AC 2011-202: STUDENTS LEARN FUNDAMENTALS OF ENGINEERING DESIGN WHILE PURSUING THEIR OWN ENTREPRENEURIAL IDEAS

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Students Learn Fundamentals of Engineering Design While Pursuing Their Own Entrepreneurial Ideas

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Abstract

Rowan University has a unique 8-semester Engineering Clinic sequence. This sequence helps develop professional skills identified in the ABET A-K criteria though project-based-learning. The specific role of the Sophomore Engineering Clinics is to provide an introduction to technical communication and engineering design principles. Design skills are further developed in discipline-specific capstone design experiences and in the Junior/Senior Engineering Clinics.

For many years, open ended design projects varying in scope from 3 weeks to a full semester have been presented in the Sophomore Engineering Clinics. In recent years, two new entrepreneurial assignments were integrated into Sophomore Clinic:

- Sophomore Clinic I (fall semester): A white paper assignment, in which students examine a product that doesn't currently exist but could foreseeably be developed in the near future, was added to Sophomore Clinic I.
- Sophomore Clinic II (spring semester): An entrepreneurial project framework, in which students propose their own idea for an entrepreneurial project and try to convince classmates to join this project. Projects that attract enough interest are run as the design projects during the rest of the semester.

A previous paper[1] examined the role and impact of these new Sophomore Clinic assignments in Rowan's college-wide effort to foster entrepreneurship in students. The proposed paper will focus on how these projects proved to be an effective vehicle for meeting the primary pedagogical goals of Sophomore Engineering Clinic: teaching engineering design and technical communication. New assessment results quantifying student success on the entrepreneurial projects, both in terms of developing student interest at the beginning of the semester and in convincing faculty at the end of the semester that a project merits additional effort in the junior year, will also be presented.

I. Background and Introduction

Project-based learning has been gaining popularity in engineering curricula to address the professional skills component (or A-K criteria) introduced by ABET in the 2000 criteria[2]. The College of Engineering at Rowan University has adopted an eight-semester sequence of courses, known as Engineering Clinics, which are integrated through the curriculum for all engineering disciplines. In this sequence, engineering students progress from working on projects with limited scope in the freshman year. During the freshman and sophomore years, the projects become increasingly ill-posed and open ended, as they are intended to provide a foundation of engineering skills needed for Junior/Senior Engineering Clinic. The sequence culminates in the

Junior/Senior Engineering Clinic, in which students work on real engineering research and design projects. Project teams work with close faculty supervision and usually consist of 3-4 students; sometimes drawn from a single discipline and sometimes representing several, depending on the needs of the particular project. Most projects are externally sponsored, either by local industry or government agencies. Students also have the opportunity to propose their own entrepreneurial clinic projects, and have them funded by the college, through the Rowan Venture Capital Fund, which was created with the support of National Collegiate Innovators and Inventors Alliance (NCIIA) grants and private donors.

This paper focuses upon the Sophomore Engineering Clinic.

Sophomore Engineering Clinic I and II

The goals of the Sophomore Engineering Clinic consist of teaching engineering design principles and technical communication (technical writing in the fall, public speaking in the spring). The Sophomore Engineering Clinics are integrated courses, team-taught by Communication and Engineering faculty. There are two 75 minute lecture periods and one 160-minute lab period each week. Students work on design problems during lab periods, which are supervised by a team of 5-6 engineering faculty representing all four Rowan engineering departments (Chemical, Civil & Environmental, Electrical & Computer, Mechanical). Lecture periods are supervised by Communication faculty. Many of the deliverables in the courses are reports and presentations about the engineering design projects, which are graded by both the Engineering and Communication faculty. Over the years, numerous design problems have been used in the course, including: baseball stadium design[3], improving energy efficiency of campus buildings[4], making rockets from 2-L soda bottles[5], designing and building trusses for cranes[6], and the optimization of wind turbines.[7] Currently, the two Sophomore Engineering Clinics integrate a sequence of three design projects of increasing complexity, as illustrated in Table 1. The next section describes Dixon's Taxonomy, a design framework that has been employed throughout the Sophomore Engineering Clinics in recent years.

Table 1 – Schematic schedule for SEC I and II

<table>
<tr><th>Course</th><th colspan="2">Design Project</th><th>Communications Instruction</th></tr>
<tr><td rowspan="2">Sophomore Engineering Clinic I</td><td colspan="2">4 week design project</td><td rowspan="2">Technical writing</td></tr>
<tr><td colspan="2">10 week design project</td></tr>
<tr><td>Sophomore Engineering Clinic II</td><td>14 week entrepreneurial project</td><td>Other design project option</td><td>Public Speaking</td></tr>
</table>

Dixon's Taxonomy

Dixon's Taxonomy, as described by Dym[8], identifies seven levels of specificity at which the solution to an engineering design problem can be known.

