

2023 ASEE IL-IN Section Conference

April 1, 2023

Edwardsville, IL

SOUTHERN ILLINOIS UNIVERSITY EDWARDSVILLE



SCHEDULE OVERVIEW

8:30 - 8:45	Welcome			
	Chris Gordon,	Conference Chair		
	Doug Tougaw	, ASEE President-E	lect	
9:00 - 10:00	Paper Session 1	Paper Session 2	Workshop (60 minutes)	
Diversity, Equity, and Inclusion in STEM Education and Outreach ey		Best practices in outreach, retention, and the first-year experience	Rethinking Engineering Course Design Using a Human-Centered Engineering Design Framework	
	Session Chair: Amardeep Kaur	Session Chair: Chris Gordon		
10:15 - 11:15	Paper Session 3	Paper Session 4		
	Beyond Boundaries: Exploring the Intersection of Access, Pedagogy, and Technology in Engineering Education Session Chair: Sinan Onal	Innovations in STEM Education: Strategies for Sustainable and Transformative Learning Session Chair: Saad Ullah		
11:30 - 12:30	Poster Session and Lu	nch	1	
12:45 - 1:30	Paper Session 5	Paper Session 6	Workshop (45 minutes)	
	Labs and Experiential Learning	Pedagogy and assessment	Improving Course Outcomes and why accessibility matters: How	
	Session Chair: Ralph	Session Chair:	to add ClassTranscribe to	
1.45 - 2.30		Action Business Me	peting	
2:30 - 4:00		Keynote and Awa	rds	

SCHEDULE AT A GLANCE

8:30 - 8:45 AM	Welcome
8:45 - 9:00 AM	Break
9:00 - 10:00 AM	SESSION 1 -Paper Sessions 1 & 2, Workshop 1
10:00 - 10:15 AM	Break
10:15 - 11:15 AM	SESSION 2 - Paper Sessions 3 & 4
11:30 - 12:30 PM	Lunch and Poster Session
12:45 -1:30 PM	SESSION 3 - Paper Session 5 & 6, Workshop 2
1:45 - 2:30 PM	Section Business Meeting
2:30 - 2:45 PM	Break
2:45 - 4:00 PM	Keynote and Awards

WORKSHOP SCHEDULE (Workshops will be held in EB 1170)

9:00 – 10am – Rethinking Engineering Course Design Using a Human-Centered Engineering Design Framework

Saadeddine Shehab, Taylor Tucker, and Alexander Pagano (University of Illinois at Urbana-Champaign)

Human-centered design (HCD) has been an important player in the future direction of engineering education. HCD offers a promising approach to both promote situated learning in engineering design projects and facilitate students' learning of modern engineering skills. However, it can be challenging to integrate HCD within established engineering courses due to competing objectives and limited instructional time. Furthermore, without guidance or training, engineering faculty may find it nebulous to connect HCD outcomes to their own course learning objectives or performance indicators. Thus, the integration of human-centered design and engineering (i.e., human-centered engineering design, or HCED) should leverage HCD approaches and mindsets to promote student learning of practical engineering design skills in a manner that is cohesive with the constraints and learning curves that engineering faculty face.

To provide support in learning about and applying human-centered design, we developed an evidencebased human-centered engineering design framework that connects HCD mindsets and other pertinent learning metrics (such as ABET outcomes and KEEN framework elements) to engineering design activities. Faculty members can use the framework as a tool to facilitate their thought processes and strategies regarding evaluating existing courses, identifying opportunity areas for incorporating HCED elements, developing new HCED-related course learning objectives, defining students' performance indicators, and connecting objectives and indicators to ABET's student learning outcomes. They can also employ the framework to assist in visualizing learning trajectories, which may be helpful for developing assessment tools and making organizational changes. In this workshop, we will present the framework and lead participants in applying it to their own courses as shown in Table 1. We will encourage participants to bring course syllabi and guide them in using the framework to identify opportunity areas within their course.

12:45 -1:30pm Improving Course Outcomes and why accessibility matters: How to add ClassTranscribe to your course

Lawrence Angrave (University of Illinois Urbana-Champaign)

ClassTranscribe - "Netflix for learning" - is an open-source system developed and used by engineering faculty and students at the University of Illinois Urbana-Champaign. ClassTranscribe improves learning for all students and provides an accessible interface to help make courses more inclusive. In this workshop you can learn how we're using it in U of I courses to improve engineering education, how you can provide videos with accurate captions (using best-in-class a combination of automated and crowd sourcing techniques), and how accessibility features helps students succeed. You'll also learn to use the latest features that can turn your lecture video content into equivalent course notes, including latex, html, pdfs and epub formats.

This session will allow participants to explore the student and instructor interface of ClassTranscribe, including creating books and "I-Notes" from lecture videos. Workshop attendees will be able to use ClassTranscribe (<u>https://ClassTranscribe.illinois.edu</u>) in their own courses. Attendees will need access to a browser (laptop or tablet with internet access) to access the ClassTranscribe website.

DETAILED SCHEDULE

SESSION 1: 9:00 – 10:00am

Paper Session 1: Diversity, Equity, and Inclusion in STEM Education and Outreach

Location: Engineering Building 1033

Session Chair: Amardeep Kaur

9:00 – 9:15am	Factors that Influence the Pursuit of
	Collegiate Aviation Maintenance Degree
	Programs: The Differences Between Women
	and Men Students
	Ashley Habig and Caroline Marete (Purdue
	University)
9:15 – 9:30am	Connecting motivations for graduate school
	with learning experiences of engineering
	undergraduates: A gender perspective
	Hsinju Chen, Mayura Kulkarni, Alyssa
	Huang, Mei-Yun Lin, Roland D. Cusick,
	Holly M. Golecki (University of Illinois
	Urbana-Champaign)
9:30 – 9:45am	Characterizing the Educational Effectiveness
	of STEM Demonstrations at Science-focused
	Events for Adult Audiences
	Tom Lucas (Purdue University)
9:45 – 10:00am	Feasibility of Using the CAPE Framework to
	Identify Gaps in Equity-focused CS
	Education Research
	Joey Reyes (Knox College &
	CSEdResearch.org), Monica M. McGill
	(CSEdResearch.org)

SESSION 1: 9:00 - 10:00am

Paper Session 2: Best practices in outreach, retention, and the first-year experience

Location: Engineering Building 1150

Session Chair: Chris Gordon

9:00 – 9:15am	Work-in-Progress: Partnerships to Create
	Opportunity through Informal Learning
	Kristin Giglietti, H. Rex Gaskins, Marcia
	Pool (University of Illinois Urbana-
	Champaign)
9:15 – 9:30am	Engineering Technology Students'
	Perceptions of a Transformed Gateway
	Course
	Rustin Webster, Matthew Turner, Brittany
	Newell (Purdue University)
9:30 – 9:45am	Work-In-Progress: An Updated Peer
	Mentorship Strategy for First Year
	Engineering
	Benjamin D. McPheron (Anderson
	University)
9:45 – 10:00am	Effect of Connected Courses on Student
	Retention in the First year Curriculum
	Chris Gordon (Southern Illinois University
	Edwardsville)

SESSION 1: 9:00 - 10:00am

Workshop 1: Rethinking Engineering Course Design Using a Human-Centered Engineering Design Framework

Location: Engineering Building 1170

Saadeddine Shehab, Taylor Tucker, and Alexander Pagano (University of Illinois at Urbana-Champaign)

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engineering design skills in a manner that is cohesive with the constraints and learning curves that engineering faculty face.

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SESSION 2: 10:15 - 11:15 am

Paper Session 3: Beyond Boundaries: Exploring the Intersection of Access, Pedagogy, and Technology in Engineering Education

Location: Engineering Building 1033

Session Chair: Sinan Onal

10:15 – 10:30am	Transitioning between a flipped civil engineering classroom and fully online learning: Lessons learned before, during, and after the COVID-19 Pandemic Ryan Fries and Chava Copalan (Southern
	Illinois University Edwardsville), Ravali
	Vennu, (Bechtel)
10:30 – 10:45am	System Design, Evaluation and Applications of Domain Term Extraction from Engineering Videos
	Jiaxi Li, Ninghan Zhong, Rob Kooper,
	Lawrence Angrave (University of Illinois
	Urbana-Champaign
10:45 – 11:00am	Exploring the Potential Benefits and Risks of
	ChatGPT in Engineering Education
	Sinan Onal (Southern Illinois University
	Edwardsville)
11:00 – 11:15am	Improving Access to Engineering Education:
	Unlocking Text and Table Data in Images and
	Videos
	Uchechukwu Uche-Ike, Lawrence Angrave
	(University of Illinois at Urbana Champaign)

SESSION 2: 10:15 – 11:15 am

Paper Session 4: Innovations in STEM Education: Strategies for Sustainable and Transformative Learning

Location: Engineering Building 1150

Session Chair: Saad Ullah

10:15 – 10:30am	Building a Sustainable Institutional Structure
	to Support STEM Scholars – Scholar Survey
	Data
	D. W. Mueller, Jr, Josué Njock Libii, Donna
	D. Holland, O. David Momoh, Peter A. Ng,
	Reynaldo M. Pablo (Purdue University Fort
	Wayne), Suleiman Ashur (Eastern Michigan
	University)
10:30 – 10:45am	Work-in-Progress: Sustainability Education in
	Law and Engineering
	Tyler J. Smith (Bradley University)
10:45 – 11:00am	Curricular Priority and Transformation of
	Construction Engineering Capstone Design
	Course
	Brandon Fulk, Kyubyung Kang (Purdue
	University)
11:00 – 11:15am	Work-In-Progress: Can We Create a Model
	Program: Insights into the Effectiveness of a
	Research Experience for Undergraduates
	La'Tonia Stiner-Jones (The Ohio State
	University)

POSTER SESSION 11:30 -12:30

Location: Engineering Building Atrium

The Global STEAM Academy – a conduct to promote STEM and Computational Thinking to non-privileged communities in the USA and Latin America through remote learning Corresponding author: Marcelo Caplan (Columbia College Chicago)

Work-in-Progress: Gamification of Security Education Corresponding author: Minh Duong (University of Illinois – Urbana Champaign)

Examining student career social capital using the Mentoring Social Capital Instrument Corresponding author: Adrian Gentry (Purdue University)

Work-in-Progress: The development and impact of digital notes on students with and without disabilities in engineering and computing courses

Corresponding author: Noah Gersich (University of Illinois – Urbana Champaign)

Applications of Piezoelectric Materials in Sports

Corresponding author: Najmus Saqib (University of Indianapolis)

Case Study of Adaptions of Concept Mapping in a Multidiscipline Engineering Course Corresponding author: Victoria Shao (University of Illinois – Urbana Champaign)

Analyzing accuracy of Word Error Rates (WER) of Artificial Intelligence (AI) generated captions compared to professional human generated captions in engineering lecture videos Corresponding author: Jessica Singh (University of Illinois – Urbana Champaign)

Undergraduate Student led Laboratory Development

Corresponding author: Narangoo Tumur (Southern Illinois University Edwardsville) Work-in-Progress: Understanding the needs of engineering and STEM students with disabilities

Corresponding author: Sujuit Vardahan (University of Illinois – Urbana Champaign)

Work In Progress: Advances in an Augmented Reality Accessible Technology Project for Engineering Education

Corresponding author: Yun (Tiger) Wang (University of Illinois – Urbana Champaign)

SESSION 3: 12:45 – 1:30 pm

Paper Session 5: Labs and Experiential Learning

Location: Engineering Building 1033

Session Chair: Ralph Tayeh

12:45 – 1:00pm	The Development of Low-Cost
	Programmable Logic Controller Labs for a
	Control Systems Course
	Benjamin D. McPheron, Devin J. Goodrich
	Michael Q. Mullinix (Anderson University)
1:00 – 1:15pm	A Hands-on Activity on Human-Powered
	Lights For a Lab Experiment and In-Class
	Demonstration
	Purno Ghosh, Frances Harackiewicz, Omer
	Elsanusi (Southern Illinois University
	Carbondale)
1:15 – 1:30pm	Work in Progress: Work in Progress: A
	Simple Plug-in Implementation of Extreme
	Audio Stretching
	Ethan Laptew, Yufeng Lu (Bradley
	University)

SESSION 3: 12:45 – 1:30 pm

Paper Session 6: Pedagogy and assessment

Location: Engineering Building 1150

Session Chair: Keqin Gu

12:45 – 1:00pm	Using Concept Maps in an Undergraduate
	Heat Transfer Course
	Najmus Saqib (University of Indianapolis)
1:00 – 1:15pm	Specifications Grading in Undergraduate
	Fluid Mechanics
	Julie Mendez (Indiana University-Purdue
	University Columbus)
1:15 – 1:30pm	Using Design Review in the Classroom
	Thomas J. Dobrowski (Purdue Northwest)

SESSION 3: 12:45 – 1:30 pm

Workshop 2: Improving Course Outcomes and why accessibility matters: How to add ClassTranscribe to your course

Lawrence Angrave (University of Illinois Urbana-Champaign)

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SECTION BUSINESS MEETING, KEYNOTE AND AWARDS: 1:45 – 4pm Location: EB 1033

Remarks: ASEE President-Elect Doug Tougaw, dean of the College of Engineering at Valparaiso

