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Full Paper: Effects of a Computational-Based First-Year Engineering Course on Student Preparation

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Abstract

This full paper presents research on the effects of a computational-based first-year engineering course on student preparation. In engineering education, there is significant discussion on what first year introduction content is most appropriate and useful for students in their academic and professional careers. In addition, how that content should be delivered is also of interest. Some engineering programs provide a conceptual framework of content to be delivered to new students. Other engineering programs may provide an interface platform for students to connect with practicing professionals to learn about their future careers. Some programs provide content that is computational-based, which exposes first year students to relevant calculations that are used in later courses. Additionally, there are some programs that incorporate elements of all three of these sets of content. If the computational-based content has a more direct relation to the engineering profession and later engineering courses, students would be exposed to basic concepts of future courses and have an early understanding of these relevant engineering topics. This research aims to present data which shows the effects that a computational-based first-year engineering course can have on student preparation for later engineering courses. This research is based on four years of data collection regarding how the computational-based spring semester first year course CE 113 (Civil Engineering Analysis) has impacted student performance in Physics 1, Statics, and Mechanics of Materials. This research also provides an outline for how other engineering programs can develop their own unique first-year computational-based courses that can have a positive impact on students' performance in later engineering courses.

Introduction and Background

A first year experience is critical in the long-term academic growth of a student. The literature is full of works that discuss the importance of a first year experience. Schluterman, Schneider, and Cassady (2010) discuss the importance of the evaluation of engineering problem solving skills of first-year engineering students [1]. The idea of delivering a more computationally-rich curriculum during the first-year was spawned at the authors' university upon an investigation of student performance during the second-year. Most notably, it was evident that civil engineering students struggled significantly in the second-year courses of Statics and Mechanics of Materials. In 2015, the 2-credit hour CE 113 (Civil Engineering Analysis) course was developed in order to expose first-year civil engineering students to more rigorous, computational-based content early in their academic careers in efforts to improve student understanding and performance in the second-year courses of Statics and Mechanics of Materials. The pre-requisite for the CE 113 course is Precalculus. The class meets for two 75-minute lecture sessions with an additional 75-minute laboratory component each week. Although the contact time is high for a 2 credit-hour course, much of the class time has group problem solving exercises and team-building engineering activities incorporated into the lecture topics. The CE 113 course was offered for the first time in the Spring 2016 semester and covers select topics in matrix Algebra; trigonometry-based Statics topics, which encompass approximately 70% of topics covered in a traditional 3-credit hour Statics course, and an introduction to Land Surveying. Assadollahi, Moore, and McGinnis (2016) present a detailed discussion on the development of the CE 113 along with time coverage of topics [2]. Table 1 gives a summary of the Statics topic coverage in the CE 113 course (Assadollahi, Moore, and McGinnis, 2016). It should be noted that at the author's home university, the pre-requisite for Statics is Physics 1 and not CE 113. The CE 113 course is a required course for all civil engineering students and is not required for other engineering majors (chemical, electrical, and mechanical).

Table 1. Time Coverage of CE 113 Statics Topics Compared to the Full Statics Course (Assadollahi, Moore, and McGinnis, 2016).

Topics	CE 113	Statics
Trigonometry Review and Vectors	1.5	4.5
Position Vectors and Dot Product	-	3
2D Equations of Equilibrium	6	4.5
3D Equations of Equilibrium	-	1.5
Moments of a Force	1.5	0.75
Moments Using Vectors and Cross Products	-	2.25
Couple Moments	3	3
Moment about and Axis	-	1
Uniform and Triangular Distributed Loads	3	1.5
Arbitrary Distributed Loads	-	1.5
2D Rigid Body Equilibrium	2	1
3D Rigid Body Equilibrium	-	1.5
Two and Three Force Members	0.5	0.5
Truss Analysis: Method of Joints	2	1.5
Zero Force Members	1	1
Truss Analysis: Method of Sections	-	0.5
Compound Beams and Frames	1.5	1.5
Machines	-	1.5
Internal Axial Forces and Torque Moments with Diagrams	3	1
Internal Shear and Moment at a Point	1.5	1
Friction	-	2
Composite Body Centroid	1.5	2
Centroid of Arbitrary Bodies	-	1
Composite Body Moment of Inertia	2	2
Moment of Inertia of Arbitrary Bodies	-	1
Total Hours	30	43

The CE 113 course best satisfies ABET Student Outcomes (1) and (7). ABET Student Outcome (1) states that students must demonstrate an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics [3]. This is best assessed through homework assignments. Various homework problems are multi-step and the "Homework" assessment category is computational and composed of topics such as matrix Algebra, vector mechanics, various statics topics, and various land surveying topics. ABET Student Outcome (7) states that students must demonstrate an ability to acquire and apply new knowledge as needed, using appropriate learning strategies [3]. Attainment of this outcome is best assessed through select course projects in which there is no obvious or clear solution. Figure 1 shows some examples of the Statics content that is assigned in the CE 113 course.

