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Data And Stakeholder Driven Redesign of a First-Year Engineering Curriculum

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Professor Christopher Brigham has received multidisciplinary training in both the life sciences and in engineering. The focus of his B.S. work was in mass transfer and distillation. After three years working in industry, Prof. Brigham received his Ph.D. in 2006. His thesis work was focused on the interplay of the human commensal organism/opportunistic pathogen Bacteroides fragilis with the mammalian host. Specifically, he examined sugar utilization and how it affects the commensal and pathogenic lifestyles of B. fragilis. Prof. Brigham then moved to Massachusetts Institute of Technology as a postdoctoral scholar and later a Research Scientist. It was during this time that he developed a passion for biomanufacturing, fermentation and bioprocess engineering. He examined the industrially relevant bacterium Ralstonia eutropha (now known as Cupriavidus necator). R. eutropha is a soil bacterium that is the model organism for polyhydroxyalkanoate (PHA) bioplastic synthesis. He examined the biology of the PHA biosynthetic machinery and gene expression changes throughout PHA homeostasis. Also, he supervised a metabolic engineering project where R. eutropha was converted from a PHA producing organism to an isobutanol biofuel producing organism. Prof. Brigham joins Wentworth Institute of Technology from the Bioengineering Department at University of Massachusetts Dartmouth, where he was an Assistant Professor. At UMass Dartmouth, Prof. Brigham expanded his interests further, examining material properties of biopolymers like PHA and chitin, producing triacylglycerols and biodiesel using the bacterium Rhodococcus opacus, and developing probiotic strains of Escherichia coli that can fight Salmonella and Clostridium infections. Also, Prof. Brigham acted as principal faculty advisor to the UMass Dartmouth iGEM (International Genetically Engineered Machine) team. He is looking forward to developing many exciting undergraduate research projects at WIT based on these interests. At Wentworth Institute of Technology, Professor Brigham engages students in research projects focused on biomanufacturing and biotechnology. Specifically, projects involve microbial conversion of waste carbon to value-added products like biofuels and bioplastics. Professor Brigham is a member of American Chemical Society, American Society of Microbiology and American Society of Engineering Education. In addition to teaching and research, Professor Brigham serves on the Wentworth Faculty Senate and the Biological Engineering ABET and Curriculum Development Committee.

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Full Paper: Data- And Stakeholder-Driven Redesign of a First-Year Engineering Curriculum

Abstract

The first-year engineering experience has significant implications on both retention and substantial student success. As institutions adjust first-year engineering programs to meet the needs of changing demographics and student expectations, various challenges arise to address the needs of all stakeholder groups while also providing a meaningful and high-value student experience. This work presents the initial findings of a multi-year study on the redesign of the first-year engineering program at Wentworth Institute of Technology in Boston, MA. This primary work focuses on the insight drawn from the institute data, stakeholder feedback, and literature review to reshape the first-year engineering program. Other institutions should benefit from the presentation of challenges caused by the original common first-year and from the impact of stakeholders' feedback on framing the redesign.

Index Terms –Data Collection, Retention, First-Year Students, Reshaping Engineering

Introduction

It is well established that first-year engineering programs have far reaching impacts on the overall quality of and student persistence in first-year engineering programs. Most of the attrition occurs during a program's first year wherein approximately 24% leave for a non-engineering major or college altogether [1]. In addition, student performance in first-year courses can serve as a predictor for overall student success regardless of their understanding of course material [2,3]. The impact of student attrition on the finances of academic institutions is well documented, however the impact on the students departing the discipline can be far more drastic for the actual students. The financial burden on the withdrawn students goes beyond just the lost time and tuition fees since leaving the engineering field costs students approximately $500k over the course of their careers [4].

Factors that contribute to students leaving engineering programs include lack of belonging, quality of advising and instruction, and performance in first-year courses. Research shows that a lack of sense of belonging is one of the biggest reasons a student leaves engineering [5]. In addition, the quality of advising and course instruction has a significant impact on student persistence in an engineering program [6,7]. Students' persistence can be greatly improved if there is a culture of collaboration in their academic environment [8]. It has been shown that fostering a community environment, both in and out of the classroom, can improve student performance and sense of belonging [9]. Persistence in an engineering program can be drastically increased through the presence of extra-curricular activities that allow for faculty and students to interact outside of the traditional classroom setting [10]. This has motivated many academic institutions to reimagine their first-year engineering programs. Often these programs adhere to the classification scheme specifying the standard components of the first year that were outlined by K. Reid and D. Reeping [11]. Although many programs fall within this classification scheme, variations arise based on the available institutional resources, institute identity and strategic plan, and overall institutional inertia that may prevent drastic changes to what has been done.