Keynote Address: "Green Ink, Great Gobs of Points, & Good Grades" by Dr. Robert Stwally III (Purdue University), 2022 recipient of the ASEE IL-IN Section Outstanding Teaching Award. **Awards**: Best Paper, Best Diversity, Equity, and Inclusion Paper, 2023 Outstanding Teacher, 2022 Outstanding Campus Representative

MAPS

https://www.siue.edu/maps/?keyword=engineering-building



Free Parking (weekends) in Lot B

ENGINEERING BUILDING



Paper Session 1: Diversity, Equity, and Inclusion in STEM Education and Outreach

Location: Engineering Building 1033

Session Chair: Amardeep Kaur

9:00 – 9:15am	Factors that Influence the Pursuit of
	Collegiate Aviation Maintenance Degree
	Programs: The Differences Between Women
	and Men Students
	Ashley Habig and Caroline Marete (Purdue
	University)
9:15 – 9:30am	Connecting motivations for graduate school
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	undergraduates: A gender perspective
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	Education Research
	Joey Reyes (Knox College &
	CSEdResearch.org), Monica M. McGill
	(CSEdResearch.org)

Factors that Influence the Pursuit of Collegiate Aviation Maintenance Degree Programs: The Differences Between Women and Men Students

Ashley Habig* Purdue University <u>Habig1@purdue.edu</u>

Caroline Marete* Purdue University <u>cmarete@purdue.edu</u>

*Corresponding author

IRB # 2023 - 80

Abstract

The Federal Aviation Admiration (FAA) reported that in 2021, 2.63% of all Airframe and Powerplant (A&P) technician Certificate holders were women. Over the years, various studies have demonstrated the underrepresentation of women and other minorities in most aviation professions. There is consensus among industry stakeholders that proactive measures are needed to increase the participation of women in the traditionally male-dominated field. In collegiate aviation programs, the ratio of female to male students pursuing all aviation majors is low. The current gender imbalance in aviation careers and aviation collegiate programs may be attributed to many factors among them the way women are influenced to pursue these fields.

This study identified and analyzed the factors that influence college students in the selection of aviation maintenance degree programs. The study was conducted using a survey sent to undergraduate students enrolled in an aviation maintenance program at a large midwestern university. Survey data was analyzed statistically using a two-tailed unpaired t-test of significance. Researchers found that there is no statistically significant difference between men and women in nine of the ten factors that influence the selection of aviation maintenance as a choice of degree program. The factor 'number of job opportunities the field offers and their level of pay' was statistically significant with men having a higher mean in its perceived influence. Notably, both women and men cited passion, interest, and aptitude in the subject as the most influential factor when choosing their degree program. Based on these findings, there are no shattering differences between what draws men and women to aviation maintenance professions, as such, it is concerning that more women are not choosing aviation maintenance as a career. Researchers recommend further studies such as interviews to examine why women are choosing not to pursue careers in aviation maintenance.

Keywords: Aviation; A&P, Collegiate aviation, aviation maintenance, diversity, women, female

Introduction

According to the 2021 FAA data, out of the estimated 313,093 active Airframe and Powerplant (A&P) Certificate technicians, only 8,231 (2.63%) were women. One can argue that progress has been made, considering that this number has more than doubled in percentage since 1996, when only 1.22% of the 329,239 A&P mechanics were women (FAA, 2023). However, the meager increase in representation of women in the aviation maintenance field has yet to show any real impact on the prevalent gender imbalance in the aviation maintenance technicians' professions. Generally, women are underrepresented in most aviation professions. For instance, only eight percent of the top 100 airline CEOs are female (Institute of Women of Aviation Worldwide, 2022).

In collegiate aviation programs, especially maintenance or engineering technology programs, female students pursuing all aviation majors are noticeably fewer. The lack of gender diversity in the aviation and aerospace industry may be attributed to many factors among them the way women are influenced in choosing careers before entering college. Marete et al. (2022) identified five factors that have contributed to the current gender gap in aviation and aerospace collegiate education. These are lack of mentorship, role models, and networking opportunities; lack of effective recruitment, retention, and outreach programs in aviation colleges; lack of gender diversity in the general STEM fields; gender stereotyping and traditional women's role in society; and persistent masculine culture in aviation and aerospace professions. Furthermore, the Women in Aviation Advisory Board (WIAAB) *Recommendations Report* released in March 2022 emphasizes the need to attract women to aviation careers at an early age (WIAAB, 2022). To increase the pipeline of women that pursue aviation careers, it is important that young girls learn about aviation careers and be able to envision themselves in those careers early in life.

Problem Statement

Based on extant literature and personal experiences as women in aviation professions, researchers of this study hypothesize there be a significant difference in the factors that influence pre-college women and men to enroll in collegiate aviation maintenance programs. An example is having family members or friends who already work in aviation maintenance professions. Historically, the aviation maintenance profession is male-

dominated and a majority of people in our society view it as such. This stereotypical view may lead young women to believe that they are not qualified or fitting to pursue careers in this field, hence shy away from trying even when they are as qualified as their male counterparts. Furthermore, the likelihood of only working with male colleagues may cause some women role models in the workplace can exacerbate the challenges young may face if they choose to pursue careers in this field. Nevertheless, some women have broken these barriers. It is worth knowing how these few women that thrive in this field have done so. This study aims to identify the factors that influence the selection of aviation maintenance degree programs. The findings of this study will contribute to the body of knowledge on the recruitment of women to aviation professions. Specially, the findings will be beneficial to college recruitment specialists who seek to increase the enrollment of women in aviation maintenance programs.

Research Question

The study will answer the following research question,

- RQ. Is there a significant difference in the factors that influence pre-college students to select an aviation maintenance collegiate program?
 - a. Ho: There is a significant difference in the factors that influence women pre-college students and men pre-college students when choosing an aviation maintenance collegiate program.
 - b. Ha: There is not a significant difference in the factors that influence women pre-college students and men pre-college students when choosing an aviation maintenance collegiate program.

Literature Review

Between 1996 and 2021, the number of women holders of an FAA Airframe and Powerplant (A&P) Certificate increased from 1.22% (1996) to 2.63% (2021). This trend is summarized in figure 1. It is unclear why despite the numerous studies that show the benefits of diverse workforces, more women have not joined the aviation maintenance profession. This slow progress should be a point of concern for all stakeholders' holders involved.



Figure 1. Total US A&Ps compared to women A&P holders

Industry projections indicate that the aviation and aerospace industry will experience a serious workforce shortage in the near term (Boeing Commercial Market Outlook, 2022). Among the reasons for the shortage are the aging and retiring baby boomers generation, and not enough generation Z entering the aviation labor force (Oliver Wyman, 2022). It is anticipated that the industry will need between 12,000 to 18,000 additional aviation maintenance professionals to meet the industry needs.

There is a demonstrable need to tap into every talented individual for the aviation and aerospace industries to meet future workforce needs, yet many minority groups including women are significantly underrepresented in the industry workforce. The impending workforce shortage will affect all stakeholders in the industry, from small Maintenance Repair and Overhaul (MRO) stations to the largest airlines. Newcomer et

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al. (2018) reported that women in maintenance professions are perceived differently by other women and men as relates to workplace environment safety, women's social acceptance, women's career choice appropriateness, and women's advancement opportunities. From women's perspective, women in maintenance professions reported feelings of not being socially accepted and being less likely to advance in their careers. On the other hand, men felt that women were socially accepted and just as capable of advancement (Newcomer et al., 2018). These varying perspectives can be problematic and hinder progress in recruiting women to the aviation workforce.

Most aviation and aerospace professions can be classified under the STEM category. Recruitment and retention of women in STEM careers has been a topic of concern for a long time. Although women who persist in STEM careers have demonstrated that women can achieve success in these fields, enrollment of women in STEM programs remains low. According to Yother (2021), focusing on the ways women are influenced to pursue these fields at an early age can stem from multiple factors including lack of formal mentorship and lack of role models in aviation fields. In addition, Edzie (2014) identified various factors that may influence women to STEM careers among them helping others in their career, having access to pre-collegiate STEM exposure, obtaining information about STEM career pathways, establishing relationships with influential stakeholders, and developing confidence in math and science.

According to OliverWyman (2022), there are changes needed in the industry to tackle the workforce shortage challenge. The changes proposed include changes in the way mechanics are trained, the way employers provide support to prospective mechanics, and the overall industry culture to help attract a younger generation of professionals. In addition, the industry could benefit from diversifying its pool of candidates by recruiting from minority groups and modernizing technology used in training like the use of artificial intelligence.

Colleges across the U.S. have been developing, implementing, and supporting programs and recruitment efforts to increase the participation of women in STEM programs. While well-meaning, it has been found that these programs and techniques do not always yield the desired results. Morrison (2019) argued that there is a

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disconnect between theory and institutional practice for diversity and inclusion programs and policies. For example, at one of the largest STEM colleges in the US (Anonymous, n.d.), the aviation maintenance and engineering technology program has seen a large increase in the number of students applying for the program since 2010, hitting its high point in 2019 – pre-pandemic year. However, although applications have gone up for both men and women, it can be observed that far fewer women apply for the program. Figure 2. shows a comparison between men and women applying to the program, admitted into the program, and attending the program.



Women Versus Men in Colliagiate Program by Year

Figure 2. Women and men applied, accepted, and attended numbers in a large midwestern university

Approximately the same percentage of women and men that apply to the program are accepted. However, there is a noticeable difference in the number of women versus men that applied to the aviation maintenance and engineering technology program. This led researchers to ask, what brings individuals to the program to begin with? Undoubtedly, the aviation and aerospace industry could benefit from increasing diversity in the workforce. More so increasing participation of women aviators. There is enough research to show that companies with a diverse workforce

tend to do well overall. By excluding women, the aviation industry is excluding half the talent pool and prospective industry labor force.

Research Methodology

The study was conducted using a survey sent to undergraduate students enrolled in an aviation maintenance program at a large midwestern university. The survey was sent using a blinded email and remained open for two weeks. The survey questions were developed using insight from conversations and interactions with aviation maintenance students at a large midwestern university, and with aviation professionals. Moreover, the researchers reviewed previous literature on the topic to support the survey's development.

Description of Participants

The participants of the survey were students in an Aeronautical Engineering Technology program at a large Midwestern university. Through this program, the student earns a bachelor's degree and the eligibility to test for FAA A&P certification. The sample pool included all undergraduate students in the program, which at the time of the study was approximately 249 students.

Description of Survey

The survey collected demographics including respondents' gender, race, and age. Respondents were asked to rate various factors on a Likert scale – from not at all (0), barely (1), somewhat (2), moderately (3), and very (4), that influenced their decision to enroll in an aviation maintenance collegiate program. The factors were: encouragement from parent/ guardian; encouragement from advisor, teacher, or friend(s); the number of job opportunities the field offers and their level of pay; interest, passion, or aptitude in subject; and reputation of the program. The full survey is attached in Appendix A.

Data Collection Plan

Participation in the survey was voluntary and this was indicated in the recruitment email. The recruitment email was sent using a blinded, private mailing list that did not identify the individuals contacted. Respondents were asked to respond to the survey only once. An initial request with the survey link was sent, and a follow reminder was sent the next week.

Results and Data Analysis

Two hundred and forty-nine (249) undergraduate students were invited to take the survey; 70 (28%) responded to the survey. Of the 70 respondents, 16 (22.9%) were women, 53 (75.7%) were men, and One identified as non-binary/ third gender as shown in table 1. Figure 3 and Figure 4 show the frequency of responses for each factor for women and men respectively.

Gender	Number of	Percentage of Respondents			
	Respondents				
Male	53	75.7%			
Female	16	22.9%			
Non-binary	1	0.014%			
Total	70	~100%			

Table 1. Distribution of Respondents by Gender

	Encouragement from Parent/ Guardian	Encouragement from Advisor, Teacher, or Friend(s)	The number of job opportunities the field offers and their level of pay	Interest, passion or aptitude in subject	Related subject in high school	College visit	College recruitment event in high school	The program reputation and/ or faculty and staff	The possibility to get additional certifications	Compatibility of with an ROTC program/ Military service
Not at all (0)	4	3	3	1	6	5	11	3	5	10
Barely (1)	4	1	1	0	6	5	1	0	1	1
Somewhat (2)	6	9	8	4	2	2	4	7	3	1
Moderately (3)	0	1	3	3	0	2	0	2	1	3
Very (4)	2	2	1	8	2	2	0	4	6	1

Figure 3. Frequency tables for women respondents

	Encouragement from Parent/ Guardian	Encouragement from Advisor, Teacher, or Friend(s)	The number of job opportunities the field offers and their level of pay	Interest, passion or aptitude in subject	Related subject in high school	College visit	College recruitment event in high school	The program reputation and/ or faculty and staff	The possibility to get additional certifications	Compatibility of with an ROTC program/ Military service
Not at all (0)	13	18	1	1	22	24	43	10	6	43
Barely (1)	8	14	5	1	13	1	6	6	6	2
Somewhat (2)	19	9	11	4	10	11	2	10	12	2
Moderately (3)	4	7	15	16	6	9	2	10	9	1
Very (4)	9	5	21	31	2	8	0	17	20	5

Figure 4. Frequency tables for male respondents

Respondents' age ranged between 18 to 27, with 19 as the median age. The majority of the students in the program are male; hence the number of women respondents is few (16 of 70). The means for each factor were calculated for men and women separately.



