Fostering Curiosity, Creating Value, and Making Connections in First-Year Students Through Product Archaeology

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 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 D. Oestreich, Rowan University
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. 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. Cheryl A. Bodnar, Rowan University

Cheryl A. Bodnar, Ph.D., CTDP is an Assistant Professor in the Department of Experiential Engineering Education at Rowan University. Dr. Bodnar’s research interests relate to the incorporation of active learning techniques 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 obtained her certification as a Training and Development Professional (CTDP) from the Canadian Society for Training and Development (CSTD) in 2010, providing her with a solid background in instructional design, facilitation and evaluation. She was selected to participate in the National Academy of Engineering (NAE) Frontiers of Engineering Education Symposium in 2013 and awarded the American Society for Engineering Education Educational Research Methods Faculty Apprentice Award in 2014.

Fostering Curiosity, Creating Value, and Making Connections in First-Year Students Through Product Archaeology

Abstract

Integration of entrepreneurial mindset (EM) into the engineering curriculum has become an increasing area of focus over the last decade. As conceptualized by KEEN (Kern Entrepreneurial Engineering Network), EM has three tenets: Curiosity, Connections, and Creating Value (the 3Cs). Curiosity is valued in students because it suggests that they are interested in being lifelong learners and extending their knowledge beyond what is covered in class. Additionally, we want our students to be able to make Connections, not only in their knowledge between what they have learned before and what they see before them, but also among people and resources. Finally, as part of embodying an EM, our students should be interested in Creating Value - ensuring that their designs and solutions will benefit stakeholders and society.

At Rowan University, a mid-size Mid-Atlantic public university, we set out to foster an Entrepreneurial Mindset in our first-year engineering students by modifying the Product Archaeology framework that was first developed by K. Lewis, et al. [1]. In our implementation, we allowed student teams to choose from a bank of products and guided them through the four phases of product archaeology (preparation, excavation, evaluation, and explanation). For the evaluation phase, each team developed and executed three or more qualitative experiments for their product. At the conclusion of the project, students wrote a report that addressed the four phases of product archaeology, including the results of their quantitative experiments. Each report was graded using an internally designed rubric, some items of which we mapped to the 3Cs. For example, the rubric item related to their research question maps to Curiosity because developing an insightful research question requires that students be curious about their products.

This project was conducted in 17 sections of a multidisciplinary first-year engineering course, in which a total of 369 students were enrolled. Students completed the project in teams of three to five. The final reports and presentations of approximately 87 teams were analyzed using a

standard rubric in which three items map to Curiosity and the other two items map to Connections and Creating Value, respectively.

The Product Archaeology project was intended to give students an experience in developing EM while also furthering the long-standing instructional objectives of the course, which include writing effective reports and analysis and collection of data. The results show, broadly, that most teams met the instructional objectives of the project.

Introduction

In recent years we have seen a shift in the economy. Individuals are no longer spending their entire careers working for a single organization. In fact, many individuals are experiencing greater than ten position changes over the course of their career [2,3]. We have also seen many individuals starting their own organizations [4,5] or working on contracts [6]. These observed changes require newly graduated engineers to not only be able to apply technical engineering skills in the workforce but also demonstrate resilience, recognize opportunities, and deal with ambiguous situations associated with open ended problems [7]. All of these traits have been associated with an entrepreneurial mindset [8].

Entrepreneurial mindset has become an area of increasing focus within engineering programs. Over the past 10-15 years, there has been an unprecedented growth in the number of engineering programs that are offering courses, co-curricular experiences, and activities integrated within existing courses that assist in developing skills associated with an entrepreneurial mindset [9-13]. One of the larger supporters of this movement has been KEEN (Kern Entrepreneurial Engineering Network). KEEN currently has 36 partner institutions that are connected together around the central goal of making entrepreneurial mindset synonymous with engineering in the near future [14]. Each of these institutions conceptualizes entrepreneurial mindset around the 3Cs - curiosity, connections, and creating value. Having a shared definition for entrepreneurial mindset allows for programs to leverage the work of one another and achieve better overall integration of content relevant to this goal within the engineering curriculum.

As entrepreneurial mindset is identified to consist of both inherent and learned traits [15], it is important that we start exposing engineering students to the concepts associated with this framework as soon as they start their engineering degree. Several programs have worked on the integration of entrepreneurial mindset into their first-year engineering design programs [16-21]. A common theme to the approach taken in many of these programs is to leverage the design process as an entryway for discussing entrepreneurial mindset. For instance, in the first-year engineering program at Arizona State University, students completed a team-based design project focused on the National Academy of Engineering Grand Challenges. Throughout the discussion of the design process students were introduced to elements of entrepreneurial mindset to encourage student exploration of the problem space and their work towards creating a product that would provide value [18]. Most of these implementations have also scaffolded the process for students by providing them with either mini projects [18] or a series of smaller activities prior to the completion of an open-ended design project [16,17].

