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# Creating Significant Learning Experiences in an Engineering Technology Bridge Course: a backward design approach

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## Introduction

Academic bridge courses are implemented to impact students' academic success by revising fundamental concepts and skills necessary to successfully complete discipline-specific courses. The bridge courses are often short (one to three weeks) and highly dense in content (commonly mathematics or math-related applications). With the support of the NSF-funded (DUE - Division of Undergraduate Education) STEM Center at Sam Houston State University (SHSU), we designed a course for upcoming engineering majors (i.e., first-year students and transfer students) that consists of a two-week-long pre-semester course organized into two main sessions. The first sessions (delivered in the mornings) were synchronous activities focused on strengthening student academic preparedness and socio-academic integration and fostering networking leading to a strong STEM learning community. The second sessions (delivered in the afternoons) were asynchronous activities focused on discipline-specific content knowledge in engineering. The engineering concepts were organized via eight learning modules covering basic math operations, applied trigonometry, functions in engineering, applied physics, introduction to statics and Microsoft Excel, and engineering economics and its applied decision. All materials in the course were designed by engineering faculty (from the chair of the department to assistant professors and lecturers in engineering) and one educational research faculty (from the department of chemistry). The course design process started with a literature review on engineering bridge courses to understand prior work, followed by surveying current engineering faculty to propose goals for the course. The designed team met weekly after setting the course goals over two semesters. The design process was initiated with backward design principles (i.e., start with the course goals, then the assessments, end with the learning activities) and continued with ongoing revision. The work herein presents this new engineering bridge course's goals, strategy, and design process. Preliminary student outcomes will be discussed based on the course's first implementation during summer 2021.

## Bridge Course Design and Development

The designed bridge course for the engineering technology students followed a similar approach to the chemistry bridge course previously reported in the 2021 ASEE Virtual Annual Conference [1]. The design model is referred to as the Integrated Course Design [2] and starts with the goals of the course, followed by an analysis of the situational factors surrounding the course, with the last step being the components of the course (i.e., assessment and feedback, learning activities, and instructional practices). Thus, the goals of the course were established before the content and learning activities were selected. The design team then explored the literature on bridge courses for college-level to determine goals for engineering technology (see table 1).

Table 1. Goals of reported engineering bridge courses.

| Ref. | Paper Title | Goals |
|---|---|---|
| [3] | Freshman Introductory Engineering Seminar Course: Coupled with Bridge Program | Academic success, leadership development, time management, the transition from high school/community college to the university, and professional development. |

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|---|---|---|
| | Equals Academic Success and Retention | |
| [4] | Model-Eliciting Activities (MEAs) as a Bridge Between Engineering Education Research and Mathematics Education Research | Problem-solving, teamwork, problem-based learning, math-engineering connection, development of ethical framework, use of model-integration activities in upper level courses. |
| [5] | The women in applied science and engineering summer bridge program: Easing the transition for first-time female engineering students | Review of chemistry, physics, and mathematics; sessions on Excel and HTML; information on university and student services (e.g., financial aid); foster community building and support systems. |
| [6] | Linear Algebra as a Bridge Course for First-year Engineering Students | E-learning system to promote prelearning strategies, problem-solving in pre-college algebra. |
| [7] | The WISE Summer Bridge Program: Assessing Student Attrition,<br>Retention, and Program Effectiveness | Academic reviews in science courses (mathematics, chemistry, physics), computer-based curricula in Maple, Excel, and HTML to better prepare students for their freshmen introductory engineering courses; forming initial contact with faculty, university resources, and other engineering students. |
| [8] | Summer Engineering Bridge Program at the University of Maryland Eastern Shore: Objectives and Enrichment Activities | Bridge the gap between high school preparation and expected standards for first-year engineering students; integration of life-skills, motivational, recreational, parental involvement, and academic components (e.g., mathematics concepts and skills to solve practical problems, comprehension of physical principles, engineering problem solving and teamwork, development of communication skills). |
| [9] | Work in Progress - An Engineering Bridge Program - The Foundation for Success for Academically At-Risk Students | Provide students interested in engineering with the foundational knowledge required to pursue their engineering program, thereby improving retention in college; assist students without the aptitude for engineering in making an early decision to select a more appropriate major, resulting in higher retention at the university. |
| [10] | Pre-Freshman Accelerated Curriculum in Engineering (PACE) Summer Bridge Program | Give the participants a 5-week mathematics course that would review algebra skills; other courses such as physics, chemistry, English, and computer science are also included in the curriculum. |
| [11] | Impacts of a summer bridge program in engineering on student retention and graduation | Raise the initial math course placement of students who otherwise would begin their engineering studies in courses below Calculus I; practice teamwork, obtain design experience, and compete in friendly competitions with other teams in order to build bonds between students. |
| [12] | Developing a Summer Bridge Course for Improving Retention in Engineering | Expose incoming students of any STEM discipline to a broad array of practical and theoretical engineering principles for the purpose of helping students make informed decisions about pursuing engineering as a study major prior to the start of their freshman year. |