Figure 5. Mean responses for women and men.

Figure 5 shows four factors that were more influential for women than men. These are (i) encouragement from an advisor, teacher, or friend(s); (ii) related subject in high school; (iii) college recruitment event in high school; and (iv) compatibility with The Reserve Officers' Training Corps (ROTC) program/ military service. For men, the most influential factors are (i) encouragement from a parent/ guardian; (ii) number of job opportunities in the field and their level of pay; (iii) interest, passion, or aptitude in the subject; (iv) college visit; (v) the programs reputation, faculty, and staff; and (vi) the possibility to get additional certifications. For both genders, interest, passion, and aptitude in the aviation field was the top influential factor, while college recruitment events in high school was the least influential factor.

The mean responses of women and men respondents in each factor were tested for significant differences using a two-tailed unpaired t-test with an α =.05. The influential

factor that had a significant difference was the number of job opportunities the field offers and their level of pay (p=0.0030), as indicated in figure 5.

Although not statistically significant, there are notable differences between women and men in three factors, (i) the perceived influence of encouragement from an advisor, teacher, or friend(s); (ii) the possibility to get additional certifications; and (iii) compatibility with and ROTC/ Military program. Respondents had the option to add comments to the survey indicating other factors that may have influenced their decision. Notably, a change in major from a different engineering degree to the more hands-on aviation maintenance degree program was listed by several respondents.

ltem	Women	Men	Mean	p-value
	Mean	Mean	Difference	
Encouragement from Parent/ Guardian	1.50	1.77	0.27	0.4636
Encouragement from Advisor,	1 88	1 38	0.50	0 1693
Teacher, or Friend(s)	1.00	1.00	0.00	0.1000
The number of job opportunities the	1.88	2.94	1.06	0.0030
field offers and their level of pay				
Interest, passion or aptitude in subject	3.06	3.42	0.36	0.2811
Related subject in high school	1.12	1.11	0.01	0.9746
College visit	1.44	1.55	0.11	0.7928
College recruitment event in high	0.56	0.30	0.26	0.2977
school				
The program's reputation and/ or	2.25	2.34	0.09	0.8263
faculty and staff				
The possibility to get additional	2.12	2.58	0.46	0.3456
certifications				
Compatibility with an ROTC program/	1.00	0.55	0.45	0.2747
Military service				

Figure 6. Test of significance in influential factors between men and women

Discussion

The current gender gap in the aviation maintenance workforce should be a concern for all stakeholders involved – airlines, regulators, Original Equipment Manufacturers (OEMs), Maintenance Repair and Overhaul centers (MROs), etc. While aviation careers are traditionally viewed as male careers, there has been a shift in recent years in the entry of women into the aviation workforce. However, progress has been slow. The findings of this study show that men and women are influenced by the same factors in their decision to pursue aviation maintenance degree programs. As such, it is unclear why women are underrepresented in aviation maintenance careers.

Researchers of this study sought to answer the question of whether there are statistically significant differences between men and women in ten factors that have been identified in the literature as influential in choosing aviation maintenance careers. The findings of this study indicate that of the ten factors tested for significance, only one factor was significantly different in its influence on men and women – 'the number of job opportunities the field offers and their level of pay'. On average men choose careers in aviation maintenance based on the prospects for higher pay than women. This could be viewed as men being confident in their abilities as aviators. Furthermore, society does not cast doubt on men who choose aviation careers. On the contrary, women must constantly prove themselves as capable aviators (Marete, 2022; Newcomer et al., 2018).

College recruitment events in high school had more influence on women than they did on men. This finding is consistent with previous studies that showed that exposure to aviation careers at an early age can help to increase interest in aviation careers for girls (WIAAB, 2022). It is not surprising that more women were influenced by recruitment events in high school. An understanding of these influential factors can be used by college recruitment programs to target and recruit more women into aviation degree programs.

Surprisingly, more women than men indicated that ROTC/ military programs had a significant influence on their choice of degree program. This is contrary to the current statistics that show only approximately 17% of active-duty military are female (Department of Defense, 2021).

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In conclusion, it can be deduced that both men and women are attracted to aviation maintenance careers by the same factors. Theoretically, there should not be any significant barriers to entry for women interested in pursuing aviation maintenance careers. In reality, young women and youth are constantly faced with challenges that draw them away from aviation careers (Newcomer et al., 2018). In the long term, without proper strategies for recruiting and retaining women in these careers, the industry faces the challenge of meeting future workforce needs. More studies are needed to better understand the barriers that women face in entering the aviation maintenance workforce.

Limitations of Study

This study has one limitation in that the number of women in the population and in the survey participants was low. Of the 70 survey respondents, only 16 were women. This limitation was minimized by using a two-tailed unpaired t-test which uses means to compute the significance of each factor.

Conclusion

This study tested the statistical significance of ten factors that influence pre-college students in selecting aviation maintenance technology as a major in college. Researchers reviewed extant literature to show the literature gap in the study of women that choose aviation maintenance as a career.

Using survey study methodology, researchers collected data from undergraduate students enrolled in an aviation maintenance technology in a large midwestern university that offers a bachelor's degree in aviation maintenance technology. The findings of the study indicate that there are not statistically significant differences in nine of ten factors identified as influential in selecting aviation maintenance careers. Based on the findings of this study, women and men are influenced by the same factors in selecting careers in aviation maintenance. However, the number of women in aviation maintenance careers remains low. Researchers conclude that more qualitative research is needed to further explore why the number of women in aviation maintenance remains low.

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Appendix A

Factors that Influence the Pursuit of Collegiate Aviation Maintenance Degree Programs

Dear Fellow Aviator,

Author's introduction - removed

What is the purpose of this study?

How long is the survey?

The survey consists of five questions. It will take you about 2 to 5 minutes to complete the survey.

How will this survey benefit me?

There are no direct benefits to you taking this survey, however, the survey will help determine what recruitment techniques are the most effective or may need more development.

Will information about me and my participation be kept confidential?

All responses will be kept strictly confidential and only authorized researchers will have access to them. Surveys will not contain any identifiable information and any reports of findings will not include quotes or experiences that could potentially identify you.

What are my rights if I take part in the study?

Your participation in this study is voluntary. You may choose at any time to discontinue participation or withdraw your participation without penalty.

Who can I contact if I have questions?

If you have any questions about this study, you can contact Ashley Habig (habig1@purdue.edu). If you have questions about your rights while taking part in the study or have concerns about the treatment of research, participants, or any other

concerns please contact the Human Research Protection Program at 765-494-5942 or email irb@purdue.edu. IRB (Institutional Review Board) Protocol Number: IRB-2023-80

Survey Questions

Click below to continue the survey.

Welcome to the Factors that Influence the Pursuit of Collegiate Aviation Degree Programs Survey!

Instructions for survey:

Please read each section carefully and answer the questions honestly. These questions are designed to reflect what influenced you the most to pursue a degree in Aviation Technology. The answers you provide are strictly confidential.

Please choose your gender:

- Male
- Female
- Non-binary/third gender
- Prefer not to say

What race best describes you? You may choose more than one.

- Black or African American
- White
- American Indian and /or Alaskan Native
- Asian
- Native Hawaiian and/or Other Pacific Islander
- Hispanic or Latino/ Latina/ Latinx
- Prefer Not to Respond

What is your age in years?

Are you a veteran?

- Yes
- No
- Prefer Not to Answer

Please mark the response that best represents the level of influence that the following factors had on you for choosing to pursue a degree in Aviation Technology.

Not at all (1) Barely (2) Somewhat (3) Moderately (4) Very (5)

- 1. Encouragement from Parent/Guardian
- 2. Encouragement from Advisor, Teacher, or Friend(s)
- 3. The number of job opportunities the field offers and their level of pay
- 4. Interest, passion, or aptitude in subject
- 5. Related subject in high school
- 6. College visit College recruitment event in high school
- 7. The AET program's reputation and/ or its faculty and staff
- 8. The possibility to get additional certifications
- 9. Compatibility of AET with an ROTC program/ Military service
- 10. Other (please specify below)

If you chose other in the question above, please elaborate here.

We hope the findings of the study will bring meaningful insights into the influential factors that bring people to our program. If you are willing and interested in participating in any future studies stemming from these findings, please click the link below to provide your email address. If you consent to share your email address for future studies, it will be kept confidential. Thank you.

Link listed here.

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Connecting motivations for graduate school with learning experiences of engineering undergraduates: A gender perspective

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Abstract

In the United States, 40% of women in STEM leave the field after graduation. Nonbinary and transgender students in STEM are also 7% more likely to transfer to non-STEM departments than their peers. While an estimated 19.5% of electrical engineering bachelor's awardees in the United States in 2021 are of historically underrepresented or marginalized genders—cisgender women, nonbinary and transgender people, a lower estimated percentage of 18.1% of doctoral recipients in the same field are of minoritized genders. Only 15.7% of tenured or tenure-track faculty members and 12% of employed engineers in the field of electrical and computer engineering are of minoritized genders. In addition, while 25% of enrolled undergraduate students in STEM are of underrepresented genders, the percentage drops to 24% for bachelor awardees, which could mean a lower retention rate for these genders. In this paper, we examine the motivation of undergraduate students for graduate studies and compare their learning and research experiences in the Department of Electrical and Computing Engineering at the University of Illinois Urbana-Champaign by their gender identities.

To gain insight on gender differences in research-related opportunities and experiences, an institutional review board-approved digital survey was conducted in the Department of Electrical and Computer Engineering at the University of Illinois Urbana-Champaign in 2022. The survey assessed the research interests and experiences of undergraduate students and the accessibility of relevant information within the department.

A total of 276 respondents, 151 of which were undergraduate students, completed the survey. Even though 65% of the undergraduate respondents showed a strong interest in applying for graduate school, numerous obstacles stand in the way. The major roadblocks

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for cisgender men and cisgender women are the lack of research experience (55.2% and 48.4%, respectively), followed by concerns for graduate school costs (39.7% and 45.2%). For transgender and nonbinary undergraduate students, their main obstacles are graduate school costs, lack of research experience, and uncertainties in graduate school applications (equally 58.3\%). Cisgender women undergraduate students are also more likely to have concerns on their grades (32.3%) being a factor in graduate school applications than cisgender men (22.4%). The news sources of campus events and research opportunities also differ among genders. While the Internet is the main source for both cisgender men (31.0%) and cisgender women (32.3%), 20.7% of cisgender men respondents receive information from graduate students they know as opposed to only 6.5% of cisgender women. Faculty members are not a major source for any gender.

This survey analysis aims to provide data to create a framework for improving the motivations of students of minority genders to pursue a graduate degree in the same field. Based on our analysis, we offer suggestions that may help make the department a safer and more supportive place where all students can learn better and continue with their research careers.

Session Diversity, Equity, Inclusion, and Access / Undergraduate Research

 ${\bf Keyword} \quad {\rm graduate\ school\ /\ gender\ minority\ /\ undergrad\ research}$

Introduction

In the United States, 40% of women in science, technology, engineering, and mathematics (STEM) leave the field after graduation [1]. Nonbinary and transgender students in STEM are also 7% more likely to transfer to non-STEM departments than their cisgender peers [2]. While an estimated 19.5% of electrical engineering bachelor's awardees in the United States in 2021 are of historically underrepresented or marginalized genders—cisgender women, nonbinary and transgender people, a lower estimated percentage of 18.1% of doctoral recipients in the same field are of minoritized genders [3, 4]. Only 15.7% of tenured or tenure-track faculty members and 12% of employed engineers in the field of electrical and computer engineering are of minoritized genders [4, 5]. In addition, while 25% of enrolled undergraduate students in STEM are of underrepresented genders, the percentage drops to 24% for bachelor awardees [4].

Many STEM-related research positions as well as industrial jobs comprise mostly of cisgender men, and the lack of gender diversity in a team can also result in reduced innovation and developments [6]. Many individuals of historically underrepresented and marginalized genders in STEM also experience systemic gender biases, devaluation, and exclusion [7, 8]. A large number of students of minoritized genders also have health challenges and lack of psychological safety which makes them more likely to leave the field [7, 9].

Oftentimes, studies on gender representations in STEM are focused on cisgender people, excluding nonbinary and transgender individuals [10, 11]. In this paper, we aim to

understand and address the issues gender minority groups—including nonbinary and transgender people—face while pursuing research careers in engineering, specifically, the following research questions:

- What are the obstacles for undergraduate students in electrical and computer engineering to pursue a graduate degree?
- What is the difference in information access between genders?
- What are some tactics to combat the gender gap in the pursuit of research careers?

This study is designed by the HUG Initiative, which is a DEI research team to promote students with minoritized genders at the University of Illinois Urbana-Champaign [12]. A survey was conducted to evaluate the research interests of different gender groups within the Department of Electrical and Computer Engineering (ECE). In order to assess the representation of gender minority groups as well as the issues faced within the department in pursuing research careers, the accessibility of research information and interest in pursuing graduate school are analyzed. The survey also provides suggestions on methods to help create a safer and a more supportive environment within the department for gender minority groups to continue with their research careers.