In this work, we seek to share our experiences with leveraging product archaeology as a foundation for building first-year engineering students' entrepreneurial mindset. Although the relationship between product archaeology and the entrepreneurial mindset was not explicitly communicated to students, there were underlying elements of the project that could be mapped directly back to the 3Cs to allow for assessment of students' approaches to curiosity, connections, and creating value in the context of this project.

Product Archaeology Overview

Product Archaeology is the "process of reconstructing the lifecycle of a product, including the customer requirements, design specifications, and manufacturing processes used to produce it" [22]. The focus of our approach centers on 4 separate phases of how to evaluate and assess the product itself; rather than a more specific product assessment [23].

The initial phase, Preparation, allows for students to perform research on the selected product that involves not only technical and design characteristics; but also how its design is influenced by 4 overarching factors:

- Global – how is or how can the product design be influenced by a combination of geographic and/or cultural differences around the world
- Societal – how is or how can the product design be influenced by ergonomics, social pressures, lifestyles in varying conditions, and diverse market demand
- Environmental – how does the surrounding physical and lifecycle environment impact the product design? All aspects of the product life cycle need to be considered (design, development, production, product support, end-of-life disposal)
- Economic – how is product design impacted by external economic conditions (world markets, GDP growth / decline, etc…) that, in turn, drive cost of materials and processes; leading to product sales and marketing

The second phase, Excavation, focuses on a physical assessment of the specific product (typically there are multiple variations of the same product; for example, 3-4 different types of Flashlights). Once physical properties are better understood (including packaging), students begin to dig deeper into research regarding questions developed during their assessment.

The third phase, Evaluation, provides students the opportunity to create their own experiments and tests to determine how well their product performs against explicit and/or derived requirements (labels, advertisements, marketing propaganda, etc…). The results of their experiments are then fed back through their research to identify correlations, expectations, and conformance to expected norms.

The final phase, Explanation, provides the opportunity for students to summarize the results of their efforts including how each product is and/or can be influenced by the four overarching factors mentioned previously. Students work in teams and present their findings both in a written report and oral presentation to the class.

The learning objectives for this project were:

- Collect, record, analyze and interpret technical data to evaluate an object or system of engineering interest;

- Demonstrate curiosity about and articulate how the context (social, environmental, and economic) in which engineering is practiced impacts solutions and designs;
- Differentiate and make connections between the contributions of different engineers (majors and professions) in the development of a product, process or system;
- Function effectively on a team with individual and joint accountability;
- Communicate engineering concepts, ideas and decisions effectively in a variety of formats

Methods

Product Archaeology was completed in 17 sections of 18-24 students enrolled in a first-year engineering course at Rowan University. Each section met twice a week during Fall 2018, once in a 75 minute session and once in a 165 minute session. The Product Archaeology project was completed over the course of five weeks in a 15-week semester. Generally, the 75 minute class meeting was dedicated to a particular engineering topic (Uncertainty, Rounding/Significant Figures, Units, Experimental Design, etc) and the 165 minute session was dedicated to product archaeology. Based on our initial rollout of this project in Fall 2017, instructors were given a choice as to how many products their class could investigate. A bank of eight products was provided for each instructor to choose from: flashlights, speakers, shampoo, glue, mugs and cups, paper towels, diapers, tennis balls. Each section investigated between one and six different products. To complete the project, the general outline for Product Archaeology as explained by K. Lewis, et al. [1] was followed, which is shown in Table 1.

Table 1. General overview of the 5 weeks of the Product Archaeology Project.

Week	Description
1	Preparation phase: Product Archaeology introduced to students; Students select product group to focus on; Students develop questions about their product and then begin research on the Global, Societal, Economic, and Environmental Aspects of the product via library research.
2	Excavation/Evaluation Phase: Students develop and conduct quantitative experiments on their product to elucidate answers to questions they developed in week 1 that weren't answered by their library research.
3	Excavation/Evaluation Phase, cont: Students complete quantitative testing including a dissection and destructive testing, if appropriate.
4	Explanation Phase: Students write lab reports and presentations to present the results of their archaeological "dig".
5	Explanation Phase, cont: Students give presentations.

Deliverables

The Product Archaeology project represented 15% of students' final grades in the course. There were three major deliverables for the project, each of which students completed in teams of 3-5: an annotated bibliography, a written report, and a presentation.

