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Consumer Reports Inspired Introduction to Engineering Project

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Freshman engineering courses play a crucial role in educating students about the various engineering disciplines and their functions, in addition to establishing a strong analytical foundation. Recognizing the importance of basic experimentation techniques, a new freshman engineering project was designed to expose students to the overall engineering profession with emphasis on developing fundamental technical and laboratory skills. The project was inspired by the popular Consumer Reports magazine, which publishes reviews of consumer products upon rigorous testing and analytical surveys. Specifically, we note the strong overlap between core functions of an engineer and the process with which Consumer Reports reviews are generated. Freshman students were asked to select three brands of a consumer product for their review with instructor consultation. The products ranged from well-marketed kitchen tools to popular children's toys. The student teams designed experiments to systematically test quantifiable properties of these products, analyze the data and recommend a specific brand. The project enabled students to practice core engineering functions such as design of experiments, measurement, data analysis, and representation. In essence, the project provided an opportunity for developing laboratory skills without necessarily requiring a strong theoretical understanding to conduct the experiments. Most importantly, the project afforded students the autonomy to design their own sub-project within the provided constraints. The students also recognized the importance of teamwork, effective communication, and project management in achieving their purpose of identifying a superior brand. This paper presents the overall scope of the project and its outcomes, including the details for adopting the Consumer Reports Project within a freshman engineering course or, alternatively, in a high school technical course. The paper highlights implementation, including project milestones, and assessment of this highly student-driven hands-on project. Pre- and post-tests were conducted to assess the effectiveness of the project in achieving the project objectives. Formative student surveys indicated a very positive response to the project, acknowledging the independence of product selection as the key aspect in making the project engaging. The highly flexible and scalable aspects of the project make it ideal as an introductory engineering project focused on developing a strong experimental foundation, at the same time providing a broad overview of the engineering profession.

Introduction

Introduction to engineering courses play a critical role in educating students about the various engineering disciplines and establishing a strong analytical foundation. In addition, these courses are often students' first exposure to college and engineering, making them important to students' persistence in their major [1,2]. At Rowan University, freshman engineering students begin their careers in the Freshman Engineering Clinic I (FECI) course. The Engineering Clinic sequence is the hallmark of the Rowan College of Engineering and serves as a foundation for multidisciplinary, project-based engineering experience for students at all levels[3].

The seven major course topics of FECI are measurements, engineering professions, teamwork, problem solving, communication, design process, and safety, professionalism, and ethics. In addition, FECI serves as engineering students' Rowan Seminar course, which is a college success course and has objectives in writing and critical thinking, library research skills, cooperative learning, and classroom management skills. As such, students taking FECI are expected to learn to take measurements in a laboratory setting, analyze and communicate the results of those measurements, and do so in teams. Previous projects developed for the freshman clinic sequence have been described extensively and include topics ranging from flashlight fabrication and design and reverse engineering a coffee machine[4,5] to detailed exploration of the human body[6]. Many of the projects conducted in FECI satisfy ABET student outcome requirements. In particular, the course overall aims to meet objectives a, b, d, g, k of the ABET Criteria for Accrediting Engineering Programs[7].

To meet both the course and ABET objectives, a project inspired by the Consumer Reports organization was developed and implemented for the first time in Fall 2011. It has subsequently been used in FECI in the Fall 2011, 2013, and 2014 semesters. The project was designed to allow students to choose their study subject with emphasis on developing the fundamental technical and laboratory skills noted above. Providing students with choice in this project takes advantage of the positive relationship between student learning and Self-Determination Theory (autonomy, competence, and relatedness) [8,9]. The project also provides an appreciable exposure to engineering design concepts that have been strongly recommended as an early introduction to the engineering profession[10]. Furthermore, the project allows instructors to easily integrate teaching and assessment of professional skills that are vital for future success of our young engineers.[11]

The Consumer Reports Project (CRP) requires student teams to choose a consumer product to test and develop three quantifiable tests to conduct on that product. Students then report on their project through a written lab report, an oral presentation, and a YouTube video. The project satisfies the course learning objectives related to measurements, teamwork, problem solving, communication, and the design process. It also gives students experience with writing and critical thinking, cooperative learning, and classroom management skills, as required by the Rowan Seminar objectives. Finally, the project is directly related to achieving ABET student outcomes a, b, d, g, and k. This paper describes the CRP in detail and reports on student perceptions and learning outcomes related to the project. Overall, the project is highly regarded by students and can be easily implemented elsewhere following the guidelines provided here.