- **Perceived Need** is the motivation for developing a new product.
- **Function** is a broad conceptualization of how the product will work, 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.

Dixon's Taxonomy is used as a tool to contextualize the purposes and goals of the design projects in the course. For the past six years, Sophomore Clinic I has started with a 4-week project on design of bottle rockets[5]. The project has very specific constraints and specifications:

- The rocket consists of a 2-L soda bottle, unmodified in any way other than addition of a clay nose cone and three identical, symmetrically placed wings.
- The clay is placed on the front in a rounded shape.
- The wings are made out of 3/8" foam board.
- The bottle is partially filled with water.
- The air inside the bottle is pressurized to 50 psi and the rocket is launched at an angle of 45 degrees.
- The sole criterion for success is perpendicular distance travelled 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., base of a 30-60-90 right triangle) that describes the wings.

Table 2 illustrates use of the taxonomy, providing a description of a bottle rocket at each level. Since the bottle rockets have no practical application and aren't intended to be a marketable product, the "Perceived Need" likely seems somewhat contrived, and the idea of "Feasibility" wasn't explored in a very substantial way. However, the bottle rocket project proved to be an effective vehicle for teaching parametric design.[5] Dym[8] noted that realistic design challenges have an "initial state" and a "final state" on the Taxonomy, and that the farther apart these states are, the more complex the problem. In the case of the bottle rocket, the "Artifact Type" information in Table 2 is substantially identical to the above constraints; thus "Artifact Type" was the initial state. The final state was "Artifact Instance;" students optimized the three parameters experimentally, fabricated a "Final Design" bottle rocket, and tested it on the last day of the project.

Table 2: Descriptions of soda bottle rockets at various levels of Dixon's Taxonomy

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	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	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

The bottle rocket project is followed by a 10-week project, which in recent years has been either a crane design project[6] or a wind turbine design project[7]. In both of these projects the "final state," as in the bottle rocket project, was "Artifact Instance;" students designed, fabricated and tested a final crane or wind turbine. In both projects, the "initial state" in Dixon's Taxonomy was "embodiment." A general description of the product was given and students were required to use specific materials of construction, but the constraints were far less rigid than for the bottle rocket project. Thus, the two SEC I design projects form a natural pedagogical progression of increasing complexity.

The focus of this paper is on an entrepreneurial design project that was created for Sophomore Engineering Clinic II. A major rationale for introducing an entrepreneurial project at this particular point in the curriculum is that it continues the progression of design challenges of increasing complexity- an entrepreneurial project challenges students to start all the way at the top of the taxonomy, identifying a "Perceived Need."

II. The "Create Your Own Entrepreneurial Project" for Sophomore Engineering Clinic II

For each of the last 12 years, Sophomore Engineering Clinic II has offered two different semester-long design projects. Both projects are presented on the first day of class and students choose one. A new project was introduced in the spring of 2007[1] as one of the two options: the "Create your own entrepreneurial project." Every student proposes to their classmates an idea for a semester-long entrepreneurial project. Based on student interest, as indicated from a selection sheet, and faculty perceptions of feasibility, 20-25% of these projects are chosen by the faculty, and a team of 4-5 students is assigned to each. The project timeline is as follows:

<u>Week one</u>: The structure and expectations of the entrepreneurial project, as well as the alternative design project, are presented to the students, and they make their selection. Table 3 summarizes the statistics for project selection for the four years the entrepreneurial project has been offered.

Table 3. Numbers of students in SEC II projects

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

Week three: Each student gives a 90 second elevator pitch describing their idea for a semester-long entrepreneurial project to their classmates; typically, an idea for a new product. Each student also submits a one-page summary of their proposed project. Based upon 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 projects will run and which students are assigned to each. A primary faculty mentor is assigned to each project. In both 2009 and 2010, a total of 18 different entrepreneurial projects ran, and three engineering faculty members supervised six projects each. The other two engineers on the faculty team supervised the alternative project, which in those years was a wind turbine project that significantly expanded upon the SEC I wind turbine project.

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.

The following sections provide more detail 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 have only 90 seconds to persuade the audience, their peers, that their product is feasible, that there is a market for their product, and that it would be an exciting project to work on.