Annotated Bibliography

For the annotated bibliography students were expected to find 12 sources to help them answer the questions they developed during Phase 1. They were then expected to format the source citation appropriately and provide an annotation that summarized the source content and analyzed the quality of the source.

Written Report

The written report was a 6-8 page, single-spaced document that followed a lab report format in which the introduction explored the four aspects of product archaeology in detail as they related to the team's product of interest. The methods and results and discussion sections detailed the three quantitative tests that students developed during the excavation and evaluation phases and linked those results back to the four phases of product archaeology. The reports were graded using the rubric shown in Table A-1. The mapping to Curiosity, Connections, and Creating Value is shown in the second column of the table.

Presentation

In a 10-12 minute presentation, student teams conveyed information similar to what they reported in their written deliverables. Using an oral presentation format allowed students to exhibit a different skill set than the written deliverable and also provided other student teams the opportunity to learn how the four aspects of product archaeology were applied to different products. The presentations were graded using the rubric shown in Table A-2, with the mapping to the three Cs indicated in the second column.

Assessment

The primary assessment tools used for this project are the rubrics shown in Table A-1 for the Final Report and Table A-2 for the Final Presentation. These rubrics were used for two purposes:

to guide instructors in assigning grades to individual student reports and presentations, and to assess the level of achievement for the Freshman cohort as a whole. Each rubric consists of a list of aspects of the project deliverable and three written descriptors corresponding to excellent, minimally acceptable and unacceptable performance with respect to each aspect. A 5-point scale is defined in which a rating of 5 corresponds to excellent, 3 to minimally acceptable and 1 to unacceptable. The evaluator can thus assign ratings of 2 or 4, if the report or presentation being evaluated is considered to show a blend of two of the descriptors. Each instructor rated each student team on a scale from 1-5 with respect to each aspect of the project. It is understood that ratings of 5 correspond to "A" performance, ratings of 3 correspond to "C" performance and ratings of 1 correspond to "F" performance. However, the specific weighting of each aspect of the report or presentation in determining the overall grade was left up to the individual instructor, and may have varied from section to section.

Each rubric can be broadly sub-divided into two categories: a communication rubric and a project-specific rubric. The communication rubrics are aspects of the report (e.g., Organization) or presentation (e.g., Effective Introduction) which specifically measure effective communication and are applicable to deliverables stemming from most any project. Indeed, these same rubrics are being used for other Introduction to Engineering projects during the spring 2019 semester. The rubric for the remaining five categories- Historical Research (information), Historical Research (sources), Research Question, Experimental/Technical Work, and Analysis- is designed to measure student achievement of the specific technical goals of the Product Archaeology project. These five categories are included in both Table A-1 and Table A-2 with identical descriptors. Thus, each team is evaluated twice with an identical rubric- once based solely on the evidence contained in the report and once based solely on the evidence contained in the presentation.

After the rubrics were developed, the authors developed a mapping between the five project-specific categories and the KEEN "three C's." The first three categories are mapped to "Curiosity." The authors contend that a student team that does thorough historical research and proposes strong research questions is exemplifying curiosity. "Experimental/Technical Work" is mapped to "Connections," because this portion of the rubric is measuring how well the students

planned and executed a strategy for answering their research question using available resources. This task is reminiscent of the following statement from KEEN's Framework Poster: "Students must be taught to habitually pursue knowledge and integrate it with their own discoveries to reveal innovative solutions" [24]. Finally, "Analysis" is mapped to "Creating Value," because this portion of the rubric is evaluating the students' understanding of and analysis of "global, societal, economic and environmental issues" relevant to their specific product.

Results & Discussion

The data used for this analysis consisted of reported rubric scores for the Final Report and Final Presentation across 14 and 15 sections of our first-year engineering course, respectively. The purpose of the analysis is to examine how the student cohorts scored across the five KEEN-related rubric items (see Table 2), determine if scores on the 3C's varied by product choice, and identify which aspects of an entrepreneurial mindset are most targeted by Product Archaeology (and likewise, which aspects need further development in regards to EML). The results are summarized in Figures 1 and 2 and Table 3 below.

