Session XXXX

Implementing Authentic, University-Level Engineering Design Coursework in Pre-College Programs for Low-Income Students

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Abstract

Effective engineering curricula are sparse at the secondary level, and often revolve around projects-for-a-grade instead of implementing solutions to real-world challenges. The upfront cost of the existing curricula can be cost prohibitive to low-income schools. The authors adapted and implemented Rice University's Freshman Design class, ENGI 120, a university-level, client-focused engineering design curriculum at Yes Prep Brays Oaks, a public charter school that serves primarily low-income, minority students. By adapting an existing model to secondary education, it is possible to ensure high-quality materials regardless of budgetary constraints. This paper explores the impact of this course on the students at YES Prep as a case study for possible partnerships between future universities and pre-college programs.

1. Introduction

Studies have shown that academic success for minority students in STEM is hindered by funding disparities yet bolstered by exposure to pre-college engineering programs [1]. Unfortunately, these factors are difficult to reconcile as high-quality pre-college engineering programs such as engineering career and technical education (E-CTE) exist in schools with low populations of minorities, English-language learners (ELLs), and students that qualify for free-and-reduced lunches [2]. Or, if a program does exist, such as Project Lead the Way, it draws from students that are already in the top percentage of their class [3] or requires an investment in specialized equipment, teacher training, and/ or curriculum cost [4]. Programs that are not cost-prohibitive may attempt to solve real-world challenges packaged as a project-for-a-grade.

In an attempt to solve this issue in a new way, the authors adapted and implemented Rice University's freshman engineering design class in a pre-college program that primarily serves low-income and minority students.

2. Adaptive Curriculum

Introduction to Engineering Design (ENGI 120), Rice University

The Introduction to Engineering Design class, ENGI 120, at Rice University is a one-semester, client-based class that students may elect to take during their freshman year. At the beginning of the class, community and industry partners pitch design problems that require an innovative solution. The students then spend the semester in 4-person design teams to solve their unique problem by

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following a 7-step, iterative, engineering design process as shown in figure 1.

The class follows a flipped-classroom model where students watch video lectures before class and spend the majority of class time working through the design process. Evaluations of student work are made based on written assignments, oral presentations, and prototype evaluations.

Introduction to Engineering Design and Problem Solving (IEDPS), Yes Prep Brays Oaks
Minimal changes have been made to the overall structure of the Rice University course. At the beginning of the course, students complete a short unit learning about the role of an engineer and what an engineer does. After this brief unit, community-members pitch design challenges. Students work in teams of 4-5 through an identical engineering design process as figure 1 to solve the design challenges. In the first semester, students complete one design challenge using the flipped-classroom model. In the second semester, students complete a second design challenge after learning how to schedule their own project timeline. All students are trained on hand tool safety and TinkerCAD, a free computer-aided design software.

Students are evaluated on written assignments that document their engineering design process. They must also complete two oral presentations per semester and multiple prototype evaluations. Students are never penalized based on their ability to successfully complete a project, however, students that follow the design process often deliver a finished product to their client.

2. Flexible Resource Demands

Because of the flexibility afforded by the engineering design process, the curriculum is repeatable without being resource intensive. The cost and project difficulty under this model scale to meet the resources available to the students.

At Rice University, the class is hosted in the Oshman Engineering Design Kitchen, a 20,000 sq. ft. makerspace with state-of-the-art equipment including laser cutters, 3D printers, machine shop, electronics lab, and wet lab. As a result, students are able to produce a greater quantity medium and high fidelity products. To help facilitate students learning technical skills, the OEDK has employed a robust network of teaching assistants and lab technicians trained on various tools and machines.

At Brays Oaks, the class takes place in a shared classroom. Students have access to two 3D printers, school craft supplies, and laptops but are welcome to bring raw materials from their home. Since its inception, five 39-piece hand tool kits and a power tool set have been donated to the class. As the class acquires more resources, students are able to produce higher fidelity prototypes without the instructor needing to revise the curriculum. One student that successfully completed the class during their junior year returned to serve as a teaching assistant in their senior year.

3. Conclusions and Future Work

The need for a more diverse pool of future engineers continues to grow. As a result, secondary schools need to develop new and innovative ways to reach all their students. By adopting the

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curriculum from a local university, the students at Yes Prep Brays Oaks were exposed to high-quality engineering education. Additionally, the authors were able to implement the course with minimal startup cost. Next year, the class will add a second section and double in size to accommodate more sophomores and seniors. The authors will also explore the impact of the class on the students' perceptions of engineering, their professional-skill competence, and their technical-skill competence in a controlled study.

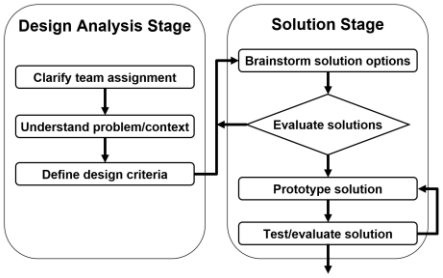

Fig. 1 Engineering Design Process Used in ENGI 120 and IEDPS

References

1. "Factors in K--12 Education That Influence the Success of Racial and Ethnic Minority Students in the STEM Circuit." 2011. *ASHE Higher Education Report* 36 (6): 27–52. https://search.ebscohost.com/login.aspx?direct=true&AuthType=cookie,ip,shib&db=a9h&AN=58687898&site=eds-live.
2. Gottfried, Michael A., and Jay Stratte Plasman. 2018. "From Secondary to Postsecondary: Charting an Engineering Career and Technical Education Pathway." *Journal of Engineering Education* 107 (4): 531–55. doi:10.1002/jee.20236.
3. BROPHY, SEAN, STACY KLEIN, MERREDITH PORTSMORE, and CHRIS ROGERS. 2008. "Advancing Engineering Education in P-12 Classrooms." *Journal of Engineering Education* 97 (3): 369–87. doi:10.1002/j.2168-9830.2008.tb00985.x.
4. Hill, Warren R. "Pre-Engineering In High School -- An Oxymoron?" In *ASEE*. Salt Lake City, 2004. https://peer.asee.org/13702.

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Dr. Matthew A. Wettergreen is Associate Teaching Professor at the Oshman Engineering Design Kitchen at Rice University. He teaches engineering design courses, including first-year engineering design and the follow-on engineering design courses. Additionally, he teaches students how to manufacture prototypes using low fidelity prototyping, iterative design, and the use of advanced manufacturing tools. In 2017 the engineering design courses at the OEDK were combined into one of the first engineering design minors in the country, credentialing students for a course of study in engineering design, teamwork, and client-based projects. Dr. Wettergreen is the faculty mentor for Rice's Design for America chapter, for which he has been awarded the Hudspeth Award for excellence in student club mentoring. He is the design of a number of academic products that help students improve their prototypes techniques including a low fidelity prototyping cart and the Laser Cutter Prototyping Library.

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