Sophomore Engineering Clinic II is an integrated course in which engineering design is taught concurrently with public speaking. Consequently, all past SEC II design projects have incorporated presentations as major deliverables. However, the elevator pitch assignment is unique in that, in addition to being a graded assignment, it also largely determines whether or not the student's proposed project will run.

In selecting projects, faculty used how popular the project was with peers as the major criteria, but reserved the right to not run 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 A gives the grading rubric for the elevator pitch. Faculty evaluation of the presentation, as scored 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. Thus if a popular project was vetoed 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 ideas, every student had the opportunity to participate in an entrepreneurial project of his or her own choosing.

Examples of projects that ran in the Spring of 2009 or 2010 include:

- Design of a rain-catch irrigation system for use in a developing country
- Design of a kitchen appliance for carbonation of fruit
- Invention of a new musical instrument
- Design of a small, non-permanent water wheel for powering small electric devices
- Invention of a "self-erasing" blackboard for classroom use
- Development of reusable, microwaveable "heating cubes" for beverages

Framework for Progressing on Project

After teams were assigned, ten weeks remained for completion of the entrepreneurial design projects. Each team was required to have informal meetings with their faculty mentor every week during the weekly lab period. Aside from these weekly 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 discussing how it can be used to guide a sound approach to design problems. It was found that many students, in their elevator pitch, were essentially describing an "Embodiment;" they had moderately specific preconceived notions of what the final product would look like. The first assignment given to teams was to identify the "Perceived Need" that the elevator pitch had identified, and brainstorm different possibilities for Function and Physical Phenomena that could meet this need. Faculty stressed that students should not progress from one level of the taxonomy to the next 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 the "Invent a New Instrument" project, a working prototype (Artifact Instance) was produced by the end of the semester. For most, the time frame and lack of budget made advancing to this stage unrealistic. Specific goals and expectations were determined for each project through dialog between the team and the primary project faculty mentor. However, to ensure that the level of rigor of all projects was comparable, the faculty team established an overall goal applicable to all projects: *by the end of the semester, the team should be able to make a case for the project 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, where most of the population is comprised of subsistence farmers and 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 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.

- "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 did 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 device cost estimate.

Final Deliverables

Each team gave a final presentation and submitted a final report. The full grading rubrics for these assignments are given in Appendices B and C. Note that because engineering design and technical communication are the primary objectives of the course, the grading rubrics emphasize 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.) does not figure prominently in the grading. Both the report rubric and the presentation rubric 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 Venture Capital Fund and continue their projects through the Junior/Senior Clinic, but whether the student team did or did not choose to further pursue the project 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 would be no more than 10 minutes long and would focus 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 presenting 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.

Preliminary Assessment

A paper[9] published in 2008, after the first two offerings of the entrepreneurial SEC II project, showed generally positive student response to the project. Survey data demonstrated that students recognized that the act communication, in the forms of informal presentations, formal presentations and written reports, helped with the design process. Thus, students recognized that "presentations are not, and should not be, a monologue that happens at the *end* of the design process. Rather, they are central to producing the type of dialogue that enables good designs to be developed."[9] This was a significant marker of the success of the entrepreneurial project. Sophomore Engineering Clinic was developed as an integrated experience in communication and design specifically to highlight the complementary nature of these skills, but prior course organizations and design projects did not always achieve the integration this successfully.

However, one significant challenge in the "Create your own entrepreneurial project" is the time frame. With only two weeks between the description of the project and the elevator pitches, students had little time to develop ideas, and often did little or no research about their proposed product before presenting it. One symptom of the lack of research was that some students gave elevator pitches on products without realizing that they already existed.

In the fall of 2008, the faculty integrated an entrepreneurial assignment into Sophomore Engineering Clinic I, partly to expand upon the benefits recognized from the entrepreneurial SEC II project, and partly to address the problem of the short time frame for developing ideas for the entrepreneurial SEC II project.

III. The White Paper Assignment in Sophomore Engineering Clinic I

SEC I is an integrated course in which engineering design is taught concurrently with technical writing. 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, prior to 2008 the course also included an individual Literature Review assignment. Each student chose a societal problem (e.g., reducing global warming, preventing serious injuries and fatalities in auto accidents, preventing or curing diseases, etc.) which is, or could be, at least partially addressed by technology. Students wrote literature reviews on the current state of knowledge and current implementation of technological solutions, as well as the prospects for future developments. Topics were required to be approved in advance by the writing instructor. This assignment served an important role in the course because it gave students experience with literature research and introduced them to standard research techniques beyond the simple web search. It was also the only major writing assignment which wasn't directly related to the team design projects completed in lab. Thus the assignment ensured that all students had the experience of developing a complete document from start to finish.