Table 2. KEEN-related Rubric Items

KEEN 3C's	**Rubric Item(s)**
Mapped to Curiosity	Historical Research (information, sources, and research questions)
Mapped to Connections	Experimental/Technical Work
Mapped to Creating Value	Analysis

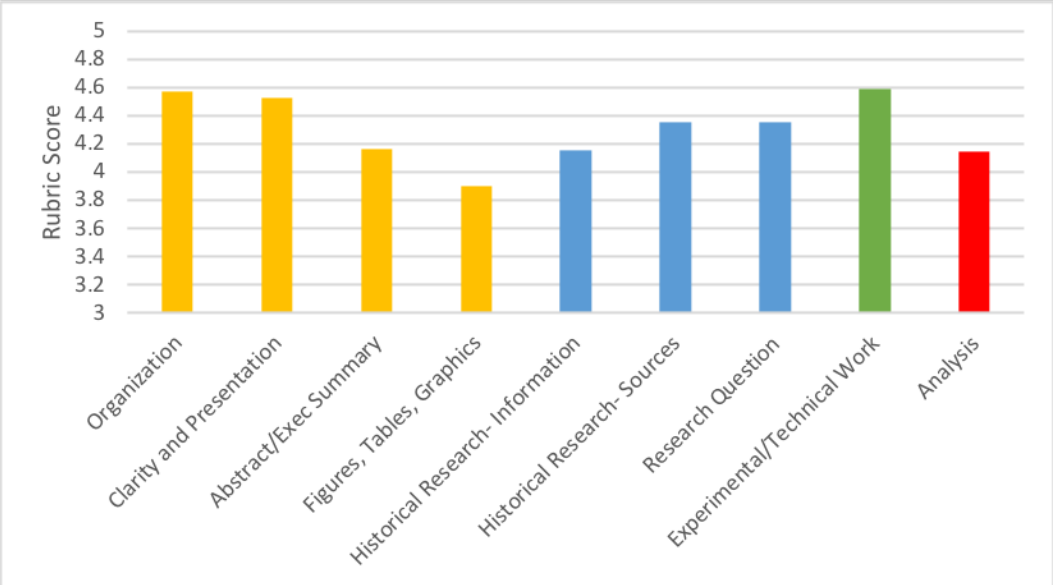

Figure 1. Average Rubric Scores for Final Report color coded by general (yellow), Curiosity (blue), Connections (green), and Creating Value (red). Y-axis does not go to 0 to better show the differences between category rubric scores.

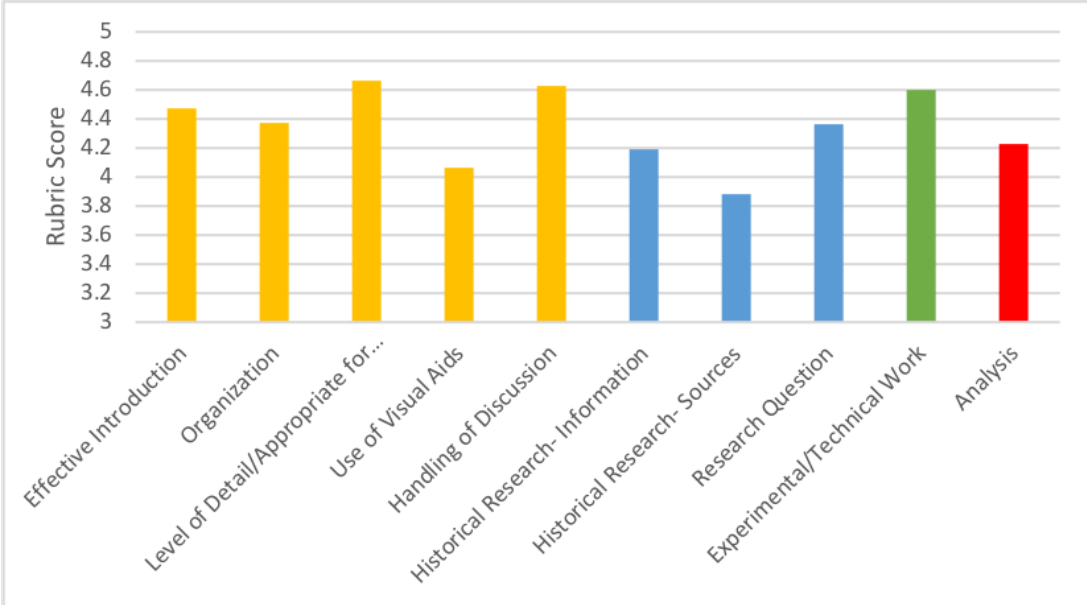

Figure 2. Average Rubric Scores for Final Presentation color coded by general (yellow), Curiosity (blue), Connections (green), and Creating Value (red). Y-axis does not go to 0 to better show the differences between category rubric scores.