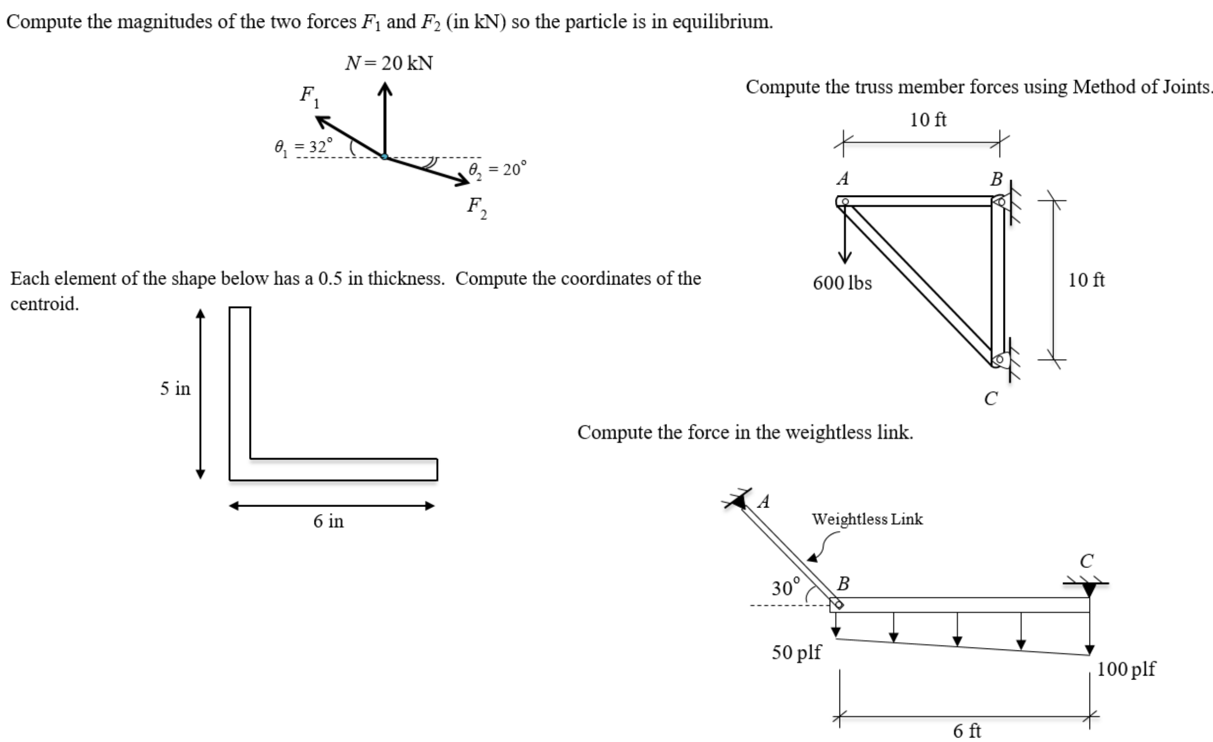

Figure 1. Sample CE 113 Homework Assignments and Quiz Problems.

The first objective of this study is to evaluate how student performance in Physics 1, Statics, and Mechanics of Materials have been impacted by prior enrollment in CE 113 based on four years of data collection. Since 70% of traditional Statics topics are covered in the CE 113 course, an investigation of how impactful the CE 113 course is with regards to Physics 1, Statics, and Mechanics of Materials courses is worthwhile. Additionally, an outline on how any engineering program can develop a first-year computational-based course is presented.

Data Management

With the approval of the university's Institutional Review Board (IRB), letter grades from Physics 1, Statics, and Mechanics of Materials classes of engineering students who have taken CE 113 were collected and compared with letter grades of students who have not taken CE 113 over a four year period of time. The student performance data is in the form of the letter grades

A, B, C, D, F, and W. The "W" grade is designated for students who withdrew from the course after the Add/Drop date but before the conclusion of the course. There is no distinction between students who earned an "F" due to performance and those who earned an "F" for other reasons. No personally identifiable information of students nor faculty members was collected.