In the fall of 2008, the faculty team revised the Literature Review assignment into a White Paper assignment. Students are now asked to identify a product that is not currently available, but could that could foreseeably be developed in the near future. Alternatively students could propose a cheaper or more efficient version of an existing product, or a better way of making a currently available product. The assignment challenges students to propose their idea, present research on related, currently existing technology, and outline future steps necessary to develop the proposed product. As in the Literature Review assignment, topics were required to be approved in advance by the writing instructor.

The White Paper assignment thus fills all the pedagogical goals of the literature review assignment, with the additional benefit that successful white papers can be readily used as a basis for elevator pitches for SEC II, and/or entrepreneurial Junior/Senior Clinic projects.

Examples of White Paper topics in the fall of 2008 included:

- "Smart Alarm Clock." The student author presented research demonstrating that it is better to wake up from REM sleep than from other stages of sleep, and proposed a programmable alarm clock. 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 demonstrated that it is possible to determine a person's sleep stage knowing his/her heart rate, and that inexpensive heart rate monitors are available. He therefore concluded that a smart alarm clock could be constructed by interfacing commercially available components with each other and writing a program that would interpret the heart rate data and determine the optimal wake-up time. This paper was the basis for a successful elevator pitch, and became one of the 18 projects run in the spring of 2009 in Sophomore Clinic II.

- "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, 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. While this was a strong white paper, the student opted to pursue a different product for her elevator pitch in SEC II.

These examples illustrate the intended spirit of the assignment.

Each white paper was graded by one writing instructor and one engineering instructor. Among the most common shortcomings of white papers observed in fall 2008 were:

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

For the fall 2009 offering of SEC I, new grading rubrics, shown in Appendix B, 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 fall 2009 and fall 2010 white papers still showed wide variation in the rigor of the research, but the faculty consensus was that student understanding of the assignment was improved: every white paper at least contained a clearly defined product idea that was legitimately distinct and unique.

IV: Assessment of Entrepreneurial Assignments

The primary pedagogical goals of the Sophomore Clinic are providing instruction in engineering design principles, technical writing and public speaking. As a secondary goal, the projects described here are intended to foster entrepreneurship in undergraduate students and increase the number of students who take advantage of the Venture Capital Fund program.

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 had the option of doing the "Create Your Own Entrepreneurial Project," but did not have the prior experience of the white paper assignment, which was introduced in the fall of 2008. Table 3 shows that in the spring 2009 and 2010 cohorts of SEC II students, who experienced the white paper, 157 of 237 (66%) students chose the entrepreneurial project, compared to 98 of 201 (49%) in the previous cohorts which did not experience the white paper.

Further, a survey was administered to the spring 2010 SEC II class, and the results are summarized in Tables 4 and 5. Notable results include:

- 47% of Sophomore Clinic 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.
- 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 (8%) reported avoiding the Entrepreneurship project because it was too unclear.

Table 4: 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?"

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

Table 5: Results of survey regarding reasons why students selected a design project.

Statement (students were instructed to circle all statements they agreed with)	**Number who agreed**	**% of total students (114)**	**% entrepreneurial students (72)**
I chose the entrepreneurial project because I have a specific idea I want to pursue	35	31%	49%
I chose the entrepreneurial project because I like the idea of doing something new and unique	57	50%	79%
I chose the entrepreneurial project because I want a change from last semester	52	46%	72%
I chose the entrepreneurial project because the wind turbine isn't very related to my major	21	18%	29%
Statement (students were instructed to circle all statements they agreed with)	**Number who agreed**	**% of total students (114)**	**% wind turbine students (42)**
I chose the wind turbine project because I am interested in renewable energy	18	16%	43%
I chose the wind turbine project because I became excited about the topic last semester	8	7%	19%
I chose the wind turbine project because I don't have an idea for an elevator pitch	23	20%	55%
I chose the wind turbine project because the entrepreneurial project is too unclear	9	8%	21%

The authors also investigated whether SEC II elevator pitches which 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 6 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 7 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."

Table 6. Meaning for student interest score

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. Rubric for feasibility 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 summarizes 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, compared to 17% (8/48) of the students whose elevator pitch was unrelated to the white paper.
- 46% (11/24) of the students whose elevator pitch was based upon the white paper earned a student interest rating of 1, 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.

