Integrating Entrepreneurial Mindset in a Multidisciplinary Course on Engineering Design and Technical Communication

Dr. Kevin D. Dahm, Rowan University

Kevin Dahm is a Professor of Chemical Engineering at Rowan University. He earned his BS from Worcester Polytechnic Institute (92) and his PhD from Massachusetts Institute of Technology (98). He has published two books, "Fundamentals of Chemical Engineering Thermodynamics" and "Interpreting Diffuse Reflectance and Transmittance." He has also published papers on effective use of simulation in engineering, teaching design and engineering economics, and assessment of student learning.

Dr. Scott Streiner, Rowan University

Dr. Scott Streiner is an assistant professor in the Experiential Engineering Education Department (ExEEd) at Rowan University. He received his Ph.D in Industrial Engineering from the University of Pittsburgh, with a focus in engineering education. His research interests include engineering global competency, curricula and assessment; pedagogical innovations through game-based and playful learning; spatial skills development and engineering ethics education. His funded research explores the nature of global competency development by assessing how international experiences improve the global perspectives of engineering students. Dr. Streiner has published papers and given presentations in global engineering education at several national conferences. Scott is an active member in the Center for the Integration of Research, Teaching, and Learning (CIRTL) both locally and nationally, as well as the American Society for Engineering Education (ASEE) and the Institute of Industrial and Systems Engineers (IISE).

Dr. Cheryl A Bodnar, Rowan University

Dr. Bodnar is an Associate Professor in the Experiential Engineering Education Department at Rowan University. Her research interests relate to the incorporation of active learning techniques such as game-based learning in undergraduate classes as well as integration of innovation and entrepreneurship into the engineering curriculum. In particular, she is interested in the impact that these tools can have on student perception of the classroom environment, motivation and learning outcomes. She was selected to participate in the National Academy of Engineering (NAE) Frontiers of Engineering Education Symposium in 2013, awarded the American Society for Engineering Education Educational Research Methods Faculty Apprentice Award in 2014 and the Raymond W. Fahien Award for Outstanding Teaching Effectiveness and Educational Scholarship presented by American Society for Engineering Education (ASEE) Chemical Engineering Division in 2017.

Dr. Kaitlin Mallouk, Rowan University

Kaitlin Mallouk is an Assistant Professor of Experiential Engineering Education at Rowan University. Prior to beginning that role, she spent five years as an Instructor in the Mechanical Engineering and Experiential Engineering Education Departments at Rowan. Kaitlin has a BS in Chemical Engineering from Cornell University and an MS and PhD in Environmental Engineering in Civil Engineering from the University of Illinois.

Mr. Bruce Oestreich, Rowan University
Dr. Ted Howell, Rowan University
Dr. Jennifer Tole, Rowan University

Integrating Entrepreneurial Mindset in a Multidisciplinary Course on Engineering Design and Technical Communication

The engineering curriculum at Rowan University includes a sophomore level two-course sequence (required for engineering students in all disciplines) in which the primary learning outcomes are engineering design and technical communication. These courses are team-taught by faculty from Engineering and from Communications; specifically, Writing Arts in the fall and Public Speaking in the spring. Historically, the fall course has featured three major course deliverables: (1) a "research sequence" consisting of a rhetorical analysis, an annotated bibliography, and a literature review, (2) a humanities assignment in which students explore the impact of technology on societal needs, and (3) laboratory and design reports stemming from hands-on engineering projects completed in lab.

During the summer of 2019, the faculty team re-designed each of these three major course deliverables, with the goal of fostering an Entrepreneurial Mindset in students and leveraging synergies between the Entrepreneurial Mindset and the existing goals of the course (engineering design and technical communication). In particular, the faculty team created a new linkage between the research sequence and the humanities assignment. The new research sequence is built around the U.N.'s Sustainable Development Goals; each student chooses one of the goals to explore through their individual rhetorical analysis, annotated bibliography, and literature review. The humanities assignment is a team project in which students explore solutions to sustainability problems on the campus of Rowan University. Different sections of the course use different engineering projects, but the faculty team has crafted a set of guidelines for the projects to ensure uniformity of experience and expectations across the sections. This paper describes, in detail, the three assignments as re-designed and offered for the first time in the Fall 2019 semester, and shows assessment data collected throughout the Fall 2019 semester.

Introduction

The importance of communication skills in engineering graduates has long been known to engineering faculty and engineering practitioners. For example, a survey of 208 engineering graduates conducted in 1999 [1] revealed that respondents spent, on average, 64% of job time on communication: 32% writing, 10% oral presentations, and 22% other oral discussions. This survey also revealed that respondents who considered themselves good communicators also believed that "their skills differentiate them from the pack," while those respondents who are not comfortable with public speaking (including speaking during meetings) believe "they are considered less competent technically." [1] In 2003, Ford and Riley presented a summary of other studies that "suggest that oral and written communication skills are one of the primary factors required of new graduates ultimately affecting their success in the workplace." [2] However, engineering students often perceive that the writing instruction they experienced in

high school, or in English or Composition courses at the University level, is not applicable to engineering [3]. Authors such as Lengsfeld, et al. [4] and Leydens and Schneider [5] have presented models for "disciplinary writing" in the engineering curriculum: that is, writing instruction that is contextualized in a way that is integrated with engineering instruction and that elucidates the importance of writing in engineering practice.

