on a topic that was identical to, or closely related to, the topic of their white paper. Notably:

- 42% (10/24) of the students whose elevator pitch was based upon the white paper earned a feasibility rating of 1 (best), compared to 17% (8/48) of the students whose elevator pitch was unrelated to the white paper.

Score	Level of Interest
1	Clearly sufficient to develop a team
2	Might be sufficient to develop a team
3	Insufficient to develop a team

Table 7: Meaning for student interest score

Score	Need	Approach	Scope
1	Clearly defined	Reasonable prospect for success	Could lead to a prototype in 3 semesters with available resources
2	Vaguely defined	Likely will need significant re-thinking	Will need a significant breakthrough to succeed
3	Can be met with other, clearly superior solution that is already available	Not technically feasible	Requires resources that will not be available

Table 8: Rubric for feasibility score

	Student Interest=1	Student Interest=2	Student Interest=3
Feasibility = 1	7	2	1
Feasibility = 2	4	5	2
Feasibility = 3	0	0	3

Table 9a: Summary of feasibility and student interest scores for the 24 elevator pitches that were based upon white papers.

	Student Interest=1	Student Interest=2	Student Interest=3
Feasibility = 1	4	1	3
Feasibility = 2	4	6	11
Feasibility = 3	6	7	6

Table 9b: Summary of feasibility and student interest scores for the 48 elevator pitches that were not based upon white papers.

- 46% (11/24) of the students whose elevator pitch was based upon the white paper earned a student interest rating of 1 (best), compared to 29% (14/48) of the students whose elevator pitch was unrelated to the white paper.
- 38% (9/24) of the students whose elevator pitch was based upon the white paper had their projects selected to run, compared to 19% (9/48) of the students whose elevator pitch was unrelated to the white paper.

While these results imply that elevator pitches stemming from white papers were more successful than those that did not, the results are not statistically significant for this sample size.

The “Student Interest” and “Feasibility” scores were assigned using the rubrics shown in Tables 7 and 8. In both cases 1=best, 3=worst.

Because the "Persuasion" points on final reports and final presentations were awarded on the basis of whether or not the team made a compelling case for funding a continuation of the project, whether or not a team received these points is a useful benchmark for whether the project can broadly be described as "successful." Table 10 demonstrates that there exists a strong correlation between the faculty's initial impression of the feasibility of the elevator pitch and the ultimate success of the project. The projects that were originally rated with "Feasibility=1" based upon the elevator pitch were more likely to lead to "successful" final assignments than projects originally rated "Feasibility=2." This difference was statistically significant when measured using the final reports (p=1.7%), while the difference in the final presentation "Persuasion" scores was smaller and not statistically significant. The teams with "Feasibility=1" projects also scored better on the final reports and presentations overall, and the "Persuasion" points alone do not account for this difference.

As intended, a number of students who participated in the entrepreneurial Sophomore Clinic projects did apply for Jr/Sr Clinic funding through the Rowan Undergraduate Venture Fund:

- The "Create Your Own Entrepreneurial Project" was first run in the spring of 2007. Two teams of students from that cohort went on to pursue entrepreneurial Junior/Senior Clinic projects, funded by the college. Both teams subsequently applied for NCIIA funding, although neither were awarded this funding. One project ultimately resulted in a publication [36]. The other project led to a start-up company, formed by a May 2009 Rowan graduate; which continued the product development that began in the Junior/Senior Engineering Clinic.
- During the fall 2010/spring 2011 semesters, three teams of students from the spring 2009 and 2010 SEC II cohorts did entrepreneurial Jr/Sr Clinic projects sponsored by the Venture Capital Fund.
- Another team of students successfully obtained *external* funding (from the EPA P3 competition) to further a project that started as a SEC II project in the spring of 2009, and is now being carried out in conjunction with the Rowan student chapter of Engineers Without Borders.

	Feasibility=1	Feasibility=2
Number of Projects	9	9
Average Final Presentation Grade	90.9%	82.1%
Average Final Report Grade	85.0%	73.1%
Average Persuasion Score- Presentation	77.8%	22.2%
Average Persuasion Score- Report	63.0%	44.4%

Table 10: Comparison of final deliverables for projects grouped by faculty assessments of their feasibility.

Thus, Rowan University students have pursued six entrepreneurial Jr/Sr Clinic projects in the four years since the entrepreneurial SEC II project was implemented. While this represents an increase compared to the prior four years, the difference is not statistically significant and cannot conclusively be attributed to the introduction of entrepreneurial Sophomore Clinic projects. Note that three of these six Jr/Sr Clinic projects were direct extensions of projects that began in SEC II, and three were completely new projects, but all six were led by teams of students who selected the entrepreneurial experience in SEC II.