Methods

An institutional review board-approved survey (IRB #23267) was conducted in the Department of Electrical and Computer Engineering at the University of Illinois Urbana-Champaign in 2022. The survey includes questions on the plans for graduate school, research experiences, and the accessibility of relevant information within the department for undergraduate students. The results of the survey were analyzed to compare different gender groups, including cisgender men, cisgender women, nonbinary or transgender persons, and those who preferred not to state their gender.

Students were asked to answer the following questions that will be analyzed in this paper:

- 1. Have you considered going to graduate school?
- 2. Among your friends who are also undergraduate students in the department, how many of them are considering graduate school?
- 3. What do you think is your greatest obstacle for attending graduate school? (Select all that apply)
- 4. Do you think you receive enough information on research opportunities, such as research internships, research projects etc.?
- 5. Where do you learn about the research opportunities? (Select all that apply)
- 6. Have you participated in the following events? (Select all that apply)
- 7. What is your main source of information on graduate school?

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8. Are you aware of the following funding opportunities? (Select all that apply)

Results

Demographics A total of 276 students responded to the survey, 151 (54.7%) of which were undergraduate students. The undergraduate respondent demographics are shown in Figure 1 where 58 (38.4%) are cisgender men, 31 (20.5%) are cisgender women, and 12 (7.9%) are nonbinary or transgender. According to school records, the number of enrolled undergraduate students in the department in Fall 2022 is 2248, where 85% are men [13].



Figure 1: Gender identity demographics of undergraduate respondents.

Plans for Graduate School For the question "Have you considered going to graduate school?", most respondents (64.96% of all undergraduate respondents) replied "yes": 59.65% of cisgender men, 64.52% of cisgender women, 69.23% of nonbinary and transgender people, and 63.64% of those who preferred not to reveal their gender. Relatively few respondents are not planning on going to graduate school, ranging between 9% to 12% for each gender.

For the responses to the question "Among your friends who are also undergraduate students in ECE, how many of them are considering graduate school?", there is no obvious trend between cisgender women whose friends are considering graduate school and those who are applying for graduate school themselves. However, for cisgender men, the more the respondents' friends are considering applying to graduate school, the more respondents indicated that they will also apply for graduate school. Also, 100% of respondents of all genders who answered that almost all their friends are applying to graduate school responded that they also plan on applying to graduate school themselves.

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Obstacles for Pursuing Graduate School Figure 2 depicts the responses of obstacles for attending graduate school the undergraduate students faced. Most cisgender respondents indicated that the lack of undergraduate research experience is the main obstacle for attending graduate school (55.2% and 48.4% for cisgender men and women, respectively). Other major obstacles for cisgender men and cisgender women include graduate school being too expensive (39.7% and 45.2%), the need to join the workforce upon graduation to support their families, and being unsure of how to prepare for graduate school application materials. For transgender and nonbinary undergraduate students, their main obstacles are graduate school costs, lack of research experience, and uncertainties in graduate school applications (equally 58.3%). Cisgender women undergraduate students are also more likely to have concerns about their grades (32.3%) being an obstacle in graduate school application than cisgender men (22.4%).



Figure 2: Undergraduate respondents' top 5 obstacles for attending graduate school.

Information on Research Opportunities The accessibility of information on research opportunities among undergraduate students was determined by asking the respondents where they learn about research opportunities and whether they believe they receive enough information on internships and research projects. Figure 3 shows the responses to "Where do you learn about the research opportunities?" Most respondents (62.3%) indicated they receive most of their information from The Grainger College of Engineering, followed by the Office of Undergraduate Research (53.0%), the Internet (39.1%), and their friends and peers (36.4%). Faculty members (21.9%) and family (2.0%) were not major sources for research opportunities for any gender. Cisgender women also rely more on the Office of Undergraduate Research as opposed to their friends and peers (58.1% versus 35.5%) than cisgender men (46.6% for both).

When asked to rate on a five-point Likert scale (1 to 5) for the question "Do you think you

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Figure 3: Undergraduate respondents' top 6 sources of research opportunity information.

receive enough information on research opportunities?" with 1 being "strongly disagree" and 5 being "strongly agree," most of the cisgender men (31.6%) and those who preferred not to state their gender (54.5%) had a rating of 3 ("neither agree nor disagree"), and most cisgender women (35.5%) and nonbinary respondents (41.7%) rated a 4 ("somewhat agree"). Very few respondents rated a 1 or a 5. The overall average for cisgender men and cisgender women are both 3.0, and nonbinary and transgender respondents have an average of 3.3.

Participation in Research Events The accessibility of information for the undergraduate respondents of each gender was also determined by asking the respondents whether they have participated in research events, including research workshops or conferences, recruiting events in the department, summer research programs at other institutions, career fairs, the undergraduate research week and symposium, and the writers workshop or retreat, as shown in Figure 4. Most of the respondents (51.0%) for all genders indicated that they have participated in career fairs at the institution with 62.1% and 48.4% of all cisgender men and cisgender women, respectively. Other major events include recruiting events in the department (31.8% of all respondents) and the undergraduate research week and symposium (17.2% of all respondents). Only 7.9% of all respondents indicated that they had participated in summer research programs. Also, very few respondents participated in research workshops and conferences, the writers workshop or retreat, or other events not listed, ranging between 2.6% to 3.3% of the total number of respondents.

Information of Funding Opportunities The survey also asked respondents whether they were aware of different funding opportunities, depicted in Figure 5. Most of the



Figure 4: Undergraduate respondents' top 4 attended research events.

respondents for all genders were aware of department scholarships with 65.5% of all cisgender men, 64.5% of all cisgender women, 58.3% of nonbinary and transgender persons, and 81.8% of those who preferred not to state their gender. 27.6% of all cisgender men, 41.7% of nonbinary and transgender respondents, and 45.5% of those who preferred not to state their gender also mentioned that they were aware of the Illinois Scholars Undergraduate Research Program in engineering as opposed to only 9.7% of all cisgender women. However, a larger proportion of cisgender women respondents are aware of other opportunities, such as the Summer Research Opportunities Program, the Fulbright Scholarship Program, and the NSF Graduate Research Fellowships Program (GRFP), compared to other gender groups.

Information on Graduate School The survey asked the respondents about their main source of information on graduate school as displayed in Figure 6. 40.0% of the undergraduate students learned the most about graduate school through either the Internet (21.2%) or the university (18.5%). 31.0% of cisgender men and 32.3% of cisgender women indicated that the Internet was the main resource for information about graduate school. Also, 29.0% of cisgender women indicated that they receive information about graduate school from family. However, many of the cisgender men respondents (20.7%) indicated that they also receive information from graduate students that they know. Most of the respondents who are nonbinary or transgender and those who did not state their gender also listed the graduate office as a main resource (41.7% and 32.0%, respectively). Relatively few students from all gender groups indicated professors as a resource for information about graduate school, ranging between about 3.4% to 8.3% of each gender group.





Figure 5: The top 5 funding opportunities undergraduate respondents are aware of.

Figure 6: Undergraduate respondents' main source of information about graduate school.

Discussion

Most undergraduate respondents stated that they will or might go to graduate school. This shows that many students, regardless of genders, are interested in pursuing research. The main obstacle for attending graduate school is the lack of undergraduate research experience. From the standpoint of the department, providing undergraduate students

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assistance in matching with faculty members and making sure that relevant information reaches the students, particularly those of minoritized genders, may be a good start to help undergraduate students kick-start their research career, especially since relatively few people receive research information from faculty members. For many respondents, being unsure of how to prepare the graduate school application materials is a major obstacles. While few students have utilized the writers workshop, it is one of the many resources that is helpful for application preparation. Many respondents of all genders also have financial concerns, and therefore, it is important for undergraduate students to be aware of scholarships and funding opportunities. In addition, cisgender women are more likely to have concerns about their grades than cisgender men. This shows that cisgender women might have lower self-efficacy compared to other gender groups and potentially leads to the underrepresentation of women in STEM [14].

The main sources of information on research opportunities for the undergraduate respondents are The Grainger College of Engineering, the Office of Undergraduate Research, the Internet, and their friends and peers. A larger proportion of cisgender men receive information from their friends and peers compared to cisgender women and nonbinary and transgender respondents, who rely more on the Office of Undergraduate Research. This shows that undergraduate students of minority genders might have a smaller community compared to the majority gender within the department, and therefore, depend more on other sources. Few students receive information about research opportunities from faculty members. Most undergraduate respondents "somewhat agree" that they receive enough information about research opportunities. For information on graduate school, most cisgender respondents cite the Internet as their main source. Cisgender men also receive information from graduate students they know, while most cisgender women receive information from family and almost none from graduate students they know. This shows that most of the majority gender group has a larger network of students and near-peer mentors while the minority gender groups receive information from other sources. As for information on funding opportunities, most respondents are aware of department scholarships. However, very few respondents are aware of the Fulbright Scholarship Program, the NSF GRFP, and the Summer Research Opportunities Program. Thus, there should be more information about these opportunities in order for undergraduate students to support themselves financially both while applying to graduate school and as a graduate student in the future and to gain more experience in conducting research.

In addition, engaging in mentoring programs and events that allow students of minority genders to meet with professionals in the field with similar backgrounds help the students feel welcomed and seen within the STEM community, and therefore, lower attrition rates [15, 16]. These activities also potentially connect students of underrepresented genders with other undergraduate students, graduate students, and faculty members, expanding their professional connections as well as sources of research information. In the meantime, it is also important for all students to learn and have discussions about the problems minoritized students face, thereby gaining awareness and fostering a more supportive atmosphere within the department.

Conclusion

The survey results display that there is space for improving the motivations of students of minority genders to pursue a graduate degree. By creating opportunities for the students to connect, learn, and gain insights on research-related information as well as being aware of the students' needs, the department can work toward building a safer and more supportive place for all students to learn better and continue with their research careers. For the future research, the HUG initiative will focus on the impact that these methods—including hosting panel discussions to connect students with scientists, mentoring programs to match undergraduate students with graduate mentors—have on the minority gender groups within the Department of Electrical and Computer Engineering. This will be done by conducting post-study surveys after various events and at the end of the school year in order to analyze whether these methods have a significant role in encouraging the pursuit of research careers among minority gender groups.

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Characterizing the Educational Effectiveness of STEM Demonstrations at Sciencefocused Events for Adult Audiences

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Science and its applications in engineering and technology are valuable tools to wield while addressing the plethora of environmental, ethical, and logistical concerns facing our modern society. It is not necessary for all individuals to work in a scientifically-focused industry, but a respect and understanding for the efforts of scientists is beneficial for large-scale collaboration to address these challenges. However, issues of trust persist between the scientific community and the general public. In this article, we show that a regional Science Center can be an effective facilitator of interaction between scientists and the general adult public by analyzing the experiences of content experts presenting demonstrations at an adult-oriented event series. This preliminary study found that adult audiences are excited to interact with live demonstrations and informally engage with experts from various disciplines to obtain new knowledge. The data shows that a Science Center hosted event is an effective way to curate experts and stimulate "just-intime" learning by demonstrating concepts with a generally recognizable application or association. These results indicate an effective structure for distributing scientific information and facilitating communication between scientists and the general public, which could benefit public trust in science and societal wellbeing.

1. Introduction

1.1 Problem Identification

Concern for the relationship between scientists and the public at large is not unique to our current moment in society, and the notion of a growing communication gap has been debated for over a century [1, 2]. Attempts to characterize the relationship between the public and science have revealed large number of factors that affect this gap. These factors include parental and community influence, issues of trust related to interests and credibility, and inconsistent portrayal of scientific work in media [3, 4]. However, science and its applications in engineering and technology are valuable when addressing many societal and environmental concerns that exist in the modern world [5]. While not every individual needs to be personally working in a scientific field, a respect and understanding for science and scientists from all sectors of society supports collaborative efforts to address large scale sustainability issues in current systems [6].

1.2 Background on the Problem

Efforts to improve knowledge and engagement with science and technology at the K-12 school level have been extensively researched and developed, and often involve support from institutions of higher learning. There has been far less work done to examine the factors contributing to adult knowledge and perception of science and technology [7]. Interestingly, the limited data does show that advances in internet connectivity and content have brought change to the way adults are exposed to knowledge. The modern paradigm often involves less prior knowledge, instead opting to "just-in-time" system of immediate access to new concepts at the moment they are required to understand an observation [8]. Even with this emerging trend, there

is an important utility in the traditional "warehouse" style of knowledge transfer from curated sources such as schools and museums due to the lack of regulation of information that is publicly available via online sources. Such distributors of knowledge offer a selection of content and experiences that are verified for accuracy and content. Science Centers, in particular, remain a valuable tool for increasing adult science literacy [9].

1.3 Proposed Solution

This work presents a hybrid of "warehouse" and "just-in-time" approaches as a way to teach scientific concepts to an adult audience. This hybrid experience is created by gathering curated sets of experts and demonstrations together into themed social events for adult audiences. Guests at the events are exposed to demonstrations of scientific concepts with experts on hand to explain and discuss the scientific concept required to understand the display in front of them. This setup is designed to respond to the research question: *Is an expert-guided demonstration in an informal setting an effective way to encourage adult learning of scientific concepts?*

The approach in this article to answering this question is to consider three aspects of guest interactions with the expert presenters. This work attempts to characterize the guests' incoming knowledge of a scientific concept, engagement during discussion with the expert, and relative understanding of the scientific concept after this interaction. The data presented was collected at two Eat Drink Do Science adults-only events hosted by the Kentucky Science Center (KSC) in Louisville, KY. The events were organized by KSC's Young Professionals Advisory Board.