Since the inception of the College of Engineering at Rowan University, the engineering curriculum has incorporated a "disciplinary" approach to communication through the two-course Sophomore Engineering Clinic (SEC) sequence. The primary learning outcomes for SEC I are engineering design and technical writing. The second course, SEC II, presents a similar integration between engineering design and public speaking. Both courses are team-taught by faculty from the College of Engineering and the College of Communication and Creative Arts, and are required for engineering students in all engineering disciplines. This paper concerns a major re-design of SEC I that was implemented for the first time in the Fall 2019 semester.

Sophomore Engineering Clinic I is organized into sections of ~20 students and has three course meetings per week: two 75-minute periods led by a faculty member from Writing Arts, and one 165-minute lab period led by a faculty member from Engineering. Hands-on engineering design projects are integrated into the lab periods, and several examples of SEC I projects have been published previously [6-11]. In recent years, SEC I has featured three major course deliverables: (1) a "research sequence" consisting of a rhetorical analysis, an annotated bibliography, and a literature review, (2) a humanities assignment in which students explore the impact of technology on societal needs, and (3) laboratory and design reports stemming from the projects. In many cases, there are two grades associated with a design project- one for the report and one for the "technical merit" of the design itself. For example, when a project on wind turbine design [6] was introduced into the course, 20% of the course grade was based upon how much electricity a student team's turbine generated, and another 20% was based upon the final design report associated with the project. (The other 60% was primarily based upon other major writing assignments that were precursors to the research sequence and humanities assignments described in this paper.)

The course structure described above is well aligned with the course objectives of engineering design and technical communication. The goal of the re-design was to maintain these central objectives while also fostering an Entrepreneurial Mindset in the engineering students. Rowan University is a partner institution of KEEN, the Kern Entrepreneurial Engineering Network [12]. The Entrepreneurial Mindset as defined by KEEN is embodied by the "three C's": curiosity, connections, and creating value. One of the predominant features of KEEN network activity is the collection and dissemination of exemplar curriculum that promotes the three C's. A searchable collection is available at [13]. Numerous examples of learning activities intended to promote Entrepreneurial Mindset in engineering students have also been published in ASEE in recent years, such as:

- Authors at Lawrence Technological University re-designed their Mechanical Engineering capstone design sequence to instill Entrepreneurial Mindset in students while still achieving desired technical objectives [14].

- Authors at Ohio Northern University integrated the "three C's" into an electric circuits course, in particular using analogy as a strategy for supporting connections [15].
- Authors at Ohio State University examined laboratory activities that were already established in their first-year engineering curriculum, with the goal of identifying already existing elements of the Entrepreneurial Mindset and recognizing opportunities for further enhancing the Entrepreneurial Mindset [16].

This paper discusses the three major course deliverables in SEC I, explains the modifications that were piloted in the Fall 2019 offering of SEC I, and presents preliminary assessment data from Fall 2019.

SEC I: The Three Major Deliverables

During the summer of 2019, the SEC I faculty team re-designed each of the three major course deliverables. The revised assignments were intended to foster an Entrepreneurial Mindset in students and leverage synergies between the Entrepreneurial Mindset and the primary goals of the course, which are engineering design and technical communication. Table 1 shows the timing of deadlines associated with each of these deliverables, and the following sections describe each in detail.

Table 1: Timing of Major Deadlines for Fall 2019 Offering of SEC I

Week	Milestones Related to Course Deliverables
1	Introduction of RESEARCH SEQEUENCE, HUMANTIES ASSIGNMENT and ENGINEERING DESIGN PROJECTS
2	
3	
4	RHETORICAL ANALYSIS completed
5	
6	
7	ANNOTATED BIBLIOGRAPHY- first draft due
8	Launch of HUMANITIES ASSIGNMENT (team formation, topic assignment etc.)
9	ANNOTATED BIBLIOGRAPHY completed
10	
11	ENGINEERING DESIGN REPORT- first draft due
12	LITERATURE REVIEW completed
13	
14	HUMANITIES ASSIGNMENT completed
15	ENGINEERING DESIGN FINAL REPORT completed

Research Sequence

The research sequence is a series of three themed assignments, completed individually: the rhetorical analysis, the annotated bibliography and the literature review. Objectives of the sequence include:

- Analyze and understand how information is presented to different audiences
- Use a range of research tools, including engineering databases
- Paraphrase, summarize, and synthesize information
- Write a critical annotated bibliography
- Write a literature review
- Cite information using the specified format

The objectives listed above describe the research sequence as it existed both before and after the re-design. However, in the Fall 2019 offering of SEC I, the following learning outcomes were introduced into the handout that was used to describe the Research Sequence to the students at the beginning of the semester:

- *Explore* and *make connections* between scholarly and non-scholarly sources related to engineering problems with global implications
- *Demonstrate curiosity about* a research topic connected to sustainable development, in part by *exploring* a range of sources of information and synthesizing them in pursuit of wider knowledge
- *Integrate* information from many sources to gain insight into research trends and applications
- *Explore* competing approaches to research and development problems by pursuing emerging knowledge, questioning accepted solutions and anticipating new directions for research

Prior to the Fall 2019 revision, students were encouraged to select a topic from a list of ~10 topics chosen by Engineering and Writing Arts instructors each semester. Other instructors allowed students to choose their own topic subject to instructor approval. The crucial requirement was that the topic be rooted in technology, but also be topical and relevant to societal considerations, such that it was well represented in both peer-reviewed technical literature and the popular press. Examples of topics used prior to 2019 include self-driving vehicles, smart grid, asteroid mining and wearable sensors.