VII. SUMMARY AND CONCLUSION

Two entrepreneurial assignments have been integrated into a multidisciplinary sophomore design course. The projects are compatible with the primary pedagogical goals of the course: teaching engineering design and technical communication. In addition, the assignments are intended to stimulate a sustained interest in entrepreneurship. One assignment, introduced in spring of 2007, is a semester-long project that challenges students to conceive of new products, "pitch" the projects to their classmates, and work in teams of 4-5 on preliminary product design. Student preference has traditionally been used to select which of the projects proposed by students would run. However, assessment data collected in the spring of 2010 suggests that faculty assessment of the feasibility of the project should be weighted more heavily in project selection, as preliminary faculty assessment was a strong predictor of the ultimate success of the project.

The other assignment, introduced in the fall of 2008, challenges students to envision a new product, and write a white paper that outlines the need for the product and describes the technical challenges associated with its development. When this assignment was introduced, it resulted in a significantly larger fraction of students choosing to pursue the semester-long entrepreneurial project option in the spring. This assignment also ensured that *all* engineering students would receive some training and exposure to entrepreneurship, rather than only the students who chose an entrepreneurial project.

While the 8-semester Engineering Clinic sequence is specific to Rowan University, the activities described here are readily implemented in other curricular structures. Significantly, while the "Create Your Own Entrepreneurial Project" was conducted within a team-taught class, *the Communication faculty had no direct role in administering the project.* The project could thus be adapted for any course in which engineering design is the primary educational objective. The White Paper assignment could similarly be adapted for any course in which technical writing is the primary educational objective.

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REFERENCES

1. T. Cassel, "Engineering Entrepreneurship at Penn," *Proceedings of the ASEE Conference and Exposition,* 2003.
2. C. D'Cruz, S. Shaikh, "Systems Engineering Entrepreneurship- A Unique Convergence of the Business and Engineering Realms,“ *Proceedings of the ASEE Conference and Exposition,* 2007.
3. J. Schaufeld, G. Tryggvason, M. Banks, "Early Exposure to Engineering Innovation and Entrepreneurship," *Proceedings of the ASEE Conference and Exposition,* 2010.
4. L. Carlson, J. Sullivan, "Exploring Entrepreneurship through Product Development:A Hands-on Approach," *Proceedings of the ASEE Conference and Exposition,* 2002.
5. H. Tze-Chi, H. Bee-Shan, "Coupling Engineering and Entrepreneurship Education through Fuel Cell Product Development", *Proceedings of the ASEE Conference and Exposition,* 2004.
6. W. Birmingham, B. Allison, J. DuPree, "Entrepreneurship via Multidisciplinary Product Development," *Proceedings of the ASEE Conference and Exposition,* 2007.
7. K. Crittenden, J. Pratt, J. Nelson, "Impact: A Multidisciplinary Approach for Creating High-Tech Startups," *Proceedings of the ASEE Conference and Exposition,* 2008.
8. D. Raviv, M. Morris, K. Ginsberg, "On Teaching and Assessing Engineering Innovation," *Proceedings of the ASEE Conference and Exposition,* 2005.
9. A. Shartrand, P. Weilerstein, M. Besterfield-Sacre, K. Golding, "Technology Entrepreneurship Programs in the U.S. Engineering Schools: Course and Program Characteristics at the Undergraduate Level," *Proceedings of the ASEE Conference and Exposition,* 2010.
10. G. Feierfiel, T. Rizk, S. Howell, P. Shamamy, C. Riedel, L. Anneberg, "The Engineering Entrepreneurship Program at Lawrence Technological University," *Proceedings of the ASEE Conference and Exposition,* 2003.
11. J. Wise, E. Kisenwether, S. Rzasa, "Assessing Engineering Entrepreneurship," *Proceedings of the ASEE Conference and Exposition,* 2003.
12. M. Raber, M. Moore, "The Enterprise Program at Michigan Technological University: A Professional Development Curriculum in Action," *Proceedings of the ASEE Conference and Exposition,* 2005.
13. J. Robinson, E. Moldt, "Technological Entrepreneurship Certificate," *Proceedings of the ASEE Conference and Exposition,* 2000.
14. P. Nelson, E. Lumsdaine, "Creating and Entrepreneurial Culture in an Engineering University," *Proceedings of the ASEE Conference and Exposition,* 2008.
15. M. Ohland, G. Zhang, C. Brawner, T. Miller, "A Longitudinal Study of Retention and Grade Performance of Participants in an Engineering Entrepreneurs Program," *Proceedings of the ASEE Conference and Exposition,* 2003.