| | | |
|---|---|---|
| [13] | MEP Summer Bridge Program: Mathematics Assessment Strategies | Introduction to engineering design philosophy and methodology: computer modeling of systems, processes, and components; design for customer satisfaction, profitability, quality and manufacturing; economic analysis; flow charting; sketching CAD; and teaming. |
| [14] | Creating a Successful Model for Minority Students' Success in Engineering: The PREF Summer Bridge Program | Three program components: social/cultural, academic, and professional development; the social/cultural component addresses family interaction and the transition from high school to college; the academic component includes those elements that affect students' present and future academic performance, specifically in Calculus, Physics, Chemistry and English; for professional development, participants complete a resume, a research paper and a presentation implementing library resources, and create an electronic portfolio showcasing their work. |
| [15] | Engineering Boot Camp: A Broadly Based Online Summer Bridge Program for Engineering Freshmen | Cultivating perseverance, math readiness, spatial visualization, adjusting to campus life, setting realistic academic expectations, choosing a career in engineering, academic and administrative resources, interaction with leaders and fellow engineering freshmen. |
| [16] | Transferring the Knowledge in a Bridge Program: Engineering Students Become Coaches | Build community among the participants and the current engineering students; introduce the participants to computing; introduce the participants to engineering and more specifically incorporate: engineering documentation and design projects, team building and team competition, use of computer software such as Microsoft Word, Excel and PowerPoint, problem solving skills, research activities; help the students achieve an attitude of "I can be a successful engineering student;" address issues relevant to freshman students such as the function of the registrars office, financial aid, and academic advisement |
| [17] | Analysis of the Impact of Participation in a Summer Bridge Program on Mathematics Course Performance by First-Semester Engineering Students | Improvement of the students' math course placement; providing students with activities in engineering and computer science in order to excite them about their future studies. |
| [18] | A Bridge to Engineering: A Personalized Precalculus (Bridge) Program | Remediate students needing precalculus help for Engineering Calculus I before their first semester in college, student retention, keeping students on their academic track. |

### *Goals*

Following the approach of Ashley et al. [19], the course goals were split into three categories: academic, psychosocial, and departmental. Two academic success goals and one psychosocial goal were selected based on the literature review. Then the department of engineering technology at SHSU was surveyed for additional goals at the department level. Figure 1 presents the selected goals for the engineering technology bridge course at SHSU.

**Goals:**

**Academic Success Goals**

- Provide math and physics remediation in the context of engineering situations.
- Increase the retention of STEM majors during the first two years of engineering degrees.

**Psychosocial Goals**

- Provide an environment to foster networking amongst students in the engineering degrees.

**Departmental Goals –** None additional already included.

Figure 1: Goals of the engineering bridge course.

### *Situational factors*

After the goals of the course were clear, the course design team set the situational factors that surround the proposed engineering bridge course. The situational factors correspond to relevant information foundational to starting the design process (e.g., learners' characteristics, the institution, and instructors) and are specific to every educational institution. The situational factors guide decisions on what best ways to deliver the assessments and feedback to the participants [2]. The situational factors are summarized in table 2.