Once students had chosen a topic, for the rhetorical analysis, they located and selected two articles related to the topic, one news or trade article and one peer-reviewed article. The rhetorical analysis required students to do the following for each of the articles:

- Give a full formal citation
- Describe the publication's genre, then describe where and how they located and chose the piece
- Describe, in detail, the purpose of the article (argue, explain, provoke, report, critique, etc.)
- Identify and define the targeted audience and their level of expected background knowledge.
- Analyze how is the article organized and explain why it is organized the way it is.
- Describe how the article use sources and what it uses those sources for.
- Explain what role, if any, visuals play in the article.

Next the students completed an annotated bibliography, which is structured in a way similar to that presented by Purdue [17]. Students were required to identify at least 10 high quality scholarly sources related to their topic and write an annotation (usually about one paragraph) for each. The annotations included a summary of the paper's findings, including an evaluation of the credibility and strength of the conclusions and a discussion of how information obtained from the source related to the topic.

To conclude the Research Sequence, students wrote a literature review. The crucial difference between the annotated bibliography and the literature review was synthesis. Each of the annotations in the annotated bibliography could be read and understood in isolation. The purpose of the literature review was to discuss the current state of knowledge regarding the topic, and how the individual sources related to each other and each informed the current state of knowledge. Students were expected to make substantial use of at least 8-10 sources in the literature review. Most of these sources were the same as those cited in the annotated bibliography, though it wasn't unusual for a student to discard one or two sources and find new ones between the annotated bibliography and the literature review.

Structurally, the revised Research Sequence is identical to the old in terms of the goals of the three assignments. The primary modification is the selection of the topic and a new linkage to the Humanities assignment. The new Research Sequence focuses on the U.N. Sustainable Development Goals (SDGs), which are presented in their entirety at [18]. Of the 17 U.N. Sustainable Development Goals, the faculty identified eight that were particularly well suited for the Research Sequence and the context of Entrepreneurial Mindset:

#3 Good Health and Well Being
#6 Clean Water and Sanitation
#7 Affordable and Clean Energy
#9 Industry, Innovation, and Infrastructure
#11 Sustainable Cities and Communities
#12 Responsible Consumption and Production
#14 Life Below Water
#15 Life on Land

The new humanities assignment, described in detail in the next section, involves applying similar principles of sustainability to the campus of Rowan University. This new linkage between the two assignments provides a strong context and motivation to the Research Sequence. In the 2018 offering of the course, the description of the literature review (as presented to the students in handouts) stated "The literature review 'sets up' a space for the writer to contribute his/her own research." In the 2019 offering of the course, this was still true but had a new immediacy: students really did have the opportunity to apply the information gained through completing the research sequence to their own project on sustainability. To facilitate this linkage, the rhetorical analysis and annotated bibliography were due earlier in the semester than they were in 2018, and the sequence was somewhat reduced in scope to encourage more meaningful engagement with the research:

- The annotated bibliography required 10 properly cited sources, but annotations only needed to be written for six of them
- The literature review required students to incorporate 6 sources, rather than 8-10, the required word count was reduced, and the use of a visual aid was added

The 2019 literature review was also given a new customer framework. As described to the students in handouts:

> For this assignment, envision yourself as a new intern at a firm competing for grant money that will fund a project connected to your research topic. Many big funders—such as the Global Innovation Fund, the MacArthur Foundation, and the Ford Foundation—connect their funding explicitly to the SDGs. (The UN itself also funds projects related to the SDGs and has released a funding strategy.) You can read more about funding for each SDG by visiting this website: Who's Funding the SDGs.
>
> You have been tasked with providing a literature review that will accompany a grant application—one that will convince its readers that your firm has a strong grasp on the current state of research in your area and a plan for where this research is headed in the near future. Your readers need the literature review to be sufficiently brief, easy to read, and accompanied by at least one visual aid (such as a table, figure, or infographic) that helps them better grasp the topic.

Thus, the new research sequence was designed to achieve all the same instructional objectives as the previous sequence, while using a new sustainability-focused and customer-oriented context intended to foster the entrepreneurial mindset. The new sequence also links to the Humanities Assignment as detailed in the next section.