16. J. Green, "Designing and Launching the Entrepreneurship and Innovation Living-Learning Program for Freshmen and Sophomores," *Proceedings of the ASEE Conference and Exposition,* 2010.

17. T. Standish-Kuon and M. Rice, "Introducing Engineering and Science Students to Entrepreneurship: Models and Influential Factors at Six Universities," *Journal of Engineering Education,* 91, 1 (2002).

18. E. Coyle, N. Clement, J. Krueger, The Innovation Initiative for Social Entrepreneurship: Fostering Awareness of Local and Global Social Issues via Entrepreneurship Education," *Proceedings of the ASEE Conference and Exposition,* 2007.

19. J. Ochs, G. Lennon, T. Watkins, G. Mitchell, A Comprehensive Model for Integrating Entrepreneurship Education and Capstone Projects while Exceeding ABET Requirements," *Proceedings of the ASEE Conference and Exposition,* 2006.

20. L.R. Latucca, P.E. Terenzini and J. F. Volkwein, "Engineering Change: A Study of the Impact of EC2000," ABET, Inc., Baltimore, MD 2006.

21. The Engineer of 2020: Visions of Engineering in the New Century, National Academy of Engineering, The National Academies Press, Washington, DC, 2005.

22. M. Ohland, S. Frillman, G. Zhang, C. Brawner and T. Miller, "The Effect of an Entrepreneurship Program on GPA and Retention," *Journal of Engineering Education,* 93, 4 (2004).

23. N. Dabbagh and D. Menasce, "Student Perceptions of Engineering Entrepreneuship: An Exploratory Study," *Journal of Engineering Education,* 95, 2 (2006).

24. J. Porter, J. Morgan, "Engineering Entrepreneurship Educational Experience (E4) Initiative: A New Model for Success," *Proceedings of the ASEE Conference and Exposition,* 2007.

25. E. Johnson, M. Budnik and D. Tougaw, "Integrating Entrepreneurship Throughout and Electrical and Computer Engineering Curriculum," *Proceedings of the ASEE Conference and Exposition,* 2009.

26. S. Condoor, M. McQuilling, "Incorporating an Entrepreneurial Mindset in Freshman Engineering Students," *Proceedings of the ASEE Conference and Exposition,* 2009.

27. A. Marchese, J. Schmalzel, S. Mandayam, T. R. Chandrupatla, "A Venture Capital Fund to Encourage Entrepreneurship and Rapid Product Development with Multidisciplinary Teams in the Junior Engineering Clinic," *Proceedings of the ASEE Conference and Exposition,* 1999.

28. P. Jansson, M. Muhlbaier, S. Blicharz, G. Digneo, "Undergraduate Entrepreneurs: Novel LED Taillight Assembly Design, Prototyping and Market Tests," *Proceedings of the ASEE Conference and Exposition,* 2004.

29. K. Dahm, W. Riddell, E. Constans, R. Harvey, J. Courtney, and P. von Lockette, "Implementing and Assessing the Converging-Diverging Model of Design in a Sequence of Sophomore Projects," *Advances in Engineering Education*, 1, 3 (2009).

30. K. Dahm, T. Merrill, W. Riddell, and L. Weiss, "Fostering Entrepreneurship While Teaching Design," Proceedings of the ASEE Annual Conference and Exposition, Louisville, KY, June 2010.

31. K. Dahm and W. Riddell, "Students Learn Fundamentals of Engineering Design While Pursuing their own Entrepreneurial Ideas," *Proceedings of the ASEE Annual Conference and Exposition***,** Vancouver, BC, June 2011.

32. C. Dym, Engineering Design. Cambridge University Press, New York, NY, 1994.

33. P. von Lockette, D. Acciani, J. Courtney, K. Dahm, C. Diao, R. Harvey, B. Pietrucha, W. Riddell "An Introduction To Parametric Design Through Bottle Rockets," *ASEE Annual Conference and Exposition*, June 2006, Chicago, IL.

34. E. Constans, J. Courtney, K. Dahm, J. Everett, C. Gabler, R. Harvey, L. Head, D. Hutto, H. Zhang, "Setting the Multidisciplinary Scene: Engineering Design and Communication in the 'Hoistinator' Project", *ASEE Annual Conference and Exposition*, June 2005, Portland, OR.