2. Background

2.1 Kentucky Science Center

The Kentucky Science Center (KSC) is located in Louisville, KY, and is the largest handson science center in the state. The KSC works to provide informal science, technology, engineering, and math education by offering vast array of experiences for all audiences at its flagship location and surrounding region. Its mission is to encourage people of all ages to "Do Science", and is motivated by the notion that "Science Matters" to society, the workforce, and to individuals and families.

2.2 Young Professionals Advisory Board

A part of the mission of the KSC is to increase the science literacy of adult audiences. The Young Professionals Advisory Board (YPAB) was formed with the mission to support the Kentucky Science Center's Mission of "*encouraging people of all ages to Do Science in Engaging, Educational, and Entertaining Ways to Inspire a Lifetime of Learning.*" Specifically, this board was formed to implement strategies to make KSC an asset to young professionals age 40 and under. This YPAB has been responsible for planning and assisting in the execution of events that would be of interest to an adult audience. The targeted events by this board in 2022 were all under the "Eat, Drink, Do Science" series, with individual themes that differentiate each event.

2.3 Eat Drink Do Science Event Series

Planning for "Eat, Drink, Do Science" (EDDS) events was the primary goal of the YPAB's work in 2022. The events in this series have been designed for adult (21+) audiences and are scheduled to occur four times a year at the time of this article's publication. In general, each event gives guests access to all fixed exhibits in the KSC, catered food and drink options, and access to

event-exclusive partner stations. The partners are invited to host a station that shows off their expertise and aligns with the specific theme of each event. The 2022 EDDS event themes during the data collection for this article were "Let's Party", which focused on the five human senses, and "Spooky Science", which targeted Halloween and Scary Movie inspired partner stations.

3. Methods

3.1 Study Design

Each demonstration examined in this study was designed with a popular culture reference that was aligned with the event theme and also was intended to be broadly familiar with the guests to motivate discussion. This was also a starting point for the participants to inquire about the guests' prior knowledge of the science on display at each station. Participants were provided with a demonstration and specific science and engineering concepts to convey through the explanation of the demonstration. Table 1 summarizes the popular references, demonstrations, and science and engineering concepts that were introduced. The details of each demonstration set up is expanded in Appendix section 6.1.

#	Popular Culture Reference	Demonstration	Concept(s) to Introduce
1	Jurassic Park movie, water ripples as a	Sound-driven Surface	Wave energy
	dinosaur takes a step	Vibration	conversion between
			various electrical and
			mechanical forms
2	Nearby object sensing in modern self-	Ultrasonic Distance	Calculating object
	driving vehicles	Measurement	distance from reflection
			time of a wave in a
			known medium
3	Playing a note on a wine glass rim as	Wine Glass Resonance	Mechanical vibration at
	seen in various TV and movie scenes		resonance
4	Pumpkin association with general	Pumpkin-key	An electrical circuit
	Halloween theme	Synthesizer	must be a complete a
			conductive loop
5	Light and sound effects heard in the	Jacob's Ladder	Charge buildup and
	movie Frankenstein (1931)		imbalance as it relates to
			sparks and lightning
6	Electromagnetic fields as depicted in	Tesla Coil	Electron movement
	"Ghost Hunter" TV shows		generates electric and
			magnetic fields

Table 1 - Summary of experiments presented and science concepts being demonstrated

The first three rows were developed to relate to sound, an element of the "Let's Party" theme. The lower three rows were related to the "Spooky Science" Movie theme. Participants in the event were asked for their feedback on their guest interactions after the event had ended. Responses were then compiled and analyzed for recurring themes regarding the guests' interaction with the participant and the demonstration.

3.2 Participation Information

Data collected from three college faculty and three graduated students from an Engineering Technology college within a large public university in the Midwestern United States. The individuals presenting a demonstration are discussed in this article as the "participants", while the attendees of the event are referred to as the "guests" and have not provided any data directly to the author. The participants each facilitated one of the demonstration tables outlined in Table 1 for the three-hour duration of one of the Eat Drink Do Science events. The event attendance varied between 150-250 guests that could have interacted with the participants.

3.3 Data Collection

After the event had ended, participants were asked to reflect on their experiences with the guests with a set of questions designed to judge guests' preexisting knowledge, active discussion and learning, and incorporation of new information into their existing understanding. The following table contains the prompt that was provided to each participant.

Directions			
In a brief paragraph	h, could you please summarize your impressions of your guest interactions		
in response to the fo	llowing questions:		
Assessment Topic	Prompt		
Preexisting	How familiar or knowledgeable were the guests about the demo you were		
Knowledge	demonstrating? (did they indicate knowledge of what it was or elements		
	of how it worked, etc.)		
Active Learning	How willing were guests to ask questions about the demo and hold a		
	discussion about the basic principles involved?		
Incorporation of	Did you feel that the guests' understanding of the demo was increased		
New Information	from the discussions they had with you?		
Event-specific	Do you have any other comments or observations that you would like to		
Reflections	share regarding the demos or event?		

Table 2 – Data collection questions to participants after each event.

3.4 Data Analysis

In response to the research question "Is an expert-guided demonstration in an informal setting an effective way to encourage adult learning of scientific concepts?", the author reviewed the reflections from all participants and identified common themes among the responses for each of the assessment areas. Results were also analyzed through from the perspective of the constructivist learning theory. Bada and Olusegun [10] characterize this as "In the most general sense, it usually means encouraging students to use active techniques (experiments, real-world problem solving) to create more knowledge and then to reflect on and talk about what they are doing and how their understanding is changing." This theory is at the core of many inquiry and

problem-based learning techniques that are common in many collegiate engineering degree programs [11-14].

4. Results

4.1 Reflections on Preexisting Knowledge

Overall, it appears that the general incoming knowledge level varied from guest to guest, but that there was frequently a recognition of the concept from popular media. A sample of quotes from the participants that characterize the guests' preexisting knowledge are:

- "It was a mixture of very knowledgeable, some and none."
- "I experienced a full spectrum of understanding from one person being able to calculate on their own, to explaining the formulas used, all the way down to explaining basic division."
- "Some had seen and/or heard of making sound with stemware, such as from a movie."
- "Most knew that sound traveled at a finite speed."
- "I would say a majority of people didn't seem to know too much about the different demos, but enjoyed relating it to things they've seen in movies or basic principles."

It is interesting to observe that the scientific concepts on display were ingrained in popular media to the point that they were generally recognized by an adult audience. It is also of note that there were multiple entry points into the discussion based on the incoming guest's knowledge base.

4.2 Reflections on Active Learning

Guests that interacted with the presented were frequently curious, engaged, and asked discerning follow-up questions. A sample of quotes from the participants that characterize the guests' active learning through observation and discussion are:

- *"Guests were excited and asked many questions, mostly regarding how the demos worked."*
- "Most were interested in the speed of sound calculations."
- "The majority would interact with myself and the demo"
- "It was better if I engaged them, but as often I was greeted with "What is this showing us?"

The reflections from the participants support the idea that guests were motivated to learn about the demonstration on display once they observed action that they didn't already understand. It was beneficial to have experts nearby to engage with the curious guests and educate them on the principals at work in the demonstration.

4.3 Reflections on Incorporation of New Information

Respondents to the survey unanimously reported that guests left their station with new knowledge about a fundamental scientific principle. In one response, the participant elaborated on their response by saying "Yes. Particularly those with no previous knowledge seemed to walk away

with more understanding of basic principles that drove our exhibits." Another respondent noted the added benefit of elaborating on an example of the scientific principle to make a connection with the guest, saying that "Yes! Especially once I hit upon the sound wave use in Jurassic Park (water in the glass/footsteps/ripples)". These quotes highlight the strength of a live demonstration and connection to prior exposure as motivation to learn about a new concept.

4.4 Discussion

This format of the active learning experiences can be classified as a constructivist pedagogy. Central to constructivist theory are the notions that students learn best when they are engaged in the learning experience and that learning is a social process [15]. Therefore, the constructivist goal is to facilitate the construction of knowledge rather than to just pass knowledge directly [16]. There is a large amount of analysis and debate of this theory as it applies to formal education [17], but constructivism is also recognized as a common mechanism of informal learning in settings such as public Science Centers [18]. The data collected from participants in this study is aligned with core components of the constructivist process: determining prior knowledge, observation and discussion of new knowledge, and reflection of what was learned.

Constructivist ideas have been shown to benefit student learning within formal school settings [19]. The preliminary results in this article give support to the idea that the approach also works well with adult audiences at informal EDDS events. Critically, the knowledge being presented has been curated for accuracy to support the educational mission of the KSC. This structure of curated "just-in-time" learning opportunities has been cited as a strong basis for forming modern learning communities to support lifelong learning [20].

4.5 Lessons Learned

Participants responded to an open-ended suggestion for comments about their experience for the last question of the reflection prompt. There were three themes that stood out among the responses. First, participants suggested avoiding a demo dependent on ambient conditions because the noise and lighting levels are not in their control. Second, that the demonstrations were instantly accessible without relying on academic-form detailed posters to present background information, as audiences rarely read accompanying posters. Finally, it was noted that prior preparation of specific talking points and goals is critical due to the limited time for conversation (typically under two minutes) due to the audience size.

5. Conclusions

5.1 Practical Summary

The reflections from the participants in this study indicate that the general adult public is interested in learning about scientific concepts that are being demonstrated in front of them. There may be implications on how important scientific information could be effectively conveyed to the general public. At a minimum, the data shows that the format of the EDDS events is a good way to curate experts, and stimulate just-in-time learning by demonstrating concepts with a generally recognizable application or association.

5.2 Limitations and Future Research

The conclusions drawn in this article are limited by the scope of the data collection. The data is based on one-sided assessment from the participants of guest interactions. There is also

opportunity to learn more if guests are able to be surveyed more specifically related to their experience as it relates to their self-assessed learning at the event. Furthermore, assessment of the topics demonstrated would need to be expanded to areas outside of engineering technology to gain insight into how the type of content is related to guest engagement.

5.3 Author Association Disclosure

The author is a member of the KSC's Young Professionals Advisory Board. As described previously, this board is tasked with organizing and executing the adult programming events where the demonstrations above were on display. However, the opinions and conclusions in this article are strictly the views of the author from the viewpoint of an event partner based on the reflections of volunteers that were unaffiliated with KSC.

6. Appendix

	Demonstration	Experiment Details		
1	Sound-driven Surface	This station is demonstrating sound acting mechanically and		
	Vibration	electrically. Participants will bang on a metal sheet pan and see rice		
		"jump" on the thin plastic diagram over the glass bowl. The chaotic		
		waveform is also captured on a microphone. Discussion includes how		
		voices travel, eardrums vibrate, brain gets signals, etc.		
2	Ultrasonic Distance	Science and parties have a long history. We all know that most of the		
	Measurement	good ideas aren't coming from in the office, but from social settings.		
		There are many examples of sketches and calculations on cocktail		
		napkins that ended up changing the world. This station will have a		
		poster detailing napkin sketches that changed the world, and the		
		of sound on a nonlyin by coloulating chiest distance from reflection time		
		of a waya in a known madium (air). Pathation time is contured with an		
		ultrasonic sensor and the object can be moved by the participants to		
		observe the changing reflection time		
3	Wine Glass Resonance	This station will let participants discuss resonance. why opera singers		
5	White Glubs Resolutive	can vibrate glass, and make a wine glass sing with a wet finger around		
		the rim. The accompanying poster will talk about resonance and music		
		show piano keys and frequencies, and help them understanding		
		"tuning" the glass by adding water. These glasses tune within roughly		
		380-730, or G4 to G5 on a piano.		
4	Pumpkin-key	This station will demonstrate completing a loop in a circuit by		
	Synthesizer	electrically connecting pumpkins into a voltage divider, which is		
		monitored by analog Arduino pins. An electrical circuit must be		
		completed by the guest by using their hand to close a conductive loop.		
		This change will be monitored by the Arduino and trigger a tone to be		
		generated when a pumpkin is touched.		
5	Jacob's Ladder	This station will demonstrate a large change imbalance being created		
		by a neon sign power supply. The large change will cause electricity to		

6.1 Detailed Demonstration Summaries

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		spark across an insulating air gap, and heat will make the spark rise up
		the metal "V" that the spark is across.
6	Tesla Coil	This station will demonstrate that a small tesla coil with high AC charge
		buildup will cause electrical and magnetic fields to be created. This will
		be verified by demonstrating the wireless activation of nearby Compact
		Fluorescent Light (CFL) bulbs.

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Feasibility of Using the CAPE Framework to Identify Gaps in Equity-focused CS Education Research

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Abstract

As computer science (CS) quickly gains ground in K-12 classrooms, CS education research (CSER) is also rapidly growing. It remains unclear, however, the extent to which this growth in research captures key equity-focused areas. In this article, we describe a pilot test to determine the feasibility of using the CAPE theoretical framework to identify coverage of equity-focused CSER. The Capacity, Access, Participation and Experience (CAPE) framework examines the capacity to offer CS education, learner access to CS education, learner participation in CS education (enrollment) and experiences learners have when learning CS. We started with one primary research question: *How feasible is it to use the CAPE framework for identify coverage gaps in K-12 CS education research*?