Project Description

The CRP requires student teams to effectively test three different brands of a product and ultimately recommend a particular brand based on their experimental results and analysis. In the process, students must identify testable and quantifiable attributes of the product, repeat controlled measurements, and build confidence in their outcomes. At the end, the teams must weigh results to recommend a superior brand. While the project is designed to be student-driven, there are several milestones to guide their progress. These milestones are elaborated below using an example of ‘superglue’ as a product of choice by a typical student team (See Fig. 1). The instructor serves an important role in guiding the student teams through each milestone. The details of the instructor’s role are provided following the milestones list. Furthermore, a variety of assessment tools can be incorporated at each milestone focusing on both technical and professional skills. The key assessment tools are presented last.

Figure 1. For an example product such as 'superglue' (cyanoacrylate glue), a student team must identify three brands with nominally similar formulation and active ingredient for testing.

Typical Project Milestones

1. **Product Selection.** A team decides to look at superglue as a consumer product. Student teams must identify three brands of superglue with the same active ingredient (such as, cyanoacrylate-based glues). Figure 1 provides an example of three American brands the student could select.
2. **Product Parameter Selection.** Next the team must brainstorm parameters for comparison between the three brands. These can range from brand shelf-life to glue-viscosity upon discharge. However, it is important for the teams to narrow parameters that are rigorously testable with simple setups and rudimentary instruments. For instance, the team may elect to test for bonding strength, thermal stability, and bonding surface quality as important parameters for comparison. On the other hand, shelf-life can prove challenging to test within the project timeframe.
3. **Design of Experiments.** The students must design experiments to repeatedly test the parameters they identified in the previous step. For instance, a team may decide to test bond strength by attaching two acrylic sheets together and measuring the pulling force required (using a fish-scale) to break the sheets apart after a specified curing time. Thermal stability of the glues can be tested by bonding two pennies together and observing the bond on a hot plate at progressively elevated temperatures; recording the maximum temperature before the bond breaks. A variety of experiments need to be vetted for equipment, cost, and effort.
4. **Repeat Measurements.** The students must repeat experiments to establish uncertainties in their measurement. This will allow them to present their results with standard errors and analytical rigor.
5. **Result Analysis and Evaluation.** The students chart their results and develop evaluation criteria to recommend a particular brand based on weights placed on their parameter tests. For instance, the team may decide to give more weight to bond strength than cure time when developing a recommendation for super glues.

Instructor as a Consultant

Considering there are several key decisions that determine a successful project outcome. The instructor is actively and continuously engaged at every milestone, assuming the role of an engineering consultant. For instance, the instructor must encourage the teams to brain storm products at the initial stages and guide them to select a product that possesses several testable and quantifiable comparison parameters. Secondly, the instructors also assists the students to identify appropriate parameters for testing. For instance, weight of an object may be a parameter that is important for the end user but it is not a parameter that requires an experimental setup, in fact, such a parameter is part of the product specification sheet that is to easy compare without physical tests. Product cost, is another such factor. Most importantly, the instructor is deeply engaged with the teams at the 'design of experiments' stage to develop a repeatable and a rigorous testing methodology for effective comparison of brands. The guidance may range from suggesting possible measurement instruments to aiding in the design of the experimental apparatus. The overall goal of the instructor is to ensure the student teams produce statistically satisfactory results for each parameter selected. These discussions also provide an opportune time to discuss the role of an engineer to produce meaningful results by identifying potential sources of errors in testing.

Student Assessment

While several assessment opportunities exist, there were three important aspects of team tasks that were identified as critical for success: product choice, documentation, and effective communication. To address these, three assessment tools were developed.

1. **CRP Proposal.** The student teams propose their product in the form of a short memo report describing their product selection, parameter selection and the initial design of experiments (testing methodology). The proposal provides an opportunity for instructor feedback on the team-specific project plan. Often resubmissions are requested for clarity or alternative experimental plan. The instructor must approve the proposal before purchases can be made.
2. **Project Workspace.** The students maintained a PBWorks.com[12] workspace to document their progress, tabulate raw data, and manage their team efforts. PBWorks.com is web-based management tool designed as wiki-styled pages for collaborative projects. The workspaces were evaluated for their management and documentation skills. Alternatively, an instructor may ask the teams to prepare a report using such a workspace.
3. **Methods and Recommendation.** Student teams prepare a presentation describing their tests, results, analysis, and their recommendation. The students must follow presentation guidelines provided by a YouTube video[13] and prepare a convincing argument for their recommendations. The presentations are peer evaluated to reinforce effective communication skills. In addition, students produce a 3-minute YouTube video modeled after the Consumer Reports videos[14] focusing mainly on their rigorous testing methodology.

Project Outcomes

Among the various benefits of implementing a student-driven project like CRP, below are few that highlight overall freshmen engineering learning objectives that CRP addresses. These are in addition to the general focus of introducing freshman students to the engineering profession.