35. S. Bakrania, W. Riddell, K. Dahm and L. Weiss, "Wind Turbines for Teaching Parametric Design," *ASEE Annual Conference and Exposition*, June 2009, Austin, TX.

36. S. Wilson, K. Blauth, W. Riddell and P. Jansson, "RFID Technology for Universally Accessible Doors in Public Buildings," *The International Journal of Technology, Knowledge and Society,* 5, 3 (2009).

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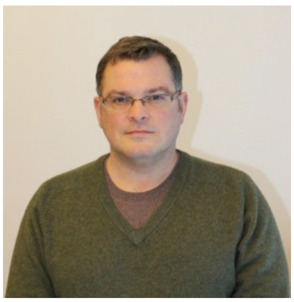

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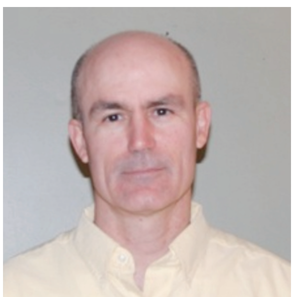

Tom Merrill's career has been dominated with projects involving transport phenomena. After graduate school at the University of Michigan and Penn State, Tom worked on absorption chillers and heat pumps at United Technologies Carrier in Syracuse N.Y. At the University of Pittsburgh Medical School, he worked on a project involving lung support devices. This technology led to the creation of a small company - Alung Technologies Inc. At Abiomed Inc. in Danvers, Massachusetts, Tom worked on a cardiovascular support device - the AB5000. He worked for Wyeth Research, Neuroscience Division, developing novel chemical and biological handling and analysis tools. FocalCool, LLC, a medical device startup, was created in 2004, operated in his basement, and funded by Angel investment and NIH grants. In 2006 he began working for

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Roberta Harvey is currently the Interim Associate Provost for Academic Affairs at Rowan University. Prior to holding this position, she was the Provost Fellow and Associate Professor in the Department of Writing Arts at Rowan University. She has been teaching writing in engineering at Rowan since 1998. She has co-authored articles addressing several areas of engineering education, including communication, design, teamwork, and assessment. She holds a Ph.D. in English with a specialization in Composition and Rhetoric from the University of Wisconsin-Milwaukee. She earned her M.A. in English, B.A. in Anthropology, and B.S. in Biology from the University of North Dakota.

Leigh Weiss retired in 2011 as an Associate Professor of Computer Science at Rowan University, having joined Rowan in 1968. He received his B.S. and M.S. from Buffalo State University in 1966/7. He had an adjunct appointment in the Department of Electrical and Computer Engineering at Rowan University.

APPENDIX A: GRADING RUBRICS FOR SEC I WHITE PAPER ASSIGNMENT

Grading criteria for Technical Writing reader: 2/3 of overall grade.

Abstract	5	
▪ Explains purpose, scope, and content of the document		
▪ Omits extraneous information		
Introduction	15	
▪ Makes a compelling case for the need to solve the problem		
▪ Identifies the purpose of the document		
▪ Provides an overview of the content and organization of the document		
Definition of the Problem	20	
▪ Defines the attributes of an effective solution to the problem		
▪ Identifies the physical phenomena that can be applied to the solution of the problem		
▪ Focuses the problem so that it is appropriate to the scope of the white paper		
▪ Provides an appropriate level of technical detail for an engineering audience		
Discussion of the Potential Solution	20	
▪ Identifies the status of the solution (innovative; in development; adaptation of existing solution; new application of existing solution; scaled implementation of existing solution; etc.)		
▪ Offers a technological solution as appropriate to the status of the problem (outlines a specific approach to a new solution; proposes a solution to a specific component of the problem; suggests a specific way to achieve a solution that is in development; explains how an existing solution will be adapted, applied, or scaled; etc.)		
▪ Provides an appropriate level of technical detail for an engineering audience		
Conclusions	10	
▪ Summarizes the problem and the need for a solution		
▪ Summarizes the progress that has been made toward the solution in the white paper		
▪ Provides recommendations for next steps that will move the idea forward		