Table 3. Summary Statistics of KEEN-related Rubric Items

KEEN-related Rubric Items	**Final Report**		**Final Presentation**	
	Average	SD	Average	SD
Historical Research-Information	4.16	1.16	4.19	1.17
Historical Research-Sources	4.36	1.08	3.88	1.33
Research Questions	4.36	0.94	4.36	0.85
Experimental/Technical Work	4.60	0.82	4.60	0.66
Analysis	4.15	1.23	4.23	0.75

Figures 1 and 2 illustrate results using the developed rubric and reveals some interesting findings regarding EML in our Product Archaeology project. Experimental/Technical Work (Connections) was found to be the high scoring rubric item and one that had the least amount of variation between student teams. This relates to the team's ability to create (and report) on an experimental plan that was well thought out and suited for the research questions - obtaining all possible information from the experiments. Conversely, based on the reports (Figure 1), the area the student teams struggled most was related to the Analysis (Creating Value) rubric item. Not all teams were able to analyze the global, societal, economic, and environmental issues with their product, nor were the discussions of such issues uniformly informed by historical research (Curiosity) or technical work (Connections). Finally, the rubric items related to historical research (Curiosity) had an interesting dynamic as it varied greatly by the item and also by the deliverable format. For example, Historical Research - Sources was a high scoring/high variance item for the Final Report (Figure 1) but a low scoring/low variance item for the Final Presentation (Figure 2). Since this item relates to explicitly using and attributing information to authoritative sources, the results indicate students excelled at this when writing in a more typical research paper format but fail to translate this to their presentations. Overall, the project resulted in relatively high scores on the 3C's, but improvements can be made to help students understand the innovations and trade-offs within the design of a product; using varied and authoritative sources when presenting on the design and broader impacts of engineered products; and analyze

these broader impacts of engineering design in respect to their product and explicating an appropriate value proposition.

Our next line of investigation was whether scores on the 3Cs varied across product choice. Table 4 reports the average scores on the KEEN-related rubric items (the three items related to Curiosity were combined for easier comparison) for the Final Reports across the different products.

Table 4. Average KEEN-related rubric items scores by product choice

		Average Scores		
Products	n	Curiosity	Connections	Creating Value
Flashlights	24	4.35	4.54	4.33
Glue	10	**4.60**	4.60	4.30
Cups/Mugs	10	*3.60*	4.60	*3.30*
Paper Towels	10	4.30	**4.80**	*3.90*
Speakers	9	3.89	**4.78**	**4.44**
Shampoo	6	**4.50**	*4.33*	**4.50**
Diapers	5	*3.40*	4.60	4.10
Tennis Balls	4	4.00	*4.38*	4.25

*Highest scores **bolded**; lowest scores *italicized*

The results above point to a few tentative conclusions. There is not a single product that is best at addressing the 3Cs as the average scores across the KEEN-related rubric items varied. We can say that some products appear to relate to the 3Cs better than others (or at least as perceived by the students). For example, speakers and shampoo yielded high scores across two of the 3Cs but yielded lower scores in the other. Cups/Mugs seem to miss the mark, especially in terms of creating value and the curiosity component for diapers was lacking compared to other product choices. Flashlights were the most frequent product chosen and the reported rubric scores for

teams who selected flashlights was quite high across the 3Cs. Glue also reported consistently high scores across the 3Cs.

The approach taken in developing the assessment rubrics was: (1) identify the desired outcomes of the project and list aspects of a report or presentation that inform whether these outcomes were achieved, (2) craft a rubric that benchmarks the performance of each team with respect to each aspect, and (3) identify aspects of the project that map to the three C's. In this case, all of the identified "project-specific" outcomes for the project were considered to be intimately related to one of the three C's. After analyzing the results obtained from the rubric, it appears that the students were broadly successful at achieving the desired "three C's" outcomes for the project, as well as generally producing effective communication. However, it also appears that the Creating Value aspect of EM would benefit from being reworked and emphasized throughout the Product Archaeology project, along with ensuring students identify the factors/issues that influence product design so they make think more broadly about engineering impact and understand the customers the products will affect.

Conclusion

A Product Archaeology project was designed for and implemented in a multidisciplinary, required, first-year engineering course. The project aimed to foster an entrepreneurial mindset in students through several of its learning objectives. To assess the project's ability to foster an entrepreneurial mindset in students a rubric was designed and used to evaluate both a team-written report and a team-presented oral presentation. Items of the rubric were mapped to the 3Cs of an entrepreneurial mindset as conceptualized by KEEN: Curiosity, Connections, and Creating Value. Our results showed that, in general, student teams scored reasonably on the rubric items that were linked to the 3Cs. Students were particularly adept at writing about and explaining their technical work and less adept at analyzing how their product and their test results were situated in the context of the four aspects of product archaeology (global, societal, economic, and environmental). Some differences were also seen depending on which consumer product the students chose to work on. However, this highlights one of the limitations of this work. Because the project was implemented across 17 sections of the first-year course, 13 instructors were involved in the assessment of the project using the rubric developed by the authors. There is

inherent variability in instructors' conceptions of the rubric items and in their grading standards, so it is possible that the differences that were observed between products is due not to the products themselves but to the instructor(s) whose students examined those products.