Humanities Assignment

A Humanities Assignment designed by Writing Arts faculty was added to the course in 2015. The assignment invited students to see themselves as part of a larger community and as professionals who are ethically responsible for identifying, researching, and deeply understanding the needs of stakeholders affected by engineering design. The assignment included the following required elements:

- group research and writing
- a visual or multimodal design, such as a website, poster, or billboard
- a final deliverable resembling a professional document, such as a white paper or project proposal

Before the Humanities Assignment was redesigned and standardized in 2019, Writing Arts instructors would choose topics for the assignment that encouraged students to generate designs and documents responsive to local community stakeholders. Examples of past topics included a stalled offshore wind energy pilot project, a beach town's dune replenishment debate, and design improvements to an urban park.

The new Humanities Assignment is called "Engineering in Society: Sustainability on Rowan's Campus." It leverages a report that was written in 2019 by the Rowan Environmental Action League, and submitted to the University President. This report was a petition for more sustainable practices on the university's campuses, with specific areas of concern including:

- carbon neutrality
- recycling
- food services materials
- sustainable transportation
- building updates and renovations

In the Fall 2019 offering of the course, students were organized in teams of 4-5, and each team was assigned a specific sustainability issue drawn directly from the petition. Teams were tasked with conducting primary and secondary research on the issue and formulating recommendations. In the handout that described the assignment to the students, primary and secondary research were defined as follows:

> Your team will demonstrate curiosity by conducting **primary research.** This will involve going onsite to the area(s) on campus affected by your specific sustainability challenge and gathering first-hand knowledge of the issue. You will also make connections between your first-hand experience and what already exists by conducting **secondary research** (a combination of both scholarly and popular sources) about best practices in your focus area to help you develop solutions to your sustainability issue here at Rowan University.

Because students had been introduced to the Humanities Assignment prior to staring the Research Sequence, instructors encouraged students to choose topics for research that might be compatible with their work in the Humanities Assignment.

The format of the final deliverable for the Humanities Assignment was a proposal communicating the team's recommendations and written with the university President and administrative personnel as the intended audience. At the time of writing, it is too early to say whether any of the student recommendations that came out of this project will be acted upon by the University.

A rubric (included in Appendix A) was crafted that evaluates four aspects of the final deliverable, weighted as follows:

- Purpose and Strength of Argument (30 points)
- Integration of Research (20 points)
- Audience Awareness (30 points)
- Format, Organization and Style (20 points)

The authors propose that if a student team produced a strong final report for this assignment, this constitutes evidence of effectiveness of their entrepreneurial mindset. More specifically:

- The “Audience Awareness” rubric emphasizes an understanding of, and a thorough and fair presentation of, relevant stakeholder perspectives. Learning about the perspectives of others is an expression of Curiosity.
- The “Integration of Research” rubric emphasizes synthesis of knowledge learned from various sources through primary and secondary research, and making Connections of this knowledge to the project at hand.
- The “Purpose and Strength of Argument” rubric emphasizes the persuasiveness of the report in demonstrating that the proposed recommendations will Create Value for stakeholders.

Engineering Design Projects

Rowan University offered 16 sections of SEC I in the Fall 2019 semester, with enrollments ranging from 16 to 21 students in a section. Ten years ago, the number of sections offered per year was only five, and all students across all sections completed the same design projects in a given year. When student growth led to a significant expansion in the number of sections (and number of different engineering instructors), it became impractical for all sections to offer the same hands-on projects as each other at the same time.

Consequently, when the engineering faculty completed the course revisions during summer 2019, they did not create a specific design project, as was done with the humanities assignment and research sequence. Instead, the faculty crafted a set of guidelines that all current and future SEC I design projects are expected to follow. The guidelines state “A good SEC I project is one that presents a substantial design challenge that is grounded in fulfilling a need. Features of the project should include: a Product, Metrics and a Customer.” In this context:

- “Product” simply means that students design a recognizable product that fills a specific need. This is most commonly, but not necessarily, achieved through the construction of a physical prototype that can be tested.
- “Metrics” are important because students should be brainstorming multiple possible solution strategies and then using a design process to identify which of these is the best. The problem doesn’t have a clear “best” solution that is easy to find, but it does have one or more recognizable metrics that can be used to demonstrate that one proposed solution is better than another.
- The “Customer” is defined broadly. It can be a specific person or company, but can also be a specific recognizable group of potential customers. The customer is intended to provide context to the product, making the project a practical and significant exercise rather than a purely academic one.

As an example, the wind turbine project [6] has been used by many sections of the course since 2008. Historically, it had been posed as a competition, as follows: The goal of the project is to design and fabricate a wind turbine that will (within given constraints) generate the maximum possible power. The team that produces the most power will earn a 100% on the “technical merit” portion of the course grade. In the re-designed course, students completed substantially

the same project tasks, and the "technical merit" is graded by the same logic. However, the project was framed as designing a product in response to the societal need for renewable energy.

The faculty team also crafted a generalized rubric (shown in Appendix A) that is intended to be applied to any SEC I design report. The aspects of the report that are evaluated using the rubric are listed below.