We then created a secondary research question for narrowing down the set of articles examined and testing its feasibility: *What are the gaps in research focused on K-12 CS education in which girls are participants in the studies?*. We chose to use an existing, publicly-available dataset of 800+ articles and examined studies in which only girls were participants (n=51), then examined each of the 51 articles to determine which key CAPE component(s) each covers. Our pilot results show that CSER among girls covers areas related to Experience (92%) and Capacity (59%), but little to no coverage in the areas of Access (0%) and Participation (2%) of girls.

To answer the primary research question and determine the feasibility of using CAPE for analyzing the entire corpus of 800+ articles (which is the next step in our research plan), we evaluated feasibility across two key areas, implementation and practicality, and found both to be satisfactory. This study is important in understanding how to identify areas of equity covered in K-12 CS education research and areas that need more attention in order to build a broader set of research knowledge for identifying promising practices for all learners.

1 Introduction

K-12 computer science (CS) education is rapidly expanding, as well as the need for more education research to investigate promising practices–particularly those that study across the educational ecosystem and the broad range of student populations and groups. With the different subgroups of students that are only becoming more diverse, particularly in the United States, there is a need to understand how well our existing body of research expands across student subgroups and whether or not gaps exist. Further, there have been calls to be more inclusive in research and previous studies have also shown gaps in equity-focused research [2, 3, 8, 13]. By

identifying such equity gaps, the broader research community can start to be more deliberate about conducting research in areas where there may be gaps [14].

In 2020, Fletcher and Warner developed the equity-focused CAPE theoretical framework to better understand the related components that impact all student learning of and growth in computer science. This includes the capacity to offer CS education, access to and participation in CS education, and experiences of those students receiving CS education. After working with CAPE for several months across various projects, we hypothesized that we could use it to help identify gaps in equity-focused CSER given its intent and focus as a framework specifically created for K-12 CS education. Our primary research question became: *How feasible is it to use the CAPE framework for identify coverage gaps in K-12 CS education research*?

In this paper, we present two methodologies—one for investigating the feasibility of using CAPE to identify gaps across a dataset focused on girls (specifically focusing on implementation and practicality of using this framework) and the other running the CAPE framework through its paces against a limited dataset as a pilot test. That is, we conducted a limited study to investigate whether or not we could use CAPE to identify the gaps in research in which girls were identified as participants in the study. Therefore, our secondary research question became: *What are the gaps in research focused on K-12 CS education in which girls are participants in the studies*?

This study is a precursor to understanding the broader landscape of equity-focused research in the computing education research literature. By understanding the areas in which the research evidence is excelling and where additional research is needed, the broader research community and stakeholders who understand the importance of filling such gaps can start to address them.

2 Background

2.1 Previous CSER Research Gaps

Multiple studies have investigated topics of research to identify knowledge gaps. Saha explores gaps in local governments' sustainability efforts to drive future research [21]. Macintosh et al. investigate research gaps as they pertain to eParticipation, finding that one of the six gaps is in equity [15]. With respect to gaps specifically in equity-focused research in general, Lubienski recognize the importance of exploring these gaps, stating that "Research on gaps between underserved groups and their more advantaged peers are important for shaping public opinion and informing education policy." [14, abstract]. Recently, Ayalew et al. used a sociological framework with an equity lens to identify the types of equity gaps in research [4]. Ab Rahim et al. conducted an interesting equity-related gap analysis that considered whether there was a research gap in the introductions of CS research articles by authors who were non-native English writers [1].

Closer to CSER, there has been a history of considering where gaps are in the research to improve our body of knowledge. Several authors (Randolph et al. [20], Heckman et al. [11], McGill and Decker [17] and Sanders et al. [22]) have considered gaps in data and methodological analysis. McGill et al. conducted an analysis to uncover gaps in instrumentation that is used to study the effectiveness of interventions [19]. Further, McGill et al. considered reporting of data and how gaps in reporting could be addressed [18].

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Figure 1: CAPE Framework as defined by Fletcher and Warner [10].

With respect to equity-focused CSER, Smith considers the gaps in participant diversity in CS education research by analyzing "...the gender composition of the subject pool, the extent to which cognitive learning results are disaggregated by gender, and whether there are gender differences in outcomes" [23, abstract]. The author found that only about one-third of studies indicated the gender composition of the participants, with only one-third of the studies that identified gender composition being female. This process aligns with participant demographics found in an earlier study [25][ANON].

Bianchini et al. considers three key areas with respect to science education research:

- Researchers organizing and sharing their work in ways that align with the same theories of teaching and learning that we promote and study,
- Researchers' framing and research methods that more directly address issues of power, voice, and even impact and
- Researchers' ability to impact funding, evaluation and policy that is equity-centered [6].

Their position is that in order to move the "equity agenda" forward, the landscape of research, practice and policy need to shift to all be equity-focused. Although these questions are differently focused, the center the researcher in the process of driving equity-focused research forward. This further supports the need to begin to understand the landscape of equity-focused research in our field, to identify the gaps, and then to address them.

2.2 The CAPE Framework

The CAPE framework is a relative newcomer to understanding and disaggregating the complexities of the CS educational ecosystem, with a particular focus on K-12 [10]. The Capacity, Access, Participation and Experience framework examines the capacity to offer CS education, learner access to CS education, learner participation in CS education (enrollment) and experiences learners have when learning CS. The framework, as shown in Figure 1, shows some leading questions that can be asked to analyze CS education at a systems-level approach. A systems-level approach considers student or teacher level outcomes and how those outcomes are situated within a larger initiative and policy level environment [5].

The CAPE framework provides a lens from which to view educational systems and whether or

not they are equitable. As such, it may be able to provide researchers a way of understanding coverage of research that falls within each of these categories and highlighting where important gaps may exist.

Given its newness, there are not currently any existing studies that look at gaps in K-12 CS education research using the CAPE framework. Though there are other frameworks that might be used to investigate those gaps, we chose to use the CAPE framework because of its particular focus on K-12 computing education and the unique insight it provides for the emergent K-12 subject area of computing education.

3 Methodology

In this section, we present the methodology for both research questions.

3.1 Primary Research Question: Feasibility

To answer our primary research question, *How feasible is it to use the CAPE framework for identify coverage gaps in K-12 CS education research?*, we adapted an existing design methodology to evaluate the feasibility of our classification process [7]. Bowen et al. provide eight successive areas of focus for such studies that include: Acceptability, Demand, Implementation, Practicality, Adaptation, Integration, Expansion and Limited Efficacy Testing. Acceptability and Demand are two areas in which we made judgment calls–our future research plans call for a way to identify gaps in equity-focused research in CS education. Therefore, we believe using the CAPE framework may be an acceptable way to identify those gaps and the demand was our own based on our future research needs. The latter areas of Adaptation, Integration, Expansion, and Limited Efficacy Testing are used to test feasibility of those who use and adapt the process and integrate it in their research, integrating into their practices, expanding the usage of it beyond its original intent and test among a broader population for efficacy. These latter four were beyond the scope of what we wanted to do in this pilot study.

Implementation, however, considers how feasible it is to implement the process. It considers four primary areas: the degree of execution of the process, its success or failure, the resources needed to implement, and the factors affecting implementation ease or difficulty [7]. Practicality is a step that follows implementation and it considers how practical the process is for both the researchers studying the process and others. It considers the efficiency, speed, or quality of implementation, positive/negative effects of using the process, ability to administer the process and a cost analysis of using the process. Based on these two definitions, these most aligned with what we wanted to explore for feasibility (see Table 1).

Though our original overarching question was *How feasible is it to use the CAPE framework for identify coverage gaps in K-12 CS education research?*, we further clarified this to two primary questions about feasibility:

- To what extent can the process of classifying articles against the CAPE framework be performed successfully?
- To what extent can classifying articles against the CAPE framework be carried out using existing means, resources, and circumstances and without outside assistance?

These two questions serve as the basis for our discussion in Section 6.

Area of focus	Our feasibility study asks	Sample outcomes of interest
Implementation	To what extent can the process	Degree of execution; Success or failure
	of classifying articles against the	of execution; Amount, type of resources
	CAPE framework be performed	needed to implement; Factors affecting
	successfully?	implementation ease or difficulty
Practicality	To what extent can classifying ar-	Efficiency, speed, or quality of implemen-
	ticles against the CAPE framework	tation; Positive/negative effects of using
	be carried out using existing means,	the process; Ability to administer the pro-
	resources, and circumstances and	cess; Cost analysis
	without outside assistance?	

Table 1: Two areas of focus (Implementation and Practicality) adapted from Bowen et al. [7].

3.2 Secondary Research Question: Girls

To conduct this pilot study and answer the secondary research question, *What are the gaps in research focused on K-12 CS education in which girls are participants in the studies?*, we needed to gather a proper dataset, develop inclusion and exclusion criteria, and then classify each article according to which category of CAPE it fell under: Capacity, Access, Participation, or Experience. We also needed to identify a methodology for determining if our process was feasible for broader studies that we or others may conduct.

3.2.1 Dataset

Our dataset is drawn from an existing, publicly-available pool of over 800 articles from the K-12 CS Education Research Resource Center [16]. This dataset was created by the authors' curating data from articles related to K-12 CS education from each of the following journals and conference publication venues (2012-2020): ACM International Computing Education Research, ACM Innovation and Technology in Computer Science Education, ACM SIGCSE Technical Symposium on Computer Science Education, ACM Transactions on Computing Education, Frontiers in Education, IEEE Global Engineering Education Conference, IEEE Transactions on Education, Journal of Educational Computing Research, Koli Calling, Taylor & Francis' Computer Science Education and Workshop in Primary and Secondary Computing Education (WIPSCE).

Using an SQL query on the dataset provided to us, we limited our dataset to articles that only used girls as participants. This allowed us to use an appropriate sample size (54 articles) for a pilot study while also focusing on an underrepresented group in computing fields. The SQL query captured the relevant articles, their abstracts, and what was measured in the study and then we placed the data in a spreadsheet and added four columns for each component of CAPE. We then downloaded all of the articles and placed them in a shared folder for further analysis.

3.2.2 Classification and Criteria

In order to classify each article under a component of CAPE, we developed inclusion and exclusion criteria for each. The inclusion/exclusion criteria was based on the CAPE definitions as follows:

• Capacity: Investigates resources (e.g. faculty, funding, curriculum and policies) in regards

to CS education

- Access: Investigates CS education offerings and/or barriers of entry (e.g. course requirements)
- Participation: Investigates enrollment in CS courses
- Experience: Investigates the student outcomes of participation in CS (e.g. content learned, attitudes)

In order to draw a clear line between what the research says and our own projection of how the research might impact a component of CAPE, we decided to only focus on what the instruments measured. For instance, a study might use positive attitudes towards CS from student surveys to show that a workshop has the potential to improve CS enrollment among girls. However, since the research is measuring attitudes rather than actual enrollment numbers, it would not be categorized under Participation.

Using this criteria, we read through the articles and specifically looked at whether the instruments measured Capacity, Access, Participation, or Experience and tagged them accordingly. We also made note of which specific constructs were measured and identified each as being *directly* investigated (direct) where the research was intended to measure this component and *indirectly* investigated where the research was not intended to measure this component, but evidence for this component was present in the research findings. For example, one of the articles classified under Participation did not measure enrollment as that was not the aim of the study, but reported on future camp enrollment numbers in the discussion section. Thus, the paper indirectly investigated participation. This is further explained in Section 4.2.

3.2.3 Process

After we established the inclusion criteria, both authors reviewed the first two papers and classified them against the CAPE components. After this was completed, the authors met via Zoom to discuss how and why they classified each study under the specific components. From this, we both classified these as falling into the Experience category. However, this also prompted a deeper discussion about how the experience was measured as part of an intervention, and the intervention was related to the Capacity component. We decided that in cases like this, we would categorize the intervention where it belonged (Capacity, Access, or Participation). Therefore, we learned very quickly that the classification process required much more thought when interventions were being classified.

Over the course of the next several weeks, the first author read through approximately 10 articles per week and categorized them under the CAPE framework. At the end of each week, both researchers met via Zoom to discuss questions, comments, and concerns about the process that the first author had. During these meetings, the second author reviewed the classifications of each article and changes were made, if necessary. This process continued until every article had been properly categorized according to our criteria.

		1 2/
Focus Area	Count	% of all articles
Pedagogy	16	31%
Resource/Tool	12	23%
Assessment	3	6%
Ecosystems	3	6%
Curriculum	2	4%

4 Results: Secondary Research Question

4.1 Capacity

As we reviewed the articles and classified those that met the definition as Capacity, we also captured the major area of focus that the intervention was targeting. As we did this, we came up with five focus areas: Pedagogy, Assessment, Resource/Tool, Curriculum, and Ecosystems (broader interventions across Capacity) (see Table 2).

Of the 51 articles, 30 (59%) of them directly measured Capacity. The majority of the articles about Capacity dealt with Pedagogy and Resources/Tools (e.g., Scratch, Google Blockly).