This paper presents a systematic approach to assess an existing first-year engineering curriculum and draw on stakeholders' feedback to formulate the objectives of a complete first-year engineering program redesign. This approach is applied as a means of self-auditing an existing curriculum and to develop the foundational principles for a new first-year engineering program.

Common First-Year Information

The School of Engineering at the Wentworth Institute of Technology is comprised of 8 Engineering majors for which approximately 450-550 first-year engineering students enroll annually. From 2014-2022, the university had a common first-year curriculum for Biological, Biomedical, Civil, Computer, Electrical, Electromechanical, General and Mechanical Engineering majors [12]. The common first-year curriculum from 2014-2022 was comprised of 32 total credits that are equally distributed between Mathematics, Science, English and Engineering (Table. 1).

Table 1: Common First-Year Curriculum 2014-2022 (R-Recitation hours per week, L-Laboratory hours per week, C – Total credit hours)

Fall				**Spring**			
Course	**R**	**L**	**C**	**Course**	**R**	**L**	**C**
Calculus 1	4	0	4	Calculus 2	4	0	4
Physics 1	3	2	4	Physics 2	4	0	4
English 1	4	0	4	English 2	4	0	4
Introduction to Engineering	1	4	3	Introduction to ENGR Design	1	4	3
Fundamentals of CA /CAM	0	2	1	Programming with MATLAB	0	2	1

Notable features of the existing first-year program are:

- Between 6 and 8 hours of laboratory experience per week.
- Interdisciplinary Introduction to Engineering Course with a rotating laboratory schedule that provides students with exposure to various engineering disciplines.
- Major-specific Introduction to Engineering Design course that is fully transferable between the various engineering majors within the University
- Exposure to engineering software packages throughout.

Curriculum Redesign Procedure

Initial steps **-** As part of an engineering curriculum reimagining initiative, in the spring of 2021, the School of Engineering assembled a First-Year Engineering Taskforce with a charge to assess the current first-year engineering sequence with the goal to develop recommendations for the school to consider improving the curriculum while making considerations for both lateral and external transfer. This taskforce was assembled to include both faculty and staff from the School of Engineering as well as staff from other stakeholder and support groups. The process employed by the taskforce for the program redesign is depicted in Table 2.

Table 2: Data collection and redesign procedure

1- Initial Data Collection (March-August 2021)
Data and insight drawn from: • Self-Assessment through Institutional Data • Stakeholder Insight: Program Curriculum Committees, Students, Lab Technicians, Admissions Office
2- Data Consolidation (August-October 2021)
Taskforce identifies common themes within the data and stakeholder insight
3- Identification of Design Objectives (November 2021)
Taskforce identifies the design objectives for the curriculum redesign

Data Collection

Institutional Effectiveness Data - Initial assessment of the existing first-year engineering program was done through soliciting the following information from the office of Institutional Effectiveness:

The number of engineering students that have left over the last five years by semester.

- *Those that stayed at the school but chose a different major (outside of engineering)*
- *Those that did not return*
- *Those who have been dismissed*

The number of students that did a lateral transfer within engineering.

The number of engineering students that obtained a C or below in Calculus I/II or Physics I/II over the last five years.

The number of students that obtained a C or below in the first discipline specific course that uses Calculus I/II or Physics I/II.

The number of students that received a C or below in the first-year engineering courses over the last five academic years and includes students who repeated the course and replaced the grade.

Stakeholder groups

Stakeholder feedback was collected through a series of questionnaires sent to the various groups. The questions provided to each stakeholder group are illustrated in Table 3.

Institutional Data Consolidation and Insight

The responses to the institutional effectiveness data request provided an array of insight that could be drawn upon for a redesign of the first-year engineering program. These include:

- A significant number of students struggle in the first semester math and science classes.
- Students that struggle in first-year math and science classes struggle in the first discipline-specific classes. Student success degrades drastically based on the number of first-year math and science classes that students receive a grade of C or lower.
- Approximately 15% of students leave the engineering program in the first year.
- Students that leave an engineering program are less likely to make a lateral move; the majority may move to a non-engineering major.
- Student persistence rate increases for those who have completed 3 terms while it is at its lowest in the first three semesters.