Use of Sources		
▪ Cites at least 5 scholarly or substantive sources		
▪ Provides evidence from sources to document the need and/or problem as appropriate		
▪ Provides evidence from sources to support the solution		
▪ Cites patent information relevant to the problem and/or solution discussed in the white paper to acknowledge similar solutions, identify different solutions, and/or demonstrate originality as appropriate		
▪ Demonstrates an effective research process, including use of a variety of library databases and effective search terms (documented in the RESEARCH RECORD)	20	
▪ Provides justification for each source by identifying the specific information it provides (documented in the RESEARCH RECORD)		
▪ Summarizes and paraphrases appropriately; did not “cut and paste”		
▪ Refers to all sources listed in the bibliography		
▪ Correctly incorporates IEEE or Author/Date citations into sentences		
▪ Lists references at the end in correct IEEE or Author/Date format		
Document Format, Mechanics, Style, Grammar, and Conventions		
▪ Follows document specifications		
▪ Uses clear and concise language	10	
▪ Follows conventions of technical style, including tone and voice		
▪ Uses correct spelling, grammar, and punctuation		
Reader 1 Total (67% of grade)	100	

Grading criteria for Engineering reader: 1/3 of overall grade

Analysis of the Engineering Problem (Introduction and Definition of the Problem)		
▪ Makes a compelling case for the need to solve the problem		
▪ Defines the attributes of an effective solution to the problem		
▪ Identifies the physical phenomena that can be applied to the solution of the problem	50	
▪ Focuses the problem so that it is appropriate to the scope of the white paper		
▪ Provides a level of technical detail appropriate for an engineering audience and includes citations for all factual information		

Presentation of the Solution (Discussion of the Potential Solution and Conclusions)	50	
▪ Identifies the status of the solution (innovative; in development; adaptation of existing solution; new application of existing solution; scaled implementation of existing solution; etc.)		
▪ Offers a technological solution as appropriate to the status of the problem (outlines a specific approach to a new solution; proposes a solution to a specific component of the problem; suggests a specific way to achieve a solution that is in development; explains how an existing solution will be adapted, applied, or scaled; etc.)		
▪ Accurately summarizes the progress that has been made toward the solution		
▪ Provides recommendations for next steps that will move the idea forward		
▪ Provides a level of technical detail appropriate for an engineering audience and includes citations for all factual information		
General Comments		
Total (33% of grade)	**100**	

APPENDIX B: FALL 2010 WHITE PAPER ASSIGNMENT DOCUMENT

Assignment 2: Academic White Paper on an Engineering Problem

Engineers use technology to help solve problems. But these problems don't come neatly packaged like homework problems. Solving problems involves identifying or even anticipating them and then choosing or developing the means of solving them. Solving problems also requires support for the idea in the form of approval and resources. A document called a white paper plays a key role in this process. The purpose of a white paper is to make the case for a particular application of technology as the solution to a problem.

There are two general types of white papers:

Commercial white papers promote a technological product or process as the solution to a problem for the purpose of selling it to make money. The emphasis in these documents is on company and product image. They are very much like advertising and tend to be brief and relatively simple.

Academic white papers are much more detailed and technical. The term “academic” does not mean that these white papers are mere classroom exercises, but rather signifies their educational and informative function. The emphasis is on carefully defining a problem and presenting a reasoned argument for a particular solution. Academic white papers are often written to seek approval of and generate interest in an idea with the goal of eventually gaining support for research and development. They can function as a kind of “concept stage” that precedes a formal project proposal. The audience for a white paper is engineers who are interested in the topic or working in relevant areas. They are disseminated through publication, via websites or listservs, at professional conferences, or within government or industry organizations.

- Commercial white papers promote technology solutions to sell them for a profit.
- Academic white papers promote technology solutions to gain support for research and development.

For this assignment, you are going to write an **academic** white paper on a topic of your choice. You will need to do research on the problem and the technology you have identified as a potential solution, using sources from the library, United States and international patent offices, and, if appropriate, from web sites. **The problem you identify should be local**. That is, the problem you identify should be found in your everyday surroundings and informed by the products you use, the various technologies you encounter on a daily basis, and your own engineering interests. The solution you identify and discuss will most likely be one of many possible solutions to that problem and/or one component of a series of technologies that must be applied together to solve a problem. The key for white papers is to think small and specific; small solutions to everyday problems can have significant effects. You are encouraged to choose a topic that represents a problem you would be interested in working on in the future. See **Topics and Solutions** below for further guidelines.

Purpose

By doing this assignment, you will learn and practice how to:

- Conduct library research using science and engineering databases
- Become familiar with engineering patents
- Research and analyze an engineering problem
- Discuss a solution and potential applications
- Develop and present a persuasive argument
- Paraphrase and summarize information from sources to support your argument
- Cite your sources and format a bibliography using an accepted engineering style
- Write in a specialized technical genre

Due Dates and Copies

This assignment will be due **in class** on **Thursday, November 4**. Please turn in **two copies**, and **email** me a Word document prior to class on November 4.