Additionally, some instructors required their students to all work on the same product, while others gave their students a choice from either all of the available products or a subset of products. Because of this, some products were more likely to be examined by students and some students may have been more or less interested in their product depending on the amount of choice they were given. This could have translated to performance on the project assessments. Another aspect of project performance was the emphasis (or lack thereof) instructors put on various pieces of the requirements. For example, it is likely that most instructors focused on the technical testing and communicating the results of that testing, which explains the high scores in the Experimental/Technical Work category. However, there may have been less focus on providing a "detailed history of the product that includes an insightful discussion of innovations and trade-offs within the design of the product," which would affect student scores in the "Historical research - information" category.

For future implementations of this project we plan to adjust the focus of the research from "historical" to "background" to allow for a broader scope of investigation for students to pursue. We also plan to interview instructors to better understand their interpretations of the project goals and rubric categories. Finally, we plan to introduce the concept of sustainability as an overarching theme in the project to meet what we see as a societal need to train engineers who are able to competently discuss and integrate sustainability in their engineering practice.

Acknowledgements

This work was supported by funding from the Kern Family Foundation through a KEEN Institutional Program Grant.

References

[1] Lewis, K., Moore-Russo, D. A., Kremer, G. E. O., Tucker, C., Simpson, T. W., Zappe, S. E., ... Williams, C. B. (2013). The development of product archaeology as a platform for contextualizing engineering design. In ASEE Annual Conference and Exposition, Conference Proceedings.

[2] Bureau of Labor Statistics (2017). Number of Jobs, Labor Market Experience, and Earnings Growth Among Americans at 50: Results from a Longitudinal Survey. https://www.bls.gov/news.release/pdf/nlsoy.pdf. Accessed on December 18, 2018.

[3] Young, J.R. (2017). How Many Times Will People Change Jobs? The Myth of the Endlessly-Job-Hopping Millennial. https://www.edsurge.com/news/2017-07-20-how-many-times-will-people-change-jobs-the-myth-of-the-endlessly-job-hopping-millennial. Accessed on December 18, 2018.

[4] Wade, S. (2014). Behind the Rise of Entrepreneurship. http://fortune.com/2014/06/12/behind-the-rise-of-entrepreneurship/. Accessed on December 18, 2018.

[5] Kauffman Foundation (2017). Kauffman Foundation: Entrepreneurship is on the Rise but Long-Term Startup Decline Leaves Millions of Americans Behind. https://www.kauffman.org/newsroom/2017/2/entrepreneurship-is-on-the-rise-but-long-term-startup-decline-leaves-millions-of-americans-behind. Accessed on December 18, 2018.

[6] NPR (2017). Contract Jobs Are The New Normal: NPR/Marist Poll. https://www.npr.org/about-npr/579672112/contract-jobs-are-the-new-normal-npr-marist-poll. Accessed on December 18, 2018.

[7] Byers, T., Seelig, T., Sheppard, S., & Weilerstein, P. (2013). Entrepreneurship its role in engineering education. *National Academy of Engineering The Bridge: Linking Engineering and Society*, 35–40.

[8] Bodnar, C. A., Clark, R. M., & Besterfield-Sacre, M. (2015). Lessons learned through sequential offerings of an innovation and entrepreneurship boot camp for sophomore engineering students. *Journal of Engineering Entrepreneurship*, *6*(1), 52–67.

[9] Condoor, S. S., & Keogh, G. (2012). Work in progress: Weekly innovation challenge: changing the mindset one step at a time every week. In *Proceedings of the 2012 Frontiers in Education Conference Proceedings*. Seattle, WA.

[10] D'Amours, C., Lague, C., & Mellor, F. (2009). Entrepreneurship Curricula and Competitions in the Faculty of Engineering of the University of Ottawa. In *American Society for Engineering Education*. Austin, TX.

[11] Kwong, C. C. Y., Thompson, P., Cheung, C. W. M., & Manzoor, H. (2012). The role of environment in fostering conductive entrepreneurial learning: Teaching the "art" of entrepreneurship in boot camps. *Journal of General Management*, *38*(1), 45–71.

[12] Patel, M., & Basu, A. (2006). How to Weave Entrepreneurship into Engineering Education: The Experience at San Jose State University. *Proceedings of the American Society for Engineering Education Conference*: 11.703.1-11.703.12.