Table 2: Situational factors related to the engineering technology bridge course.

| Factor | Characteristics |
|---|---|
| Instructors | 1) **Faculty** from the Department of Engineering Technology will be eligible to teach the course.<br>2) **Teaching assistants:** the Department of Engineering Technology will hire teaching assistants for the course. TAs could participate halftime or full-time in the bridge course sessions. |
| Participants | 1) **STEM majors** enrolled in engineering degrees during the following Fall semester.<br>2) **Recruitment**: posting information on the STEM Center website and emailing first-time college students or transfer students during summertime.<br>4) **Diagnostic test**: students will complete a 15-min math test to evaluate their math level. Those students scoring at the high end of the test may choose not to complete the course.<br>3) **Number of participants**: 30 or fewer. This supports implementation fidelity as instructors and TAs will not be overwhelmed by many students, especially during the first-time implementation. In subsequent deployments, the enrollment will be increased. |
| Course sessions | 1) **Instructional team**: sessions are managed by (2 – 4) faculty with (2 – 3) teaching assistants.<br>2) **Course duration**: two weeks during the summer terms.<br>3) **Work sessions**: Morning sessions for learning frameworks activities in collaboration with other bridge course participants in math and chemistry. Afternoon session planned for 2-3 hours of active work on engineering-related activities. |
| Physical space | 1) **STEM Center:** active learning classrooms (two specialized classrooms) with a capacity of 30 students each. |

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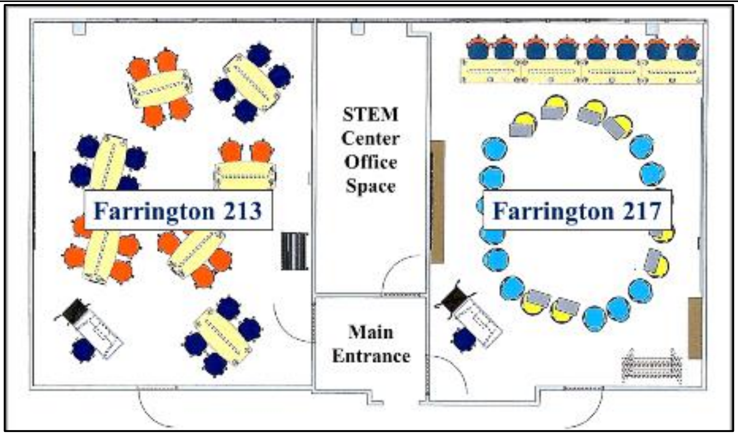
|---|---|
| | <br><br>2) **Department of Engineering Technology** classrooms and workshop spaces available during summer terms. |
| Other relevant factors | Due to the COVID-19 pandemic:<br>• Plans for synchronous sessions for learning frameworks content.<br>• Plans for asynchronous engineering learning materials delivered via course management system (i.e., Blackboard).<br>• Consideration of TA tutoring sessions to support students during asynchronous work in the afternoons. |

***Assessment and feedback***

The assessment and feedback components were identified to address the goals of the course. Below is a summary of the assessment strategies per goal chosen.

1. Provide math and physics, remediation in the context of engineering situations: Reported assessments to utilize:
    - Math skills (without a calculator): Math-Up Skill Test (MUST) [20]
    - Quantitative Reasoning Instrument [20]
    - Other in-house questionnaires (targeting engineering technology related context)
2. Increase the retention of STEM majors during the first two years of engineering degrees: Track student performance and their majors over two semesters after the bridge course.
3. Provide an environment to foster networking amongst students in engineering degrees. Implement data collection protocols:
    - Classroom observations by an external evaluator.
    - Surveys/questionnaires related to their experience with group work during and after the bridge course.