4.2 Access and Participation

None of the articles measured Access and only one article (indirectly) measured Participation. The one article relating to participation was indirect since the research was not intended to measure enrollment but reported on it in the article. The author aimed to find the impact of an outreach camp on computing confidence, intent to persist, social support, and computing outcome expectations. The survey instruments measured these constructs rather than enrollment. However, in the Discussion section the author makes note of camp enrollment numbers. Thus, participation is indirectly investigated.

4.3 Experience

Similar to Capacity, as we started classifying Experience reports, we also identified the construct that was investigated (e.g., self-efficacy, perceptions about CS). Once we tagged each with the area of investigation for the research, we then cross-referenced this with categorizations created in [ANON] and [12] and used previously defined construct terminology. We learned that 23 constructs were measured across these articles (see Table 3).

Of the articles, 47 (88%) directly measured the Experience of girls in CS. The most frequent construct measured Enjoyment followed by Confidence and Content Knowledge, respectively.

5 Discussion: Secondary Research Question

When considering the results in total (Table 4), we see that the majority (92%) of the articles that specifically have girls as participants are focused on the student experience. This is a significant number, yet also not surprising–centering education research on the learner experience is vital to understanding interventions that specifically target students.

However, as Fletcher and Warner indicate via the CAPE framework, Capacity is the foundation of creating an ecosystem that supports student learning. By only focusing on the learner experience,

Construct	Count	%
Enjoyment	20	40%
Confidence	16	31%
Content Knowledge	14	27%
Intent to Pursue (CS Related Career)	11	22%
Engagement	11	22%
Intent to Pursue (CS Related Major)	11	22%
Self-efficacy	10	20%
Usefulness	10	20%
Motivation	9	18%
Intent to Pursue (CS Related Courses)	6	12%
Satisfaction	6	12%
Beliefs/Perceptions	5	10%
Belonging	3	6%
Collaboration	3	6%
Support	3	6%
Identity	3	6%
Problem Solving Strategies	3	6%
Comfort with Peers	1	2%
Perceptions about CS (general)	1	2%
Perceptions about Topic being Taught (in intervention)	1	2%
Self Concept	1	2%
Self Regulation	1	2%
Persistence	1	2%

Table 3: Articles that were classified as Experience, with the construct measured.

it directs our attention away from the structural needs of a healthy education ecosystem in which all students can thrive. Organizations that support the professional development of teachers and the growth of a school's, district's, state's or country's ability to offer CS courses and extracurricular activities would all fall into the Capacity component of CAPE–yet this area is not measured nearly as frequently as Experience. Capacity's relationship to Access and Participation also cannot be adequately studied without studies that explicitly study these two components.

Further, by understanding the importance of Access and Participation, one can start to also understand the importance of research focused on both [24]. For example, if a school only offers CS courses that conflict with a physical education class that is popular with volleyball or softball players (girls), this limits the ability for these students to *participate* in formal CS education because their *access* to it is restricted. Or, if the requirement for CS is Algebra II, yet only college-oriented students typically take Algebra II, then students who may not take Algebra II would not be able to participate due to limited access. Research that studies barriers to access and participation (which must be addressed at the capacity level) are critical if we are to design and promote CS for all students.

When taking a closer look at the focus areas of Capacity research as related to offering girls CS

Table 4: Overall results of the process. Papers that studied Capacity and Experience were all directly measuring these two. Participation was only indirectly measured as a byproduct of a study that measured both Capacity and Experience. To highlight the overlaps with Capacity, we also provide Capacity with each other component.

	Count	%
Capacity	30	59%
Access	0	0%
Participation	1	2%
Experience	47	92%
Capacity + Access only	0	0%
Capacity + Participation only	0	0%
Capacity + Experience only	29	57%
Capacity + Participation + Experience	29	57%

education, we see that Pedagogy (31%) is the most frequently examined focus area of these papers, whiles Resources/Tools are not too far behind (23%). However, Capacity covers so much more–administrator support, teacher factors (e.g., experience, equity training, growth mindset), guidance counselor training and experience, classroom factors, etc. These are all vital areas to study as they affect girls' access to CS education, their participation in the courses, and, of course, their experiences in the classroom. The focus areas seem to overlook an important aspect of Capacity that the CAPE framework asks: Who has the human and financial resources to offer CS? While many of the articles in our dataset can be classified as Capacity, none of the articles investigated the financial resources that schools have to implement the pedagogy and incorporate the resources/tools being studied.

When taking a closer look at the constructs investigated under student experience, we see that the most researched constructs are Enjoyment (40%), Confidence (31%), and Content knowledge (27%). While Enjoyment is an important construct, it is not always the most accurate measure. For instance, external factors can influence the extent to which participants enjoy an experience (e.g. time of day of the camp, prior relationships with other participants, food/refreshments being offered, etc) [9, 12]. Also, some of the other constructs can be an indicator of enjoyment. For example, if a student is intending to pursue CS, whether as a major or as a career, it stands to reason that the student likely had some positive experience with the subject already. Additionally, if the course was high quality and the students could relate to the material, their enjoyment levels would rise [9]. Without a way to discern why the "enjoyment" is occurring, we cannot easily relate this to its primary cause. Content knowledge, on the other hand, can be measured as a more direct result of the topic being taught in the course.

While it is important to have diversity amongst components of CAPE, it is also important to have variety amongst the constructs measured within each component. For example, Farrington et al. state that Study Skills is a core area that researchers should study given its impact on student academic achievement and growth [9]. However, Study Skills was not an area that researchers studied among girls-only participant studies, thus indicating a gap in the research. The authors also mention that other academic behaviors can influence grades and achievement test scores. These include class attendance and homework completion are important constructs to measure (as

well as their barriers). As important as they have been noted in prior research findings, neither of these appear as a measurement in the articles we reviewed.

6 Results & Discussion: Primary Research Question

To measure the primary research question *How feasible is it to use the CAPE framework for identify coverage gaps in K-12 CS education research?*, we examined each of our subquestions related to feasibility, one for implementation and one for practicality.

6.1 Implementation

In regards to Implementation, we set out to reflect on and answer the feasibility question: *To what extent can the process of classifying articles against the CAPE framework be performed successfully?*

6.1.1 Degree of execution

For the most part we were successful in the execution of this process. Since the dataset was relatively small, we looked at both research articles and experience reports. We were able to successfully categorize all of the articles in our dataset according to the CAPE framework and the results showed us gaps in the research for this particular set of data. The high degree of execution in this pilot study showed us that it is possible to implement this process on a larger scale. Implementation on a larger dataset is likely to yield greater results by highlighting more significant gaps in the literature.

6.1.2 Success or failure of execution

The high degree of execution was possible. After we resolved the initial challenges, we were able to classify each paper as measuring one or more of the CAPE components. Before narrowing the definitions, we initially came to different categorizations of the studies. Several articles mentioned various aspects of Capacity, Access, Participation, and Experience and there was too much room for interpretation without clarifying definitions. We needed to limit subjectivity involved in the process by creating stricter definitions of what should be included in each category. Once we decided to only look at what the researchers measured rather than discussed in the paper (e.g., future goals of the project or future predictions of the impact on participants), we were successful in our execution.

6.1.3 Amount, type of resources needed to implement

The entire process took approximately 72 hours to complete. Around half of our time was spent building and clarifying the methodology, while the other half was spent reviewing the articles. It took less time to categorize a paper as we became more familiar with the process and the specifics of what we were looking for.

This also took less time due to the fact that our dataset was essentially at our fingertips. Using an existing dataset rather than having to construct one from scratch greatly reduced the resources needed for this research study.

6.1.4 Factors affecting implementation ease or difficulty

There were a number of factors that made it easier and more challenging for us. Since researchers themselves do not classify their papers as belonging to one or more of the CAPE components and

we were specifically looking at what was measured, we could not use a keyword search or automate the process. To classifying the papers, we were required to read through each individual article. The beginning of the categorization process was harder as we were still working with loose definitions of CAPE, but it became easier as our definitions became clearer.

As mentioned in the previous section, one factor that made the process easier is that we already had the dataset at hand and this simplified the process of gathering relevant articles. Rather than searching for articles in the existing literature, we were able to obtain relevant articles within a few minutes through a query.

6.2 Practicality

For the practicality of this process, we set out to reflect on and answer the question: *To what extent can classifying articles against the CAPE framework be carried out using existing means, resources, and circumstances and without outside assistance?*

6.2.1 Efficiency, speed, or quality of implementation

The process we used is fairly efficient as we were able to successfully categorize the dataset under the CAPE components relatively quickly- in part because of the already existing dataset. We were also able to produce high quality results with limited subjectivity since we were strictly looking at what was measured.

6.2.2 Positive/negative effects of using the process

Although we did not yield earth-shattering results, we can start to see that classifying articles along the CAPE framework to look for gaps in equity-focused research is viable and produces positive effects. For instance, we can start to see the gaps in the literature in our own limited dataset. For example, there was a large gap in research that investigated access and participation. When applied to larger datasets, this categorization process will show researchers where attention needs to be focused.

6.2.3 Ability to administer the process

Once we had developed the inclusion/criteria for each category of CAPE, we were able to categorize each article with relative ease. With our formal definitions that we provide here, we anticipate that others will also be able to adapt this process and that we will be able to also use these definitions in a larger, more complex dataset.

6.2.4 Cost analysis

Few resources were necessary to conduct this analysis. Since we had easy access to the articles [ANON], there was no pay wall or cost incurred reviewing the articles (other than our time and effort costs).

7 Limitations

We specifically focused on papers that focused on girls and had no participants who were boys for this pilot study. In this regard, our dataset is limited—however, intentionally so. Still, papers that include participants who were only boys or had participants of both genders were not reviewed. As we expand our process, it may illustrate other differences between these types of studies.

As it is in our study, after the first three articles were used to baseline the analysis process, one researcher classified the papers and met with the other researcher to discuss the classifications weekly. Additional researchers might be able to provide broader or more nuanced perspective on how classifications can be performed. More researchers could also provide us with more resources to have multiple researchers independently categorize the studies and then conduct interrater reliability on the classifications to provide greater assurance that they were classified appropriately.

There may be other frameworks for analyzing the body of research to determine where the equity gaps exist in research. In the future, we plan to investigate other frameworks for scoping the literature as well to see if they might offer more information about research gaps. However, the CAPE framework holds great promise and we are more likely to expand upon this by building out further subcomponents of each of the CAPE components in our future scoping reviews–since it has been specifically created for CAPE.

Lastly, it would also be ideal to compare these gaps with what is considered to be important factors that impact student achievement and growth. Though we did not go as far as to conduct that analysis in this paper, we plan on doing so in our future research.

8 Conclusion

In this paper we have shown that it is possible to classify K-12 CS Education research papers along the CAPE framework. We collected and classified 51 CS education research papers and our analysis has revealed gaps in areas of participation and access. We also evaluated the feasibility of this process by looking at implementation and practicality. In regards to implementation, we found that the process of classifying articles against the CAPE framework can be performed successfully and with a high degree of execution. In terms of practicality, we found this process relatively efficient due to the few resources needed and the speed at which we were able to gather our dataset and classify the articles.

While these results are not representative of the entire current CS education literature, our pilot study demonstrates that it is feasible to implement this process on a larger dataset, which is the next step in our research. This would provide greater insight into where our attention needs to be focused in regards to equity driven research.

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Paper Session 2: Best practices in outreach, retention, and the first-year experience

Location: Engineering Building 1150

Session Chair: Chris Gordon

0.00 0.15	
9:00 – 9:15am	Work-in-Progress: Partnerships to Create
	Opportunity through Informal Learning
	Kristin Giglietti, H. Rex Gaskins, Marcia
	Pool (University of Illinois Urbana-
	Champaign)
9:15 – 9:30am	Engineering Technology Students'
	Perceptions of a Transformed Gateway
	Course
	Rustin Webster, Matthew Turner, Brittany
	Newell (Purdue University)
9:30 – 9:45am	Work-In-Progress: An Updated Peer
	Mentorship Strategy for First Year
	Engineering
	Benjamin D. McPheron (Anderson
	University)
9:45 – 10:00am	Effect of Connected Courses on Student
	Retention in the First year Curriculum
	Chris Gordon (Southern Illinois University
	Edwardsville)

Work-in-Progress: Partnerships to Create Opportunity through Informal Learning

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Abstract

While many Science, Technology, Engineering, and Math (STEM) programs exist, these are not always easily accessible due to many factors including cost and lack of communication; therefore, greater access to these programs is needed to create and foster existing interest that could lead to STEM careers. Additionally, it has been shown that student's interest in STEM begins decreasing in middle school, thus hindering the pathway to a STEM career. Through this program, we aim to increase access to STEM fields by exposing elementary and middle school students from low-income and underrepresented (UR) communities to STEM career pathways through hands-on activities and continued mentorship. The activities will be offered in collaboration with community partners (e.g., YMCA, Big Brothers Big Sisters) to facilitate students' engagement in STEM beyond the classroom. By offering this program, we aim to (1) inspire continued interest in STEM and (2) strengthen STEM interest through use of a societally relevant problem (i.e. grand challenge) as a theme for our activities. This year, we began establishing formal partnerships with local K-12 organizations, including those that engage students in their own communities. We involved sophomore undergraduates in developing activities; offered an on-campus activity for a community organization; and with partner organizations, worked through the logistics of offering programs at their facilities and scheduled upcoming visits. All activities are created and piloted before being offered and are connected to the Next Generation Science Standards, so the programs are grade appropriate and reinforce concepts presented at school. Each session is targeted to be one hour which includes introduction to the lessons, related hands-on activities, and connection of the lesson/activity to STEM careers through discussing disciplines and majors that provide training to conduct work relevant to the activity. After we receive institutional review board approval, we will use modified versions of published and validated surveys to collect data to answer these research questions: (1) Does participation in the program increase student's interest in STEM? and (2) Does participation in the program increase a student's STEM career aspirations?