Topics and Solutions

As noted above, you are required to choose a topic found in your local surroundings so that you can more readily define the problem and also so that the research will be of future use to you. **You will also have the option of using your research as the basis for your design project in Sophomore Clinic II this coming spring**. The following guidelines and constraints on topics also apply:

- Your topic must be researchable and feasible, which primarily means that published information exists and can be obtained within the timeframe of the assignment.
- Your topic cannot involve an already established solution (such as catalytic converters as a solution to pollution caused by automobile emissions) but may involve a solution that is in development but not yet implemented (such as alternative fuels).
- You may adapt solutions and/or technologies that have been implemented in other areas (for example, harnessing the power generated from friction to charge batteries while riding a bicycle). In these cases your discussion of the solution may be in terms of scale (how to reduce the size of a technology), chemistry (how to alter the components of a material to make it lighter or more malleable), or implementation (how to address the solution from a different perspective).
- **All topics must be approved by your writing instructor and may be changed only with permission.**

For example, a former student wanted to address the problem faced by many home and professional bakers: the hardening of brown sugar. The problem here is related to the chemical makeup of brown sugar, which makes it more prone to hold moisture than white sugar. One potential solution might be to alter the chemical makeup of the sugar itself. This, however, could prove costly and might sacrifice taste. The solution the student argued for was ultimately a plastic container with a porous moisture barrier designed specifically for and sold with brown sugar. In the discussion of the solution the student sketched a prototype of the container, described the moisture barrier technology, and discussed how it would keep the sugar from hardening. Another student who looked at the problem of car fuel and energy efficiency proposed car solar panels as a solution. However, rather than discussing the properties and implementation of solar panels (which are an established technology and could easily be stuck to the roof) the student proposed, sketched, and described the effects of a new electrical circuit that incorporated the stored energy generated by the solar panels to power just the electrical components of the car (AC, radio, windows, door locks).

Research Requirements

A white paper must be based on reliable information, which usually means formally published (peer- or editor-reviewed) information—books, journal articles, conference proceedings, and patents. **Where appropriate**, authoritative and credible web sources may be included. Web sources might be included if, for example, a topic were so cutting edge that little research had actually been published. You must include information from **at least five formally published sources**. You must also **cite all sources using formal citation**. See below for information about citation formats.

Your sources must be suitable for college-level academic work on a technical subject. That means, for instance, no general encyclopedias, no popular magazines like *Time* or *Newsweek*, no general newspaper articles, and no general web sources. If you are in doubt about a source, ask.

For each source, you must provide the following information as a record of your research process:

1. Complete identification of the source
2. Database or search method and search terms you used to find it
3. Justification for the source, including an evaluation of its quality and a brief description of the type of information it provides

Attach these research notes to the white paper.

Length, Format, and Content

The white paper should be 5-7 pages double-spaced or the equivalent. Use a standard 12 pt font and 1-inch margins. The white paper should include the following sections with headings:

- **Abstract**
  Provide an overview of the scope and purpose of the white paper that gets the reader interested. Keep the abstract concise by focusing on a nutshell description of the problem and its proposed solution. Other aspects of the project, such as distinguishing your proposal from existing products and giving evidence that your solution is feasible, are essential later in the report, but are probably beyond the scope of an abstract.

- **Introduction**
  Explain the general context of the problem and why it needs to be solved. (In other words, you are defining the “Perceived Need” level of Dixon’s Taxonomy, providing a rationale for why

the problem is significant.) Briefly summarize the purpose of your white paper and describe its organization and content.

- Definition of the Problem
  Provide a detailed technical analysis of the problem in terms of the features of an effective solution. (Here, you are identifying the "Function" and "Physical Phenomena," or physical, scientific and engineering principles that can be applied to the problem, levels of Dixon's Taxonomy). Provide any technical background information that is necessary for understanding the problem and the solution. As part of defining the problem, this section can also describe any relevant current products or solutions and explain why they are inadequate.
- Discussion of the Potential Solution
  Describe the proposed solution, discussing the specific technologies that will be applied. (This advances the "Embodiment" and perhaps the "Artifact Type" or even "Advance Instance" levels of Dixon's Taxonomy.) As part of this explanation, indicate the status of the solution (innovative; in development; adaptation of existing solution; new application of existing solution; scaled implementation of existing solution; etc.). This section can also contrast the proposed solution with existing products and make the case that the proposed solution has unique value.
- Conclusions
  Summarize the problem and the proposed solution. Give a clear indication of the current status of knowledge with respect to the proposed solution, highlight the progress made in the white paper, and describe specific next steps that are necessary for implementation of the proposed solution.
- References
  List all sources cited in the paper using numbered (IEEE) or author-date (ASCE or APA style) format. This will be covered in class.