Student Performance in Physics 1

Engineering student performance data in the Physics 1 course was collected over a four year period of time. Data is presented for students who were enrolled in Physics 1 either concurrently with CE 113 or after being enrolled in CE 113 (Population A). From Spring 2016 until Spring 2019, there were 33 engineering students in Population A. Data is also presented for engineering students who enrolled in Physics 1 but never enrolled in CE 113 or who enrolled in Physics 1 prior to enrolling in CE 113 (Population B). From Spring 2016 until Spring 2019, there were 159 students in Population B. Figure 2 shows a visual comparison between the percentages of students earning each grade for each of the population groups. The data shows that the percentage of students in Population A is higher for A and B grades, while the percentage of students in Population B is higher for C, D, F, and W grades. In fact, 0% of Population A earned a grade of D, F, and W. In general, students who were enrolled in CE 113 concurrently or prior to Physics 1 performed better than students who either never enrolled in CE 113 or enrolled in CE 113 after completing Physics 1.

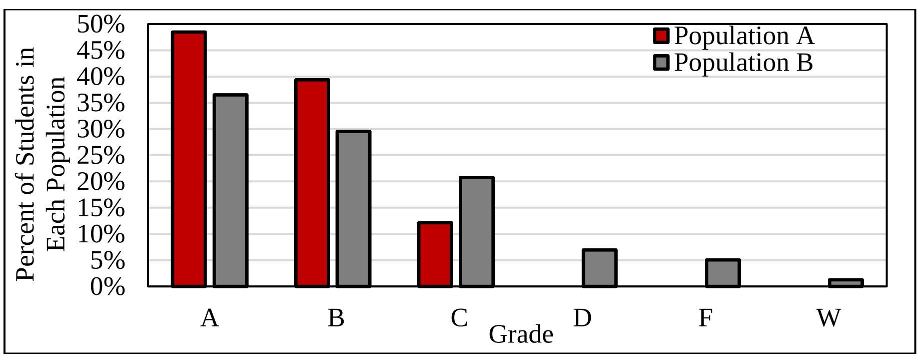

Figure 2. Physics 1 Grade Comparison.

Student Performance in Statics

Performance data in the Statics course was collected over four years. Data is presented for students who were enrolled in Statics either concurrently with CE 113 or after being enrolled in CE 113 (Population A). From Spring 2016 until Spring 2019, there were 40 engineering students in Population A. Data is also presented for engineering students who enrolled in Statics but never enrolled in CE 113 or who enrolled in Statics prior to enrolling in CE 113 (Population B). From Spring 2016 until Spring 2019, there were 129 students in Population B. Figure 3 shows a comparison between the percentages of students earning each grade for each population group. The data shows that the percentage of students in Population A is slightly higher for A and B grades. The percentage of students in Population B is slightly higher for C and F grades and significantly higher for D and W grades. In general, students who were enrolled in CE 113 concurrently or prior to Statics performed better than students who either never enrolled in CE 113 or enrolled in CE 113 after completing Statics.

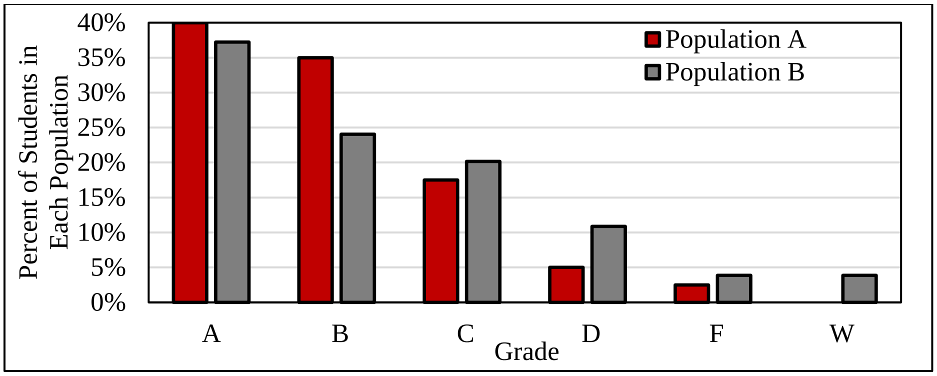

Figure 3. Statics Grade Comparison.

Student Performance in Mechanics of Materials

Performance data in the Mechanics of Materials course was collected over four years. Data is presented for students who were enrolled in Mechanics of Materials after being enrolled in CE 113 (Population A). From Spring 2016 until Spring 2019, there were 43 engineering students in Population A. Data is also presented for engineering students who enrolled in Mechanics of Materials but never enrolled in CE 113 (Population B). There were no students who enrolled in Mechanics of Materials prior to enrolling in CE 113. From Spring 2016 until Spring 2019, there were 61 students in Population B. Figure 4 shows a comparison between the percentages of students earning each grade for each population group. The data shows that the percentage of students in Population A is significantly higher for A and B grades. The percentage of students in Population B is slightly higher for the C grade and significantly higher for D, F, and W grades. In general, students who were enrolled in CE 113 prior to Mechanics of Materials performed significantly better than students who either never enrolled in CE 113.