Stakeholder Group Data Consolidation and Insight

The Taskforce members consolidated and identified common themes within the stakeholder groups. Each stakeholder group had specific insight into the first-year engineering program. Various stakeholder groups were surveyed in summer 2021. Their perception and insight into the current first-year curriculum are as follows:

Table 3: Stakeholder Group Questions

Program Curriculum Committees	Students	Admissions	Lab Support Personnel
What skills are necessary for students to have a working knowledge upon completing their first year in _____ engineering? Do you feel that the current common first-year curriculum provides these skills? Explain What technical knowledge do students need to be successful in sophomore level courses in _____ engineering? Do you feel that the current common first-year curriculum provides this knowledge? Explain How could the first-year engineering program be improved? How could we innovate to make our first-year program stand out?	How do you perceive the current first-year engineering program at Wentworth Institute of Technology? If possible, please elaborate on what aspects of the Wentworth Institute of Technology engineering first-year influenced your answer to Q1. How do you think the School of Engineering can add value to the first year? Did the common first year have any influence on your decision to attend Wentworth Institute of Technology? How do you think students can be better supported during the first year? What can the School of Engineering (or individual engineering programs) do to improve first year curriculum? In your opinion, what would make for a more transformative first-year experience at Wentworth Institute of Technology?	What are some of the needs of incoming students? Are there specific needs for incoming engineering students that could be facilitated from the school of engineering? What are your perceptions of the admissions requirements for incoming engineering students? How could we innovate to improve the first-year engineering program for incoming students?	In your opinion, what skills are necessary for students to have a working knowledge in, upon completing their first year in electrical, computer, mechanical, biomedical, electromechanical, et al. engineering? Do you feel that the current common first-year curriculum provides these skills? Please Explain. In your opinion, what are the strong aspects of our first-year engineering program? What are the weak aspects of our first-year engineering program? What do you suggest being changed in the curriculum to expose our first-year students to the laboratories while minimizing the impact on the actual lab space and equipment?

Program Curriculum Committees $(n = 4)$[1]: The various SOE Program Curriculum committees identified an array of insights into the first-year program and its potential impact on student performance in Engineering Programs:

- There is significant concern around student performance when applying mathematics in subsequent courses. Often this is precalculus material such as trigonometry, arithmetic with fractions and complex numbers.
- Considerable time is allocated to content not related to specific majors. For example, students learn software or spend time in labs that may not apply to their chosen major.

[1] n is the sample size.

- Considerable time is taken in sophomore level courses to instruct students in major specific instrumentation, software and technical concepts that could be introduced in the first year.
- The current first-year program lacks rigor in engineering courses and does not contribute extensively developing skills that are necessary for being successful in an engineering program.

Students **($n = 142$):** Students have indicated that they want more hands-on learning and/or lab-based learning opportunities. Students also want more major-specific content in the first year and more exposure to the engineering profession and insight into professional engineering practice. Lastly, students indicated a desire for more/better quality attention from faculty, staff, and administrators and out-of-class learning opportunities.

Admissions:

- Many students start the first year with varying strengths in math (SOE requires precalculus). Of the applications received, lack of preparation in mathematics is among the most common challenges for incoming students.
- The SOE curriculum seems rigid and should have more flexibility to support students if they fall behind or get off track. In addition, Admissions wants to make sure that students are prepared/have the proper preparation for their courses when they arrive at the University.
- Admissions indicated that many first-year students want to know more about the various engineering programs to decide which to pursue at the time of application. First-generation students appear to not know what to ask when they have questions about their program/major; Admissions tries to be proactive in getting ahead of potential questions; would like additional examples or resources to share, a preview of courses or syllabi, updating the website to direct to more information of what to expect.

Laboratory Support Staff **($n = 4$):**

- Students are limited in their applied knowledge in instrumentation, measurement, and basic critical thinking skills as they enter engineering laboratories after the first year.
- Concern that students are accepted into engineering programs with limited possibility of completing their degree in 6 years.

Data and Stakeholder Driven Design Objectives

The taskforce conducted a series of meetings in the fall of 2021 to identify and consolidate common themes within the institutional data and stakeholder feedback to identify actionable items for the curriculum redesign. The focus of these discussions was on specifying desired outcomes, existing pain points, and necessary interventions. The summarized list of the actionable items of this exercise are:

- The combination of Calculus 1 and Physics 1 in the first semester provides additional challenges for students. The Math and Science sequence should be adjusted to allow for each program to specify program needs and avoid scheduling Physics1 and Calculus1 in the first semester.
- Laboratory experience should be integrated throughout the first-year engineering program
- Students should gain exposure to skills and tools related for their chosen engineering discipline, however, to allow for both internal and external transfers, first-year engineering courses should not serve as prerequisites for sophomore level discipline specific courses.
- Additional Student support and program oversight is necessary for a successful first-year engineering program.
- Students need increased emphasis on extracurricular activities to enhance student identification with the School of Engineering and the University.

- Engineering courses need to be divided into both program-specific and mixed discipline to both improve identification with the University and the individual engineering programs.

Conclusion

The systematic approach to collecting institutional data and soliciting stakeholder feedback has provided a set of design constraints and objectives for the first-year engineering program redesign revision. At Wentworth Institute of Technology, these considerations will be utilized to perform a comprehensive redesign of the first-year engineering curriculum to address the set objectives. The details of the program revision and evaluation and the additional findings of this study will be presented in a future paper.

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