[13] Reid, K. J., & Ferguson, D. M. (2011). Work in progress: Enhancing the entrepreneurial mindset of freshman engineers. In *Proceedings of the 41st ASEE/IEEE Frontiers in Education Conference*. http://doi.org/doi:10.1109/fie.2011.6142734

[14] KEEN (2018). Partner Institutions. https://engineeringunleashed.com/partners.aspx. Accessed on December 18, 2018.

[15] Kalkan, M., Kaygusuz, C. (2012). The Psychology of Entrepreneurship. Entrepreneurship - Born, Made and Educated. Edited by Thierry Burger-Helmchen. InTech, Rijeka, Croatia, 3-26.

[16] Bernal, A., Brackin, P., House, R.A., McCormack, J.P., Watt, A., Riley, B. (2017). Entrepreneurial Thinking in a First-Year Engineering Design Studio. *ASEE 2017 Annual Conference and Exposition*, June 25-28, 2017. Columbus, Ohio.

[17] Fraley, M., Raber, M., Hein, G.L. (2018). Work in Progress: Entrepreneurial Mindset in First-Year Engineering Courses. *First-Year Engineering Experience (FYEE) Conference*, July 24-16, 2018. Glassboro, New Jersey.

[18] Huerta, M.V., London, J.S., Trowbridge, A., Avalos, M.A., Huang, W., McKenna, A.E. (2017). Cultivating the entrepreneurial mindset through design: Insights from thematic analysis of first-year engineering students' reflections.

[19] Jensen, M.J., Schlegel, J.L. (2017). Implementing an Entrepreneurial Mindset Design Project in an Introductory Engineering Course. *ASEE 2017 Annual Conference and Exposition*, June 25-28, 2017. Columbus, Ohio.

[20] Park, H. (2017). Fostering and Establishing an Engineering Entrepreneurial Mindset through Freshman Engineering Discovery Courses Integrated with an Entrepreneurially Minded Learning (EML) Pedagogic Approach. *First Year Engineering Experience (FYEE) Conference*, August 6-8, 2017. Daytona Beach, Fl.

[21] Wang, C. (2017). Teaching Entrepreneurial Mindset in a First-Year Introduction to Engineering Course. *ASEE 2017 Annual Conference and Exposition*, June 25-28, 2017. Columbus, Ohio.

[22] Product Archaeology. (2014, May). Retrieved from http://www.productarchaeology.org/index.html Accessed 18 October 2018.

[23] What is Product Archaeology. (2014, May). Retrieved from http://www.productarchaeology.org/web_pages/information/what_is_product_archaeology.html Accessed 18 October 2018.

[24] KEEN (2018). “Framework Poster,” https://keenwarehouseprod.blob.core.windows.net/keen-downloads/KEEN_Framework_spread.pdf Accessed December 18, 2018.

Appendix

TABLE A-1: Rubric for Product Archaeology Final Reports

Category	**Mapped 3C**	**5 (Excellent)**	**3 (Minimal Acceptable)**	**1 (Unacceptable)**
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/appendices 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 and 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/ Exec Summary		Summary stands on its own and provides a compelling overview that includes statement of objectives, provides quantitative results, and summarizes conclusions and recommendations	Summary is generally adequate but misses some pertinent information.	Summary doesn't address fundamental questions about project, such as objectives, approaches, conclusions and recommendations.

Figures, Tables, Graphics		Illustrations, figures and tables are clear and informative, well positioned within report, and captioned in sufficient detail to stand on their own.	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.
Historical Research-information	Curiosity	The report provides a detailed history of the product that includes an insightful discussion of innovations and trade-offs within the design of the product.	The report provides an adequate history of the product. Coverage of innovations, sub-designs and trade-offs between them is accurate but sparse.	The report provides little or no historical insight. The reader has no information beyond what is obvious to a typical user of the product.
Historical Research-sources	Curiosity	Several authoritative sources are used, and attribution of information to sources is clear and follows guidelines.	Multiple sources are listed but there is a possible concern-e.g., over-reliance on a single source, role of some sources isn't clear, one source is of dubious merit, etc. Attribution of information to sources is generally done, but source of some information is unclear and/or attribution doesn't always follow guidelines.	There is a fundamental concern about the research, such as failure to use authoritative sources, unattributed quotations, no research beyond sources provided by the instructor, etc.