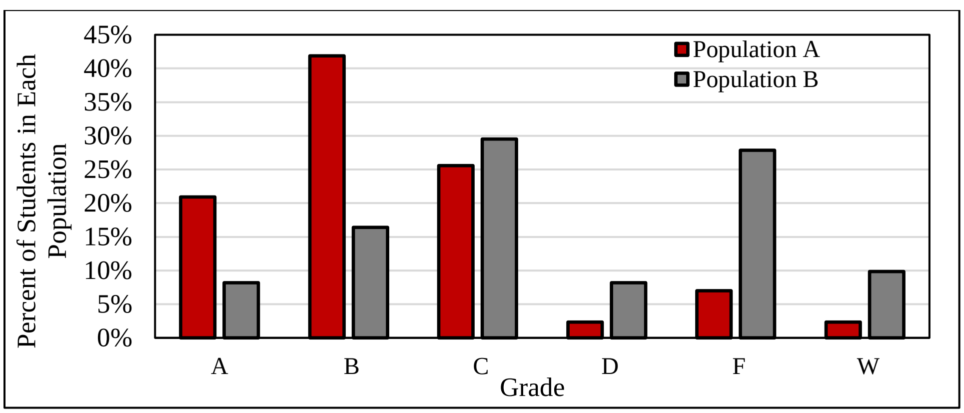

Figure 4. Mechanics of Materials Grade Comparison.

Course Development Algorithm

A simple algorithm is presented to develop a computational-based first-year course. First, identify the potential need for a computational-based first-year course. Perform program and curricular investigations that include course evaluations, student performance in later courses, and attrition rates throughout the program. Next, identify curricular and topic weaknesses in later courses. Develop content on these topics that can be delivered to first-year students. Be mindful of pre-requisite material. Cater the topics to the level of mathematics and science at which the first-year students are. Identify applicable ABET Student Outcomes. Collect data to show student performance in later courses. Repeat this process for the newly-developed course for continuous improvement. Figure 5 shows a flow chart of this algorithm.

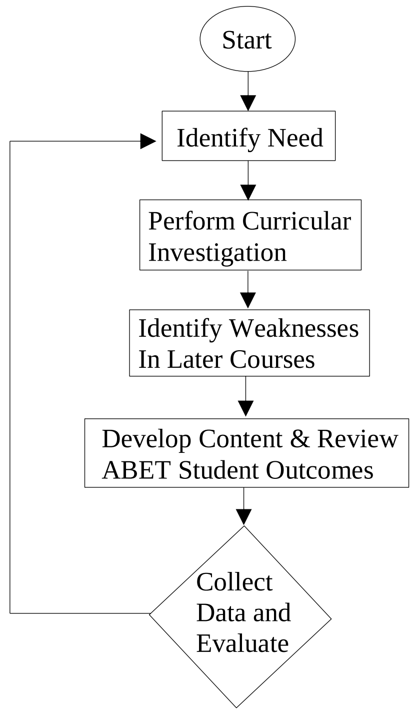

Figure 5. Flow Chart of First-Year Computational Course Development.

Conclusion and Discussion

Data is presented on the impact of a computational-based first-year engineering course on later courses. The grade distributions from Figures 2 through 4 show that students who completed the CE 113 course performed overall better in Physics 1, Statics, and Mechanics of Materials when compared to students who did not enroll in the CE 113 course. The CE 113 course best satisfies ABET Student Outcomes (1) and (7) based on the assessments within the course. Finally, an algorithm for the development of any computational-based first-year course is presented.

References

[1] Schluterman, H. A., Schneider, K., and Cassady, C.R. (2010) "Evaluating Engineering Problem Solving Skills of First-Year Engineering Students" *ASEE Midwest Section Conference, Lawrence, KS, 2010.*

[2] Assadollahi, A., Moore, C., and McGinnis, R. E., (2016) "Pedagogical Updates of the Civil Engineering Freshman Course Sequence" *First Year Engineering Experience Conference, Columbus, OH, 2016.*

[3] ABET Inc. "Criteria for Accrediting Engineering Programs, 2019-2020" ABET, Inc., Baltimore, Maryland, 2018, *<https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2019-2020/#GC3>* (May 13, 2020).