- Use of Literature (Curiosity)
- Experiment and Theory (Curiosity)
- Understanding of Physical Principles (Connections)
- Design Process and Physical Principles (Connections)
- Metrics for Quality of Design (Creating Value)
- Optimization of Metrics (Creating Value)

- Report Organization
- Clarity and Presentation
- Abstract or Exec Summary
- Figures, Tables, Graphics

While all 10 of these are clearly relevant to the instructional objectives of the course (technical writing and engineering design), the faculty team also considers the first six to be related to the "three C's", as indicated above. The last four relate strictly to the quality of the writing.

This rubric was written to be applicable to design reports in general, and it is recognized that in some cases, one or more portions of the rubric might not apply to a specific project. Consequently, specific point weightings were not incorporated into the rubric, as was done in the Literature Review and Humanities Assignment rubrics. Instead, the rubric describes three levels of performance for each of the 10 aspects of the report (5=outstanding, 3=minimally acceptable, 1=failing) and the instructors rated each report on a scale from 1-5 (or "not applicable") with respect to each element, but the weighting of these individual ratings in the report grade was left up to the instructor.

Assessment

The final report for the Humanities Assignment was effectively the culmination of the integrated Research Sequence/Humanities Assignment experience, and was graded by Writing Arts faculty. Table 2 summarizes the data for 72 teams across 16 sections. Overall, student performance was very good, with student teams earning a mean score of ~90% of the possible points in all four categories. Students were particularly strong in the areas related to purpose and strength of argument (creating value) and audience awareness (curiosity), with the highest scores corresponding to the student's ability to anticipate how their audience would receive their design

suggestions. This suggests that the assignment's redesign, which enabled students to write about a topic directly connected to their campus and to their peers, enabled them to write with a clear, well-defined audience in mind. Similarly, student teams performed well when creating value through targeted arguments about sustainability issues on their campus. Anecdotal feedback suggests that the sustainability focus of these assignments was popular with students.

Table 2: Summary of Fall 2019 performance on Humanities Assignment Final Report

	EM Component	Max Points	Mean Rating	Mean Rating (%)	Std Dev (%)
Purpose and Strength of Argument	Creating Value	30	27.6	92.0	7.2
Integration of Research	Connections	20	17.7	88.5	8.6
Audience Awareness	Curiosity	30	27.9	93.0	4.7
Format, Organization, Style	n/a	20	18.4	92.0	8.4

The design report was effectively the culminating experience in the engineering design project, and was graded by Engineering faculty. Table 3 summarizes the data for 67 teams. Note that the method of assigning teams was left at the discretion of the individual instructor and the teams for the Humanities and Design projects were not necessarily the same. Also, portions of the engineering project rubric were rated as "not applicable" to some projects, so the number of data points differs for different items and is shown in the table. Recall that in this rubric 5=excellent, 3=minimally acceptable and 1=failing with respect to a given indicator. Consequently, a mean rating of approximately 4 with a standard deviation of approximately 1 represents a performance that is generally good, though not as uniformly strong as was seen in the Humanities Assignment. The weakest point (mean=3.72, standard dev=1.04) was the Use of Literature, which is mapped to Curiosity. However, another rubric item mapped to curiosity (Experiment and Theory) had a mean rating of 4.06 ± 0.84. This suggests that students may exemplify curiosity, but struggle with integrating literature into engineering reports. The engineering faculty on average rated the students particularly highly in the course outcomes that were specifically related to writing. This suggests that the re-designed course, which emphasized entrepreneurial mindset, is indeed still effective in meeting the long-standing course objective of developing technical writing skills.

The strongest point (mean=4.14, standard dev=1.04) was the Design Process and Physical Principles, which is mapped to Connections. The other rubric item mapped to Connections (Understanding of Physical Principles) also had a high rating, which suggests that students were able to connect the design principles to their design implementation and performance, as well as being able to apply the theoretical framework during the implementation. The two rubric items that correspond to Creating Value (Metrics for Quality of Design and Optimization of Metrics) were not quite as high, which could be due to a lack of opportunities to optimize designs in previous courses. Students made customer connections in First-Year Engineering Clinic 2 (which

they took the semester before SEC 1) but the projects in that course didn't require them to iterate and use metrics to develop the optimum design that leads to value creation.

Table 3: Summary of Fall 2019 performance on Design Reports stemming from engineering projects (5=excellent, 3=minimally acceptable, 1=failing)

	EM Component	Number of Teams	Mean Rating	Std. Dev.
Use of Literature	Curiosity	62	3.72	1.04
Experiment and Theory	Curiosity	58	4.06	0.84
Understanding of Physical Principles	Connections	62	4.06	0.87
Design Process and Physical Principles	Connections	58	4.14	0.86
Metrics for Quality of Design	Creating Value	62	4.00	0.92
Optimization of Metrics	Creating Value	67	3.99	0.98
Report Organization	n/a	67	4.11	0.86
Clarity and Presentation	n/a	67	4.24	0.77
Abstract or Exec Summary	n/a	67	4.32	0.74
Figures, Tables, Graphics	n/a	67	3.97	0.81

Summary

Sophomore Engineering Clinic I is an interdisciplinary course that has historically been used to promote two primary instructional objectives: technical writing and engineering design. In the Fall 2019 semester, the faculty team piloted a newly re-designed SEC I that was intended to achieve these objectives while also fostering the entrepreneurial mindset (EM) in engineering students. Assessment of the student reports from the Humanities Assignment as well as Design Reports stemming from engineering projects show good performance both on the indicators that were considered technical outcomes related to EM and on the indicators that are related to quality of writing. The authors believe that this is an indication that the new structure was indeed effective at achieving the primary goals of SEC I while also giving all engineering students an immersion in projects that involve applying the entrepreneurial mindset. However, more compelling assessments will be collected in upcoming semesters, when the Fall 2019 cohort of sophomores are tracked through their junior and senior years. The faculty team will be investigating whether there are significant differences between this cohort and prior cohorts in terms of their performance in clinic courses in general and their expression of EM specifically.