Research Question	Curiosity	The report explores one or more substantial and significant research questions. Answering the research question will shed light on a key aspect of the product's function and/or value.	Report presents one or more research question, but they are relatively uninspired or low-impact questions.	Report does not present a clear "research question."
Experimental/ Technical Work	Connections	The experimental plan is well thought out and ideally suited to answering the research question(s). All possible information is obtained from the experiments.	The experimental plan produces some relevant data but isn't optimal. Some useful information that could have been obtained from the experiments either was not collected or is not reported.	The experimental plan is fundamentally flawed in either its design or its execution. The research question cannot be answered using the given data.
Analysis	Creating Value	The report presents an excellent analysis of global, societal, economic and environmental issues. The discussion is thoroughly informed by both historical research and lab work.	The report presents an acceptable analysis of global, societal, economic and environmental issues. The discussion is accurate but often doesn't progress beyond broad and obvious statements. Historical research and/or lab results are used in a meaningful way but there is more that could be said.	The discussion of global, societal, economic and environmental issues is fundamentally flawed. Some of the components are missing completely or are discussed in a way that is inconsistent with the historical research and/or lab results.

TABLE A-2: Rubric for Product Archaeology Final Presentations

Category	**Mapped 3C**	**5 (Excellent)**	**3 (Minimal Acceptable)**	**1 (Unacceptable)**
Effective Introduction		Presentation includes a compelling introduction that conveys the scope and purpose of the project. Audience knows what to expect and has a good reason to listen.	Introduction is clear but doesn't address all salient aspects of project or is not as compelling as it could be.	Presentation has no real introduction, or a misleading introduction.
Organization		Presentation covers all key aspects of project, is logically organized and consistently clear. Speakers are well prepared and delivery is smooth.	Presentation covers the essential elements of project but sometimes difficult to follow. Speakers moderately well prepared but give uneven presentations.	Presentation is incomplete, disoranized, and unclear. Speakers clearly unprepared.
Level of detail, appropriate for audience		Presentation is sufficiently detailed to be informative and compelling without getting bogged down in minor issues.	Presents most of the necessary information, but glosses over some important issues and/or spends excessive time on minor ones.	Substantial information missing. Leaves critical questions unanswered.
Uses visual aids effectively		Visual aids are clear and informative, and are used effectively without serving as a "crutch" for speaker.	Visual aids are helpful but have some flaws: some slides overcrowded, sparse, have distracting elements, etc. Speakers sometimes seem unsure of what to say next until slide comes up.	Visual aids are haphazardly done and not helpful.

Handling discussion		Questions are encouraged and answered clearly, completely and professionally.	Answers to questions are pertinent but not completely satisfactory. Team is professional in demeanor but doesn't know, or doesn't communicate, some things they should know.	Answers to questions are incoherent, wrong, and/or unprofessional.
Historical Research-information	Curiosity	The report provides a detailed history of the product that includes an insightful discussion of innovations and trade-offs within the design of the product.	The report provides an adequate history of the product. Coverage of innovations, sub-designs and trade-offs between them is accurate but sparse.	The report provides little or no historical insight. The reader has no information beyond what is obvious to a typical user of the product.
Historical Research-sources	Curiosity	Several authoritative sources are used, and attribution of information to sources is clear and follows guidelines.	Multiple sources are listed but there is a possible concern-e.g., over-reliance on a single source, role of some sources isn't clear, one source is of dubious merit, etc. Attribution of information to sources is generally done, but source of some information is unclear and/or attribution doesn't always follow guidelines.	There is a fundamental concern about the research, such as failure to use authoritative sources, unattributed quotations, no research beyond sources provided by the instructor, etc.

Research Question	Curiosity	The report explores one or more substantial and significant research questions. Answering the research question will shed light on a key aspect of the product's function and/or value.	Report presents one or more research question, but they are relatively uninspired or low-impact questions.	Report does not present a clear "research question."
Experimental / Technical Work	Connections	The experimental plan is well thought out and ideally suited to answering the research question(s). All possible information is obtained from the experiments.	The experimental plan produces some relevant data but isn't optimal. Some useful information that could have been obtained from the experiments either was not collected or is not reported.	The experimental plan is fundamentally flawed in either its design or its execution. The research question cannot be answered using the given data.
Analysis	Creating Value	The report presents an excellent analysis of global, societal, economic and environmental issues. The discussion is thoroughly informed by both historical research and lab work.	The report presents an acceptable analysis of global, societal, economic and environmental issues. The discussion is accurate but often doesn't progress beyond broad and obvious statements. Historical research and/or lab results are used in a meaningful way but there is more that could be said.	The discussion of global, societal, economic and environmental issues is fundamentally flawed. Some of the components are missing completely or are discussed in a way that is inconsistent with the historical research and/or lab results.