Additional subheadings are optional. Headings should be distinguished from the text; specific formatting will be described by your writing instructor. Number your pages.

Grading Criteria

In class, we will cover how to select appropriate information, develop and support your argument, and organize and present your research. Much of the grade will be based on the quality of your research, including appropriateness of sources as reflected in your research notes. We will also look closely at the quality of the argument, including your explanation of the problem and your support for your solution. Adherence to citation and bibliography formats will also be evaluated. Your white paper will be read and graded by your writing instructor and one of the Sophomore Clinic engineering faculty.

APPENDIX C: ELEVATOR PITCH EVALUATION SHEET.

Speaker's Name: ______________________ **Speech Time:**

E = Excellent G = Good A = Average P = Poor U = Unacceptable

Presentation (2/3 of the overall grade)

Content E G A P U

- Introduction gained audience attention and developed interest.
- Project was introduced and described clearly.
- Main points were appropriate to the specific purpose.
- Content appeals to the audience.
- Presentation has a clear ending.
- Presentation ended with a memorable closing statement.

Organization E G A P U

- Overall, the presentation was easy to follow.
- Transitions used effectively throughout the speech.
- Presentation contained a clear intro, body and conclusion.

Style E G A P U

- Language choices create a persuasive tone.
- Language choices create interest, communicate enthusiasm.
- Language choices were clear and accurate.

Delivery E G A P U

- Employed an extemporaneous style.
- Maintained eye contact.
- Used voice effect. (vocal variety, volume, rate, articulation, pronunc.).
- Used physical action effectively (gestures, posture, body movement).
- Adhered to the time limit (90 seconds).

Overall E G A P U

- Presentation developed a strong persuasive appeal and approach.
- Presentation was adapted to the audience.

- Presentation effectively communicated student enthusiasm.
- Preparation and rehearsal is evident.

Student Response (1/3 of the overall grade)

Student interest indicated quality of presentation.

Presentation Grade: ________/ 100

Response Grade: _______/50

APPENDIX D: FINAL PRESENTATION EVALUATION SHEET.

Team Name:____

Speaker's Names:____________________________________**Speech Time:**_________________

E = Excellent, G = Good, A = Average, P = Poor, U = Unacceptable

Presentation (90 Points)

Content – Introduction E G A P U

- Project was introduced and described clearly.
- Need for design was presented clearly.
- Constraints were presented clearly.
- Criteria were presented clearly.
- Function was presented clearly.

Content – Design Ideas E G A P U

- Competition identified, as appropriate.
- Governing principles and available technology discussed.
- Significant ideas from brainstorming discussed.

Content – Proposed Next Steps E G A P U

- Ideas were evaluated based on criteria.
- Remaining efforts discussed.
- Reasonable assessment of status given.

Organization	E	G	A	P	U

- Presented outline of talk.
- Overall, the presentation was easy to follow.
- Transitions used effectively throughout the speech.
- Presentation contained a clear intro, body and conclusion.
- Leads viewer to stated conclusions.

Style and Delivery	E	G	A	P	U

- Language choices were clear and accurate.
- Employed an extemporaneous style.
- Maintained eye contact.
- Used voice effect. (vocal variety, volume, rate, articulation, pronunc.).
- Used physical action effectively (gestures, posture, body movement).
- Effectively used the allocated time (12 minutes).

Overall	E	G	A	P	U

- Introduction gained audience attention and developed interest.
- Main points were appropriate to the specific purpose.
- Presentation was adapted to the audience.
- Presentation effectively communicated student enthusiasm.
- Preparation and rehearsal is evident.

Graphics	E	G	A	P	U

- Font size big enough to see.
- Each slide had a digestible amount of information.
- If used, animations are effective, not distracting.
- Graphs have labels on all axes.
- Pictures complement spoken words.