1. **Measurement and Data Analysis.** For CRP, students measure, collect, analyze and interpret data from their tests. Students become inherently familiar with the important role of measurement and data analysis in their tasks. Furthermore, the students have the opportunity to recognize sources of errors in their experiments, which serves as an excellent foundation for their engineering career.
2. **Teamwork.** Students must work within their assigned teams to select a product, determine which tests to conduct, and complete the testing - all within a relatively constrained time frame (typically 6 weeks). Due to the open-ended nature of the project, team dynamics become very important in successfully completing this assignment, as evident from team workspaces.
3. **Communication.** Depending on the instructors' choices, students can have several written and oral components to this project. For example, student might write a wiki webpage, create a video, and present their methodology and results to the class. Teams must prepare and present technical information in graphical forms using plots, charts and tables as instructed using a prepared YouTube video[15]. Such an early emphasis on communication skills is important for a strong professional engineering foundation[11].
4. **Design Process.** While students must determine their own testing procedures, the students become acutely aware of the key design parameters of a product. Especially considering towards the end the teams must weigh the dominant aspect of a product over others. This is evident when students are rationalizing their final brand recommendation based on their quantitative results.
5. **Project Management.** Students must recognize their deliverables and manage their efforts accordingly. It is typical for teams to divide their tasks among team members to achieve their objectives. Project management concepts can be assessed and incorporated into instructions using workspaces as an assessment tool.

Project Impact

To test how the CRP influenced students' approaches to effective experimentation, a pre-CRP test and a post-CRP test was designed. The tests involved preselected product brands and the students were asked questions to assess their ability to think about ways to rigorously test the brands for an ultimate recommendation. The tests were specifically looking at how CRP helped the students become better test-engineers. Figure 2 presents the products that were used to ask targeted questions while Table 1 provides a list of questions the students were asked.

Figure 2. Sample product images displayed for the pre- and post-project tests. (a) An image of glow sticks used for the Pre-Project Test and (b) An image of three brands of disposable razors used for the Post-Project Test.

Table 1. A list of questions asked for the pre- and post-project tests referring to the images provided in Figure 2. [Product] is a placeholder for (a) glow sticks or (b) disposable razors.

Instruction	You are asked to review three [product] brands for an average consumer. Answer the following questions related to your approach.
Question	*Statements*
1	In your review you need to test various properties of the [product] that an end user would consider before deciding to purchase a particular brand. Identify as many relevant properties of a [product] as you can think of.
2	Select a single property and describe a test (or a series of tests) that will be conducted to measure or quantify that property. Identify measurement tools, methods, and their limitations.

3	List ways that you could ensure the quality and reliability of your measurements.
4	Describe how you would visually represent the results of your experiment.
5	List aspects of this overall effort that could be important in generating a rigorous review.

To compare the results for question 1 in Table 1, the number of relevant properties identified by students were counted in the pre- and post-test. The results showed that there was no statistical difference in the number of properties students identified: students identified 4.65 properties in the pre-test (95% Confidence Interval 4.21 – 5.08) and 4.60 properties in the post-test (95% Confidence Interval 4.23 – 4.97). Results from questions 2 through 5 of the pre- and post-test were compared by looking for keywords that were indicative of rigorous testing (accuracy, precision, standard deviation, calibration, repeated testing, etc.). Each individual student's comments were compared in the pre- and post-test and the quality of their response with respect to the aforementioned terms was noted. For questions 3 and 4 there was little impact of completing the project on the quality of students' responses (see Table 2 for data), and in fact, 21% of students provided a lower quality response in the post-test than in the pre-test. This may have been due to students being exposed to several of the key concepts shortly before taking the pre-test. For example, students were introduced to the CRP and to basic engineering statistics and graphing less than a month before the pre-test was administered.

Table 2. Comparison of the quality of student responses to the Pre- and Post-test (N=47).

Question No.	% Improved	% Declined	% Unchanged
3	9	21	70
4	6	15	79
5	34	17	49

However, there were marked differences between the pre- and post-test for the students' responses to question 5, which was a more open-ended, general question regarding their overall testing approach. 34% of students showed improvement in the quality of their answer to question 5, while 17% showed regression and 49% showed no change. Furthermore, four students failed to respond to question 5 for their pre-test but provided a response after completion of CRP. A few representative student comments are provided in Table 3 for each of these trends. The results, suggest students are able to better respond to the rigorous testing question possibly influenced by the tasks involved in the project. For instance, the students were asked to prepare a YouTube video highlighting their experimental approach to develop confidence towards their results. One can assume that such activities, that included preparing final presentations with their brand recommendations, provided a better perspective on a rigorous testing methodology.

Table 3. Example student responses to question 5.