***Learning materials – Course content***

The bridge course focused on its applied math and physics remediation goal by using solved problems in those disciplines clearly linked to the practical engineering situations and problems. For example, instead of working out math problems typically encountered in engineering courses, teaching and learning materials were created and framed within the engineering context that will require math or physics knowledge to solve. Thus, bridge course participants were exposed to everyday engineering activities that could not be solved without math or physics skills. To this end, three main ideas were included in the course, and they were connected to the specific math and physics content that students needed remediation before starting their semester-long engineering courses. Reference textbooks were instrumental in creating the learning materials [21 - 26]. The three main ideas are:

1. **Units and Measurement**: Introduction to the International System and the Imperial System
    a. Get students acquainted with the two systems.
    b. Focus on significant differences for units of energy, mass, and distance.

2. **Problem-solving in Engineering**
    a. Physics and chemistry-related situations in the engineering world
        i. Material science
        ii. Forces
    b. Math applications in engineering
        i. Trigonometry
        ii. Basics of vector operations
        iii. Basics of calculus (rate of change, slope, velocity, acceleration, etc.)
        iv. Linear equations (substitution method, solution, etc.)

3. **Calculations in Engineering**
    a. Basics of Excel (or other programs)
        i. Formula input
        ii. Calculation sheets
    b. Graphing data in Excel
        i. Physics data
        ii. Chemistry data
        iii. Other types of data sources

***Learning materials – Instructional practices***

All materials were designed by engineering technology faculty (i.e., one professor, two assistant professors, and one lecturer instructor) and one educational research faculty from the department of chemistry who has experience with the past chemistry bridge courses. The educational research faculty had experience designing a similar bridge course at the institution [1] and helped the engineering technology faculty navigate the design process. After setting the course goals, situational factors, and assessments, the designed team met weekly over two semesters to create the learning materials and the corresponding instructional practices. Early on in the design, it was decided that the course would be delivered asynchronously due to the COVID-19 pandemic. Thus, the materials were organized into a sequence of learning modules that participants can complete over the two weeks of the bridge course. The learning modules were initially distributed amongst the course design team for content creation and later revised by all the team members. Finally, two undergraduate students (teaching assistants) worked on the modules and provided final suggestions and revisions to the content. Each learning module had its own formative and summative assessments to track student progress and completion of the work. During the implementation of the course, instructors and teaching assistants checked and graded the assignments. Table 3 presents the learning modules for the final course and the corresponding learning objectives.

Table 3: Learning modules in the Engineering Technology Bridge Course.

| Module | Title | Learning Objectives |
|---|---|---|
| 0 | Basic math operations and graphical interpretation | • Use mixed numbers to calculate dimensions of objects, land area, and simple estimations of material required in industrial applications.<br>• Summarize the information presented in a graph.<br>• Formulate conclusions from data presented in graphical form. |
| 1 | Units and Measurements | • Understand the importance of units and measurements in the field of Engineering.<br>• Different systems of units, conversion from one system to another. |
| 2 | Applied Trigonometry | • Understand the basics of Trigonometry relations and Laws.<br>• Application of Trigonometry in computer vision and estimation of aircraft speed. |
| 3 | Functions in Engineering | • Use linear equations to solve problems.<br>• Recognize the quadratic function and its graphical representation.<br>• Work with exponents in calculations. |
| 4 | Introduction to Engineering Statics | • Definition and basics of vectors.<br>• Resolution and components of vectors.<br>• Vector addition using graphical and analytical methods.<br>• Application of vectors in the Engineering field. |
| 5 | Introduction to Applied Physics | • Perform calculations related to forces on engineering examples.<br>• Use the concept of work in simple calculations.<br>• Understand power and energy in physics applications. |
| 6 | Introduction to Microsoft Excel | • Explain the basics of the Excel workbook, including cells and their addresses, a range, and how to create formulas.<br>• Discuss and describe the origin of the spreadsheet.<br>• Enter data into a spreadsheet.<br>• Create a formula in a spreadsheet. |
| 7 | Engineering Economics | • Perform calculations with simple interest and compound interest.<br>• Draw cash flow diagrams and determine the present, future, and annual worth. |
| 8 | Decision Making | • Use present, and future worth estimates to make decisions and provide recommendations.<br>• Use annual worth estimates to make decisions and provide recommendations. |