Table 8a. 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	7	2	1
Feasibility = 2	4	5	2
Feasibility = 3	0	0	3

Table 8b. Summary of feasibility and student interest scores for the 48 elevator pitches that *were not* 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

Of the 18 projects chosen to run in the spring of 2010, nine were based upon elevator pitches that stemmed from white papers. Table 9 shows that the final deliverables, on average, were comparable for these two groups, though slightly better for the projects that were based upon white papers. Overall, the class average was 79.0% on the final report and 86.5% on the final presentation; a solid overall performance relative to the communication and design goals of the course.

A more compelling comparison is shown in Table 10. Nine of the chosen projects had a faculty-assigned "feasibility" rating of 1, and nine had a "feasibility" rating of 2. Table 10 shows a strong correlation between the original faculty assessment of the feasibility of the project and whether the teams ultimately produced a strong case for continuation of the project.

Table 9. Comparison of final deliverables for projects that were and were not based upon white papers.

	Based on White Paper	Not Based on White Paper
Number of Projects	9	9
Average Final Presentation Grade	86.5%	86.6%
Average Final Report Grade	82.4%	75.7%
Average Persuasion Score- Presentation	55.6%	44.4%
Average Persuasion Score- Report	55.6%	51.8%

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

	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%

V. Lasting Effect of Entrepreneurial Assignments

The intent of the entrepreneurial sophomore clinic assignments was to meet the primary pedagogical goals of the courses- engineering design and technical communication- while also promoting a sustained interest in entrepreneurship lasting beyond the Sophomore Engineering Clinic. 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 also applied for NCIIA funding, although neither were awarded this funding. One project ultimately resulted in a publication[10]. The other project led to a start-up company, formed by a May 2009 Rowan graduate; which is continuing the product development that began in the Junior/Senior Engineering Clinic.

Three teams of students from the spring 2009 and 2010 SEC II cohorts are currently doing 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. Thus, Rowan University students have pursued six entrepreneurial projects in the four years since the entrepreneurial SEC II project was implemented.

VI: Summary and Conclusion

Many engineering programs seek to introduce design skills into the lower levels of the curriculum, rather than confining design to the capstone design course. This paper describes how entrepreneurship was integrated into a sophomore design sequence. The “Create your own entrepreneurial design project” is a semester-long design experience in which teams of 4-5 students pursue entrepreneurial ideas. The goal of the project is to start with an idea and develop it to the point where the team can make a compelling case that the idea has enough merit to deserve funding from either an internal or external source. The primary pedagogical goals of the Sophomore Engineering Clinics are teaching technical communication and engineering design. Two years ago, a preliminary assessment through faculty observations and student surveys suggested that the entrepreneurial design project served the primary pedagogical goals of Sophomore Clinic at least as well as prior projects had, and that it also accomplished the secondary objective of inspiring at least some students to pursue their own entrepreneurial ideas.

Consequently, the role of entrepreneurship in the Sophomore Engineering Clinic has now been expanded into a sequence: a white paper assignment in the fall, followed by the semester-long entrepreneurial design experience in the spring. The white paper assignment, like the entrepreneurial design project, was found to meet the primary pedagogical goals of the course at least as well as the assignment it replaced. Assessment data summarized in Tables 4-10 show that the introduction of the white paper assignment led to more students pursuing the entrepreneurial design project, and allowed at least some students to begin the design project with a better starting point. Selection of projects has been primarily based upon the expressed preferences of students. However, an initial faculty perception of the feasibility of entrepreneurial design project ideas has proved to be highly predictive of ultimate success of the team in producing a compelling case for funding. Consequently, in future offerings of the project, faculty assessment will be weighted more heavily in the process of selecting projects.

While the 8-semester Engineering Clinic sequence is specific to Rowan University, the activities described here could be 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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Appendix A: 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 B: 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 C: 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		

Appendix D: Grading Rubrics for SEC I White Paper Assignment

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

Sophomore Clinic I – Fall 2009
Grading Criteria for Assignment 2: White Paper on an Engineering Problem

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	20	
▪ 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)		
▪ 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	10	
▪ Follows document specifications		
▪ Uses clear and concise language		
▪ Follows conventions of technical style, including tone and voice		
▪ Uses correct spelling, grammar, and punctuation		
Total (67% of grade)	100	

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

Sophomore Clinic I – Fall 2009
Grading Criteria for Assignment 2: White Paper on an Engineering Problem
Reader 2

Analysis of the Engineering Problem (Introduction and Definition of the Problem)	50	
▪ 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		
▪ 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	