Classification	Pre-Test	Post-Test
Improvement	"I would believe results if the report showed proof of conducting the actual results, such as pictures or data tables of each test, if the report was formatted properly, and if the procedure to test the glow sticks made sense."	"Meticulous when performing the tests, Organization with data and materials, Appropriate graphs and charts are used to convey what is essential, Pros and cons of each razor"
Decline	"I would check to make sure each aspect of the glow stick was tested the appropriate amount of times to ensure precision."	"A rigorous review should include how long the product lasts, which is important information for the consumer."
No Change	"The average results of the tests, consistency of the results from the tests, background info on the glow sticks, info on the companies"	"The precision of the results would be important, the averages are also extremely important for showing which razor is the best. The procedure and materials would be important to show how the results were obtained, and an explanation of why the tests work for judging each razor."

Student Perception Survey

Upon project completion, students were also surveyed on the CRP overall as a term project for a freshman engineering course. Table 4 lists the four rated questions that the students were asked. The table provides averages of ratings ranging from 1 for 'not at all' to 5 for 'very.' A total of 16 responses were received from one of the sections of the course.

Table 4. A summary of quantitative section of student survey (N=16) on the effectiveness of the project. The ratings range from 1 for 'not at all' to 5 for 'very'.

	Questions	Avg. Rating
1	How important were the following technical skills to your success in CRP: Measurement, Data Analysis, and Experimental Design?	4.44
2	How important were the engineering 'soft' skills to your success in CRP: Teamwork, Project Management and Communication (written and oral)?	4.50
3	How comfortable are you at describing to someone what an engineering does with a specific example?	4.19

4	How much did CRP influence your understanding of the engineering profession?	3.63
5	What did you like about the CRP?	(open-ended)
6	How would you change this project?	(open-ended)

As summarized by Table 4, the students clearly recognized the importance of technical skills and 'soft' skills in their success with CRP, rating both these questions with > 4.4. The later results are especially notable considering ABET's emphasis on professional skills for engineering students.[11] Curiously, students were comfortable with their ability to describe what an engineer does as a result of CRP (average rating of 4.2), however felt CRP contributed less to help them understand the engineering profession as a whole (average rating of 3.6). The discrepancy here can be explained by the broader implication of the term 'engineering profession' compared to providing a specific example, say from technical testing standpoint. Overall, the responses are viewed positively considering 'providing an exposure to the profession' was one of the aims of the project. The nominally high scores for the rated questions also support the project outcomes described earlier. These conclusions are also supported by the responses to the two open-ended questions asked at the end in Table 4: "What did you like about the CRP?" and "How would you change this project?"

In summary, an overwhelming number of students (75% of responses) commented on the freedom of selecting their own products and tests as the best thing they enjoyed about CRP. A representative comment from a student was, "I liked that we had the freedom to choose a product and the tests for the product. This showed me that this is what I may be doing in the work field and enhanced my understanding of engineering." 20% of the comments specifically mentioned the chance to gain communication and team management experience was beneficial, while 25% noted the project provided a good perspective on the engineering profession. The responses to the second open-ended question in Table 4 related to suggestions for changing the project in the future, were also very positive. For instance, 50% of the students recommended, "not to alter the project." While, two individual comments proposed increasing the project budget and extending the project time frame - suggestions that were viewed positively towards the success of CRP. Two representative comments were: "I would not change very much because I know that there are times when there is a problem that an engineer is assigned, but there is not enough background information to list a specific set of instruction that he or she must follow. Research is the key to solving problem." and "I would not. I feel the different parts of this project successfully test ones ability to work in a team that must complete multiple jobs in a given time period." The overall conclusions of the student survey strongly support the project outcomes, in addition to giving students an exposure to engineering.

Conclusion

Introductory engineering courses aim to expose freshmen students to the engineering profession and provide basic training in technical skills. However, without a firm theoretical basis and technical context, traditional instruction can seem disengaging to students. Alternatively, hands-on projects that entail aspects of the engineering profession and provide opportunities to teach fundamental engineering skills that are critical for students' success in engineering programs can prove highly effective. Typical basic technical skills include measurements, data analysis, design process, and communication. The CRP described in this paper is an ideal fit for freshman engineering courses. The CRP affords "autonomy, mastery and purpose" to the students that make it a compelling choice from both the student and pedagogical perspective[16]. Students specifically noted the freedom to select their test subject as the most appealing aspect.

Additionally, the CRP is highly flexible—it requires minimal preparation and instrumentation to implement. As a result, one of the authors has already used CRP within a semester-long high-school technical course. This flexibility also makes the CRP a strong candidate for a summer engineering workshop activity to inspire middle-school students to pursue STEM fields. Overall, CRP provides a strong platform for developing highly engaging hands-on projects or activities for students with little or no technical background.

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