Literature Cited

[1] Sageev, P., and Romanski, C., "A Message from Recent Engineering Graduates in the Workplace: Results of a Survey on Technical Communication Skills." *Journal of Engineering Education*, 90, 4 (2001).

[2] J. Ford and L. Riley, "Integrating Communication and Engineering Education: A Look at Curricula, Courses, and Support Systems," *Journal of Engineering Education*, 92, 4 (2003).

[3] Bergmann, L. S., & Zepernick, J. Disciplinarity and transfer: Students' perceptions of learning to write. WPA: Writing Program Administration, 31, 1-2, (2007).

[4] C. Lengsfeld, G. Edelstein, J. Black, N. Hightower, M. Root, K. Stevens and M. Whitt, "Engineering Concepts and Communication: A Two-Quarter Course Sequence" *Journal of Engineering Education* 93, 1 (2004).

[5] J. Leydens and J. Schneider, "Innovations in Composition Programs that Educate Engineers: Drivers, Opportunities and Challenges," *Journal of Engineering Education*, 98, 3 (2009).

[6] S. Bakrania, W. Riddell, K. Dahm and L. Weiss, "Wind Turbines for Teaching Parametric Design," Paper presented at 2009 ASEE Annual Conference and Exposition, Austin, TX, June 2009.

[7] P. von Lockette, E. Constans, J. Courtney, K. Dahm, W. Riddell, R. Harvey, "CONVERGING-DIVERGING DESIGN STRATEGIES IN A SOPHOMORE LEVEL DESIGN SEQUENCE: REVIEW OF AN ELECTROMECHANICAL PROJECT," Paper presented at 2007 ASEE Annual Conference and Exposition, Honolulu, HI, June 2007.

[8] W. Riddell, P. Jansson, K. Dahm, H. Benavidez, J. Haynes, D. Schowalter, "CONSERVATION OF ENERGY FOR CAMPUS BUILDINGS: DESIGN, COMMUNICATION AND ENVIRONMENTALISM THROUGH PROJECT BASED LEARNING," Paper presented at 2006 ASEE Annual Conference and Exposition, Chicago, IL, June 2006.

[9] E. Constans, K. D. Dahm, K. Hollar, J. Kadlowec, A. J. Marchese, B. Sukumaran, C. Sun, and P. von Lockette, "The Sophomore Engineering Clinic I: Integrating Statics, Solid Mechanics and Product Development in a Sophomore Level Design Course," Paper presented at 2001 ASEE Annual Conference and Exposition, Albuquerque, NM, June 2001.

[10] K. D. Dahm and J. A. Newell, "Baseball Stadium Design: Teaching Engineering Economics and Technical Communication in a Multi-Disciplinary Setting," Journal of SMET Education: Innovations and Research, 2, 1 (2001).

[11] W. Riddell, S. Bakrania, K. Bhatia, K. Dahm, R. Harvey and L. Weiss, "Putting the Horse Before the Cart: Fitting a new project into established design and writing pedagogy," Paper presented at 2009 ASEE Middle Atlantic Section Spring Conference, Baltimore, MD, April 2009.

[12] https://engineeringunleashed.com/about.aspx , accessed 11/19/2019

[13] https://engineeringunleashed.com/cards.aspx, accessed 11/19/2019

[14] Mynderse, J. A., & Liu, L., & Gerhart, A. L., & Fletcher, R. W., & Vejdani, H., & Jing, W., & Yee, K. E. "Development of an Entrepreneurial Mind-set within a Three-Semester Mechanical Engineering Capstone Design Sequence Based on the SAE Collegiate Design Series," Paper

presented at 2019 ASEE Annual Conference & Exposition , Tampa, Florida, June 2019. Available at https://peer.asee.org/32651

[15] LeBlanc, H. J., & Al-Olimat, K. S., & Khan, M. A., & Hassan, F., "How Analogies Fit in a Framework for Supporting the Entrepreneurial Mind-set in an Electric Circuits Course," Paper presented at 2019 ASEE Annual Conference & Exposition, Tampa, Florida, June 2019. Available at https://peer.asee.org/32890

[16] Sattele, N. R., & Kecskemety, K. M., & Parris, K. A. A., "Analysis of the Entrepreneurial Mind-set Elements in Established First-year Engineering Labs: Analysis Process and Lessons Learned and Changes for the Future," Paper presented at 2019 ASEE Annual Conference & Exposition , Tampa, Florida, June 2019. Available at https://peer.asee.org/32089