Persuasion (10 Points)

Based on this presentation, I would be willing to advise this project next semester. Y N

Presentation Grade: _________/ **100**

APPENDIX E: GRADING RUBRICS FOR FINAL SEC II REPORT

Grading Criteria for Final Report: Reader 1 – entire document

Demonstrates awareness of audience and purpose	**15**	
❑ Abstract succinctly and accurately summarizes paper		
❑ Employs appropriate technical style and tone for designated audience.		
❑ Includes appropriate level of detail in the body of the report for designated audience and genre.		
Demonstrates understanding of the design problem	**25**	
❑ Demonstrates need for design.		
❑ Describes specific and rational constraints.		
❑ Describes specific and rational criteria.		
❑ Criteria enable design ideas to be ranked.		
❑ Function of design is well defined.		
Demonstrates understanding of environment for design	**20**	
❑ Gives complete and thorough description of competition that allows assessment against own design ideas.		
❑ Describes off-the-shelf technology available for incorporating into design.		
❑ Demonstrates understanding of governing principles used in design.		
Demonstrates thoughtful design approach	**15**	
❑ Identifies several different reasonable design ideas.		
❑ Uses criteria to select one of more ideas as best.		
❑ Comparison of design ideas are made at the same level of Dixon's taxonomy.		
❑ Suggest rational approach for continued effort.		
Makes persuasive case for follow up support	**10**	
❑ Convinces reader that additional effort and support will be worthwhile. (Y/N)		
Demonstrates ability to follow document specifications and meet requirements	**15**	
❑ Organizes content according to specified subsections and follows appropriate conventions for each (content, tense, grammatical structure)		
❑ Follows document format instructions (font, page limit, etc.)		
❑ Tables and Figures have titles and are numbered appropriately		
❑ Proofreads and corrects errors (spelling, grammar, punctuation)		
Total		

SOPHOMORE CLINIC II – DESIGN COMPETITION

Grading Criteria for Final Report: Reader 2 – No Appendices

Demonstrates awareness of audience and purpose	**15**	
❑ Abstract succinctly and accurately summarizes paper		
❑ Employs appropriate technical style and tone for designated audience.		
❑ Includes appropriate level of detail in the body of the report for designated audience and genre.		
Demonstrates understanding of the design problem	**25**	
❑ Demonstrates Need for design.		
❑ Describes specific and rational Constraints.		
❑ Describes specific and rational Criteria.		
❑ Criteria enable design ideas to be ranked.		
❑ Function of design is well defined.		
Demonstrates understanding of environment for design	**20**	
❑ Gives effective summary of competition that allows assessment against own design ideas.		
❑ Summarizes off-the-shelf technology available for incorporating into design.		
❑ Utilizes governing principles in design.		
Demonstrates thoughtful design approach	**15**	
❑ Identifies several different reasonable design ideas.		
❑ Uses criteria to select one of more ideas as best.		
❑ Comparison of design ideas are made at the same level of Dixon's taxonomy.		
❑ Suggest rational approach for continued effort.		
Makes persuasive case for follow up support	**10**	
❑ Convinces reader that additional effort and support will be worthwhile. (Y/N)		
Demonstrates ability to follow document specifications and meet requirements	**15**	
❑ Organizes content according to specified subsections and follows appropriate conventions for each (content, tense, grammatical structure)		
❑ Follows document format instructions (font, page limit, etc.)		
❑ Tables and Figures have titles and are numbered appropriately		
❑ Proofreads and corrects errors (spelling, grammar, punctuation)		
Total		

SOPHOMORE CLINIC II – DESIGN COMPETITION

Grading Criteria for Final Report: Reader 3 – Abstract, Figs, Tables, Conclusion

Abstract Conveys Main Idea	**25**	
❑ Succinctly summarizes the paper		
❑ Conveys Need for design.		
❑ Conveys Function of design.		
Demonstrates understanding of the design problem	**20**	
❑ Constraints are summarized in table.		
❑ Criteria are summarized in table.		
❑ Criteria enable design ideas to be ranked.		
Demonstrates understanding of environment for design	**15**	
❑ Figures convey design ideas.		
❑ Tables or Figures used to convey several different ideas that were considered.		
❑ Rational for decision conveyed graphically.		
Demonstrates thoughtful design approach	**15**	
❑ Identifies several different reasonable design ideas.		
❑ Uses criteria to select one of more ideas as best.		
❑ Comparison of design ideas are made at the same level of Dixon's taxonomy.		
❑ Suggest rational approach for continued effort.		
Makes persuasive case for follow up support	**10**	
❑ Convinces reader that report may contain evidence that additional effort and support will be worthwhile. (Y/N)		
Demonstrates ability to follow document specifications and meet requirements	**15**	
❑ Tables and Figures have titles and are numbered appropriately		
❑ Titles for Figures and Tables allow them to be interpreted as stand alone images		
❑ All axes are labeled and have units		
Total		