**Summer 2021 – Course implementation**

The STEM Center at SHSU has supported 295 students since its initial bridge course offering in 2018 (See table 4). Five tracks are offered, including the engineering bridge course presented in this paper. During summer 2021, the engineering bridge course had a low enrollment compared to the other tracks available. This might be due to its remote learning approach and low interest that incoming students had in such method of instruction due to burnout with the instructional strategies used in online/remote courses. However, the engineering faculty was not discouraged as the first time implementation of the math course in 2018 was equally low.

The teaching team consisted of a professor), one assistant professor, and one lecturer from the department. The educational researcher was also part of the teaching team. All of the faculty were also members of the course design team. Additionally, two teaching assistants (undergraduate engineering technology students) were hired and trained on the learning modules and activities two weeks before the summer bridge course.

Table 4: Summer Bridge Courses student enrolment between 2018 and 2021.

| **Preparatory Pathway to Target Course** | **Summer 2018 – in-person course** | **Summer 2019 – in-person course** | **Summer 2020 – online course** | **Summer 2021 – online course** |
|---|---|---|---|---|
| Pre-Calculus or Trigonometry (MATH 1314 & 1316 & 1410) | 10 | 13 | 29 | 33 |
| Calculus I (MATH 1420) | -- | 14 | 21 | 7 |
| General Chemistry I (CHEM 1411) | -- | -- | 60 | 67 |
| General Chemistry II (CHEM 1412) | -- | -- | -- | 32 |
| Engineering Technology (ETEC 1010) | -- | -- | -- | 9 |
| **Totals** | **10** | **27** | **110** | **148** |

The course was delivered four weeks before the Fall semester started between July 19 and 30, 2021. The participants took advantage of the opportunity to engage with faculty and teaching assistants to improve their preparation for the upcoming fall semester. Retention of students during summer 2021 was a particular issue. Only four students fully completed the two-week course and related activities of the nine enrolled students. We reached out to the missing students who reported that work and family responsibilities limited their ability to complete the course. Thus, although they wanted to partake in the class, they needed to focus on critical personal needs before the start of the semester. In the future, the STEM Center will move to on-campus events to promote higher participation and retention, which might encourage the successful completion of all activities. Under the situational factors of the summer 2021 implementation (i.e., online delivery due to COVID-19), we believe the social activities integrated into the course (i.e., synchronous morning classes, invited speakers, faculty and administrator's meet and greet) did keep students engaged. However, on-campus activities are vital for students and faculty connections to strengthen and grow naturally.

Of the students that completed the course, all four reported feeling more prepared for the engineering coursework in the future and felt more confident about their capabilities in engineering based on the end-of-course survey. Due to the low completion rate of the course, the assessment instruments used in the class do not provide representative results to determine the impact on students' understanding of the content covered in the course. The STEM Center staff will track students' performance in their engineering majors and collect more data in future implementations of the bridge course to determine its impact on the participant's academic performance.

Overall, the engineering technology teaching team concluded that the course content and activities effectively kept the students engaged and active during the two weeks. Those participating students got to engage with future faculty personally and know about the dynamics and organization of their major's department. Additionally, the students got to build the starting point of their social network within the university, not just with other students in their majors but across the College of Science and Engineering Technology.

## Conclusions

This paper presented the design process for a novel engineering technology bridge course. The course focused on remediation of applied math and physics concepts to strengthen student academic preparedness. It also promotes socio-academic integration fostering networking with faculty and students in engineering to foster a strong learning community. The bridge course experience may lead to higher retention of engineering and technology degree students. The STEM Center and the course design team are confident the bridge courses are a beneficial experience for the participants and will continue to implement the courses in the upcoming years. Next year, we plan to revise the learning materials and deliver the engineering course to assess its impact on the academic success of engineering technology majors.

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