[17] https://owl.purdue.edu/owl/general_writing/common_writing_assignments/annotated_bibliographies/annotated_bibliography_samples.html, accessed 1/9/2020

[18] https://sustainabledevelopment.un.org/, accessed 1/15/2020

Appendix A: Project Rubrics

The complete rubric for the Humanities Assignment final report is shown here:

	Exceptional	**Strong**	**Adequate**	**Inadequate**
Purpose and Strength of Argument ***(mapped to Creating Value)***	(27-30) Excellent awareness of how your approach creates value for your various audiences; Purpose of document is apparent from the outset; extremely clear what action audience is being persuaded to take and how/why this action will create value.	(24-26) Very good awareness of how your approach creates value for your various audiences; Purpose of document is mostly apparent from the outset; clear what action audience is being persuaded to take and how/why this action will create value.	(21-23) Some awareness of how your approach creates value for your various audiences; Purpose of document is not completely apparent from the outset; somewhat clear what action audience is being persuaded to take and how/why this action will create value.	(20 and below) Little to no awareness of how your approach creates value for your various audiences; Purpose of document is not apparent from the outset; unclear what action audience is being persuaded to take and how/why this action will create value.
Integration of Research	(18-20) *Logos:* Masterfully makes connections	(16-17) *Logos:* Mostly makes connections	(14-15) *Logos:* Unevenly makes connections	(13 and below) *Logos:* Does not make connections across the

(mapped to Connections)	across the various pieces of research by effectively using high-quality, persuasive evidence to support an argument; solidifies those connections by using evidence that is well-chosen for this particular audience. *Pathos:* masterfully maintains an awareness of how this solution creates value by appealing to emotions of the audience in ways that are effective and also well-balanced with appeals to reason and the credibility of the authors. *Ethos:* masterfully establishes credibility with the audience by presenting and connecting research that is trustworthy and relevant while also effectively engaging opposing viewpoints so as to strengthen the authors' own argument	across the various pieces of research by effectively using high-quality, persuasive evidence to support an argument; solidifies those connections by using evidence that is generally well-chosen for this particular audience. *Pathos:* Mostly maintains an awareness of how this solution creates value by appealing to emotions of the audience in ways that are effective and also somewhat balanced with appeals to reason and the credibility of the authors. *Ethos:* Mostly establishes credibility with the audience by presenting and connecting research that is trustworthy and relevant while also attempting to engage opposing viewpoints so as to strengthen the authors' own argument	across the various pieces of research by using somewhat persuasive evidence to support an argument; solidifies those connections by using evidence that is sometimes well-chosen for this particular audience. *Pathos:* Unevenly maintains an awareness of how this solution creates value by appealing to emotions of the audience in ways that are effective and also somewhat balanced with appeals to reason and the credibility of the authors. *Ethos:* Unevenly establishes credibility with the audience by presenting and connecting research that is trustworthy and relevant; Uneven or unsuccessful attempt to engage opposing viewpoints so as to strengthen the authors' own argument	various pieces of research by using persuasive evidence to support an argument; does not solidify those connections by using evidence that is well-chosen for this particular audience. *Pathos:* Does not maintain an awareness of how this solution creates value by appealing to emotions of the audience in ways that are effective and also somewhat balanced with appeals to reason and the credibility of the authors. *Ethos:* Does not establish credibility with the audience by presenting and connecting research that is trustworthy and relevant; does not attempt to engage opposing viewpoints so as to strengthen the authors' own argument

Audience Awareness **(mapped to *Curiosity*)**	(28-30) Masterfully displays an exploration of curiosity by fully and fairly representing and responding to various stakeholder perspectives through an insightful analysis of audience needs and desires	(25-27) Mostly displays an exploration of curiosity by fully and fairly representing and responding to various stakeholder perspectives through a solid analysis of audience needs and desires	(24-21) Exploration of curiosity and response to stakeholder perspectives is somewhat lacking; analysis of audience needs and desires needs development	(20 and under) Little to no exploration of curiosity and response to stakeholder perspectives; analysis of audience needs and desires is absent or lacking
Format, Organization, and Style	(18-20) Ideas are organized logically; each paragraph has a main idea and there is a logical progression in the ordering of information Tone and style are appropriate for this audience and purpose Excellent control of grammar and mechanics; writing is free from errors	(16-17) Ideas are organized somewhat logically; most paragraphs have a main idea and there is some logical progression in the ordering of information Tone and style are mostly appropriate for this audience and purpose Good control of grammar and mechanics; few errors in writing	(14-15) Ideas are not always organized logically; main idea is sometimes missing and there is not always a logical progression in the ordering of information Tone and style are unevenly appropriate for this audience and purpose Adequate control of grammar and mechanics; Several sentence-level errors	(13 and below) Little or no logical organization of ideas; most paragraphs lacking main idea and there is little logical ordering of information. Tone and style are not appropriate for this audience and purpose Inadequate control of grammar and mechanics; Distracting sentence-level errors that affect meaning

The generalized rubric for SEC I engineering design project reports is shown here:

	5 (outstanding)	**3 (minimally acceptable)**	**1 (failing)**
Use of Literature ***(mapped to curiosity)***	The report demonstrates knowledge of authoritative sources that are relevant to the needs of the customer, goes beyond materials supplied by the instructor, and uses consistently proper citations. The report clearly articulates what was learned from these sources and relates it to the project in a way that is compelling and appropriate for the audience.	The report demonstrates some knowledge of relevant literature and has appropriate citations, but with recognizable shortcomings (e.g., only uses sources recommended by instructor, uses sources of dubious merit). The report attempts to connect information learned from sources to the project, but the connection may be unclear or tenuous, or discussed in a way that is inappropriate for the audience.	The report demonstrates no evidence of use of literature, or there is a fundamental problem with the literature review (e.g., badly misunderstands or misrepresents the source material)
Experiment and Theory ***(mapped to curiosity)***	The report correctly applies theory accurately to make predictions, compares theoretical predictions to obtained results, and gives a critical and insightful analysis that includes plausible explanations for discrepancies.	The report applies theory in a broadly reasonable way but may have minor errors in execution. The report compares predictions to theory in a way that has some merit, but with recognizable shortcomings (e.g., makes only qualitative observations when quantitative ones are possible, overlooks the most likely reasons for discrepancy)	The report fails to make any meaningful comparison between experiment and theory.
Understanding of Physical Principles ***(mapped to connections)***	The report demonstrates a thorough and insightful understanding of physical principles that are relevant to the project, and discusses them at a level of detail that is appropriate for the audience.	The report demonstrates an accurate but somewhat cursory understanding of physical principles that are relevant to the project. The discussion is correct but the level of detail may not be well suited to the audience.	The report completely overlooks or fundamentally misunderstands physical principles that are relevant to the project.
Design Process and Physical Principles ***(mapped to connections)***	The report shows evidence of developing and carrying out a design process that is efficient and is meaningfully informed by	The report describes a design process that leads to some meaningful progress but has recognizable shortcomings (e.g.,	The report fails to give a clear description of the design process, or the design process was haphazard and failed to

	relevant physical principles.	inefficient, overreliance on empiricism, not well informed by relevant physical principles)	produce meaningful progress
Metrics for Quality of Design ***(mapped to creating value)***	The report demonstrates that the design process was meaningfully and fully informed by relevant metrics. The team had clear goals and implemented a strategy that would produce a design solution that was optimized, according to the identified metrics.	The report shows evidence of a design process that led to meaningful progress, but had recognizable shortcomings (e.g., spent excessive time on secondary issues and never got around to addressing some important ones, doesn't well account for some of the metrics, doesn't fully utilize available resources)	The report doesn't give a clear description of a design process, or the design process is not at all connected to the customer needs or the identified metrics for the project.
Optimization of Metrics ***(mapped to creating value)***	The report demonstrates that the design process was meaningfully and fully informed by relevant metrics. The team had clear goals and implemented a strategy that would produce a design solution that was optimized, according to the identified metrics.	The report shows evidence of a design process that led to meaningful progress, but had recognizable shortcomings (e.g., spent excessive time on secondary issues and never got around to addressing some important ones, doesn't well account for some of the metrics, doesn't fully utilize available resources)	The report doesn't give a clear description of a design process, or the design process is not at all connected to the customer needs or the identified metrics for the project.
Report Organization	Report is extremely well organized. Every section has a descriptive heading and a clear and explicitly stated purpose. Cross-referencing to figures and appendices is used effectively wherever it is needed.	Report is divided into reasonable sections but some material may be repeated or oddly placed. Cross-referencing to figures/appendicies is generally used but sometimes missing or haphazard.	The report shows little or no organization. Reader has to expend unreasonable effort to figure out what's going on.
Clarity of Presentation	Report is written with great clarity and is easy to read and understand. Report is concise and free of grammatical and spelling errors.	Report conveys information adequately, but is at times unclear, wordy and/or unfocused. The number of instances of grammar and/or spelling errors is noticeable but not outrageous.	The report fails to convey information clearly. It has so many problems with ambiguous phrasings, lack of focus, grammar, and/or spelling, that the reader can't follow it.

Abstract or Executive Summary	Summary stands on its own and provides a compelling overview that includes statement of objectives, provides quantitative results, and summarizes conclusions and recommendations	All needed illustrations, figures and tables are present and contain useful information, but sometimes lack clarity and/or aren't well described in the captions.	Illustrations, figures and tables are missing or incomprehensible. Captions are missing or haphazard.
Figures, Tables and/or Graphics	The student or team presents an excellent design report that is technically accurate and appropriate to the needs of the customer, including proper organization and formatting, concrete descriptive language, and detail appropriate to the audience.	The report is broadly appropriate to the needs of the customer and presents a recognizable solution to the problem, but is inconsistent, with some shortcomings such as minor technical errors, awkward organization, lapses in clarity, too much or too little detail for the audience.	The report fundamentally fails to address the needs of the customer (e.g., substantial technical errors, design does not meet customer needs, so unclear that the reader cannot determine what solution the writer is proposing, etc.)