Introduction

While many Science, Technology, Engineering, and Math (STEM) programs exist, these are not always easily accessible due to many factors including cost and lack of communication; therefore, greater access to these programs is needed to create and foster existing interest that could lead to STEM careers¹. Additionally, it has been shown that student's interest in STEM begins decreasing in middle school thus hindering the pathway to a STEM career². To address this need, we established an outreach program that engages the local community organizations to increase access to STEM fields by exposing elementary and middle school students from low-income and underrepresented (UR) communities to STEM career pathways through hands-on activities and continued mentorship. The program is evidence-based and incorporates best practices for STEM diversity and inclusion: cultivating partnerships and collaborations,

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providing authentic STEM engagement, and developing and retaining student interest through effective mentorship³. The program will provide equitable access to STEM training through hands-on activities, expose UR youth to STEM career pathways, and introduce mentors to guide learning.

To accomplish this, we weave a socially relevant topic, cancer, which also has well-established disparities amongst UR populations, into our STEM activities to create a connection between everyday life and STEM content⁴. Then, hands-on activities are used to engage students and spark continued interest in STEM to increase the likelihood of student's pursuing advanced math and science classes⁵ which support college preparation. Finally, activities offered in an informal setting support student's STEM career plans¹; therefore, we anticipate the activities will inspire student's interest in pursuing STEM careers.

By offering this program, we aim to (1) inspire continued interest in STEM and (2) strengthen STEM interest through use of a societally relevant problem (i.e. cancer) as a theme for our activities. Herein, we describe our process of establishing partnerships, developing material, considering challenges with logistics or in offering material, and formulating next steps.

Program development

The education team within the Cancer Center at Illinois (CCIL) developed formal collaborations with organizations who serve the local community, such as YMCA and Big Brothers Big Sisters. Numerous meetings and site visits were held to better understand the programs and their needs. Specific items such as timing of the programs, number and age of potential participants, space and facility needs for the programming, necessity of background checks to participate at their facilities, and other items were addressed. From discussions with partner organizations, it was determined what programming would best benefit the organization's needs. For the Stephens Family YMCA (Champaign, IL), a one hour program that offered hands-on STEM activities^{6, 7} to elementary and middle school students participating in Y on the Fly (a YMCA program that is located and offered in underserved communities and not at the central YMCA facility) was planned and offered twice a month, and for Big Brothers Big Sisters of Central Illinois, an on-campus activity day (about three hours) was offered once per academic semester in which the Littles attended with their Bigs.

In addition to several activities the team already developed, we engaged STEM undergraduate students to develop, pilot, and refine lesson plans and activities with the goal of having a library of ready to go material. With internal funding, we were able to hire three undergraduate students to work two to three hours per week to support the delivery of the program; these students were trained^{8, 9} by CCIL staff (including best practices of outreach, working with diverse audiences, and communicating to lay audiences). The student workers introduce the module, guide hands-on activities, and finish the session by discussing disciplines and majors that provide training to conduct cancer focused research relevant to the activity. While the student workers will be the main on-site mentors (due to background check requirements), we also plan to engage the Cancer Center at Illinois Student Organization (CCIL-SO), a registered student organization, as a source of additional mentors for future on-campus events.

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Programmatic challenges

Identifying and sustaining partnerships: A significant amount of time was devoted to identifying community and school-based programs with which we could partner. In some instances, we encountered difficulty in making and sustaining initial contacts with community groups due to leadership changes, staffing concerns, and lingering impacts of the pandemic in the partner groups. Some groups, especially those in more rural locations, had little information on their websites and little to no social media presence; this made it challenging to find contact information and learn about their programs.

Overlap with existing programs: The University of Illinois Urbana-Champaign has a strong commitment to community engagement and outreach with numerous units and registered student organizations having long standing outreach programming. Unfortunately, there is no centralized list or contact person who is aware of all the campus outreach activities. Therefore, this required an investigation of multiple websites and discussions with units to learn of existing programming and partnerships in order to prevent overlap and duplication of programming.

Informal setting (non-classroom): Informal STEM programming has numerous benefits to the participants¹⁰, but also comes with several obstacles that will be different than outreach efforts in a school-based setting. Many afterschool programs are offered to a wide age range, which makes it challenging to develop age- and ability-appropriate lessons. The Y on the Fly program for example, serves students in kindergarten through fifth grade. Although many students attend the program regularly for the entire school year, attendance can vary, and students may exit or join the program throughout the academic year. This may affect data collection and attempts to understand the impacts of our programming. Because we are one component of an existing program at YMCA, the logistics of handling parental consent, student assent, and pre-program is handled by the community partner. For programs we have hosted on our campus, these items were accomplished in the online registration process. In the afterschool program, we rely heavily on the partnering staff to distribute these items at the beginning of the program since we do not have direct contact with the participant's parents/guardians.

Protection of minors: Protection of minors is of utmost importance. The background check process for volunteers varies by organization and school system; some require checks for all volunteers that enter their facility while others have different requirements if teacher/other background checked individual is present. The lead time to complete these checks and their expense can become prohibitive when trying to integrate large numbers of university student mentors into the outreach programming. Additionally, if we do secure a background check for an undergraduate student to participate, we ask they commit to at least one semester of engagement.

Sample Activities

We use a variety of activities; some are widely available online, and others are developed by our team and students. One example is summarized here, and a link to the example's full lesson plan (including step-by-step instructions, connection to Next Generation Science Standards, material list, and facility considerations) and additional lesson plans for other activities (continuously updated) is available here: <u>https://go.illinois.edu/CCILoutreach</u>.

Strawberry DNA: Students will learn about DNA: what it is, why it provides valuable information, how genetic factors influence cancer risk, and how genetic testing can guide targeted therapy. Students will then perform a hands-on activity to extract DNA from strawberries, and following this, the mentors will lead a discussion on disciplines/majors that provide training to support this type of work. *Cancer research connection*: Genetic testing to identify mutations associated with cancer development and guide targeted cancer therapy *Some relevant majors that work in this area*: BME, ChBE, MSE, MCB, CHEM

Future plans

During Spring 2023, we piloted and refined STEM lessons and activities and gained experience working with community partners to better understand their needs and processes. Insights gained during this time support program improvement and preparation for data collection to begin in Summer/Fall 2023. Understanding each partner's participant registration process and ongoing participation rates will support us in developing our protocol to collect the consent, assent, and pre-survey responses, as a means to maximize participation in the study. Once institutional review board approval is received, we will begin research participant recruitment (targeting middle school and above) during our partner's registration process for the 2023-2024 afterschool program and begin data collection.

We will use a modified version of the (1) STEM Semantics Survey¹¹ to identify student's interest level pre- and post-program and (2) STEM Career Interest Survey (STEM-CIS)¹² to ascertain any changes in career aspiration pre- and post-program. The mentors will also provide qualitative feedback on changes in student's interest during the program. Together, the quantitative and qualitative data will support our understanding of the program impact.

With experience and program refinement, we will broaden our impact by expanding our outreach programming to additional community partners and/or schools and recruit and train cohorts of university student mentors to scale up our established model.

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Effect of Connected Courses on Student Retention in the First-year Curriculum

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Abstract

This paper describes results of an initiative to place freshmen residents of an engineering and technology residential community into a common course in their first semester. The motivation of this initiative is to enhance retention of first-year freshmen by facilitating study group formation. Freshman engineering students at the investigator's university are provided access to multiple retention-focused initiatives including residential hall-based mathematics tutoring, supplemental instruction in mathematics and physics sections, and industry mentoring. The school began an initiative to intentionally enroll freshmen in the engineering-focused residential hall in a common course in the first year of engineering curricula. Students in the focused interest community were pre-registered for selected courses, based upon their interest in engineering and their academic preparedness. During the registration period, students could opt out of the pre-registered course. The purpose of this effort is to enhance student success by fostering social connections of students in first year connected courses and lessons learned from the connected course cohorts. First-year retention of students in connected classes was higher in each cohort in comparison to students without connected classes.

Introduction

Residential learning communities are a high impact practice with a positive effect on educational outcomes (e.g. Dahl et al, 2020). The Southern Illinois University Edwardsville School of Engineering maintains a freshman residential community (referred to as a focused interest community or FIC) for engineering and technology within one of its freshman residence halls, which is across the street from the building that houses the School. Students with an interest in engineering and technology can opt in to this residential community in their freshman year. The community is typically comprised of 100-150 students in any given year. In addition to social programing throughout the year, the community is supported by a faculty fellow from the School who interacts with the community throughout the academic year. Math tutoring is provided five nights per week. Students do not necessarily have to major in disciplines in the School or even be eligible for courses in the School.

Due to the increase in popularity of majors in the School and by extension in the residential community, the residential community increased from one wing to three wings beginning in Year 1, providing a sufficient number of students to pursue residentially connected courses.
Beginning in Year 2, the housing and academic advising units made concerted efforts to place students from the housing community in a common course. To implement this approach, the housing office reserved a set number of seats in selected first-year courses prior to when freshmen completed their registration. Once incoming students selected their housing community, they were pre-registered in first year courses according to their interest and academic preparedness. Students were then free to make changes during the registration period, but few did. This work in progress sturdy evaluates the initial success of students in these connected courses by comparing the rates of D, F, and W grades of students in the courses with students in the residentially connected population.

Assessment

In Year 2, 65 FIC students were placed in the following three connected courses: Introduction to Engineering Problem Solving Section 1, Introduction to Engineering Problem Solving Section 2, and Calculus I Section 1. The course sizes ranged from 25 for the introduction to engineering section to 57 for the Calculus I class. While the class size for the math class was larger than the engineering sections, the course format included mandatory small group problem solving sessions as part of the weekly course format.

	# students	# FIC	Course DFW rate	Course DFW rate,
	overall	students	overall	FIC students
Intro – Section 1	25	22	28% (7/25)	22.7% (5/22)
Intro - Section 2	25	20	24% (6/25)	15% (3/20)
Calc I- Section 1	57	26	26.3% (15/57)	19.2 (5/26)

Of these, eight students enrolled in two connected courses. The DFW rate of these students was 0% (0/16). The DFW rate of the residentially connected students ranged from 5.3% to 9% better than the overall course DFW rate for the three sections. The 19.1% overall DFW rate of the residentially connected student population was 7.1% better than the 26.2% DFW rate of the overall set of courses.

In Year 3, 81 students participated in the following four connected courses: Introduction to Engineering Problem Solving and Calculus I. Again, the math sections included mandatory small group problem solving sessions as a weekly course component.

	# students	# FIC	Course DFW rate	Course DFW rate,
	overall	students	overall	FIC students
Intro – Section 1	25	14	16.0% (4/25)	7.1% (1/14)
Intro - Section 2	25	23	16.0% (4/25)	17.4% (4/23)
Intro – Section 3	25	18	16.0% (4/25)	22.2% (4/18)
Intro - Section 2	25	15	24.0% (6/25)	20.0% (3/15)
Calc I- Section 2	52	18	34.6% (16/52)	18.8% (3/16)
Calc I- Section 3	57	20	35.1% (20/57)	36.4% (8/22)

Of these, 27 students enrolled in two connected courses. The DFW rate of the connected course for these students was 37% (10/27). The DFW rate of the residentially connected students ranged from 6.2% worse to 12% better than the overall DFW rate at the course level. The 21.3% total DFW rate for the residentially connected student population was 4.5% better than the 25.8% total DFW rate for the overall set of courses.

In Year 4, students were connected to the following courses: Introduction to Engineering Problem Solving and Introduction to Computer Science. This included two large section sizes: one for an introductory computer science class and one for an introduction to engineering class. Additionally, the section size for the introduction to engineering courses were increased from 25 to 30 to accommodate a surge in enrollment.

	# students	# FIC	Course DFW rate	Course DFW rate,
	overall	students	overall	FIC students
Intro Section 1	30	15	13.3% (4/30)	6.7% (1/15)
Intro Section 2	30	19	16.7% (5/30)	15.8% (3/19)
Intro Section 3	30	22	13.3% (4/30)	9.1% (2/22)
Intro Section 4	80	25	3.8% (3/80)	8.0% (2/25)
Intro CS Section 1	75	19	17% (19/75)	21% (4/19)

The DFW rate of the residentially connected students ranged from 4.3% worse to 6.7% better than the overall DFW rate at the course level. The 12% total DFW rate for the residentially connected student population was 2.3% better than the 14.3% total DFW rate for the overall set of courses. The DFW rate in the larger engineering and computer science sections was worse than the class average, suggesting that the benefits of group formation and peer instruction was not as easily replicated in larger classes.

Conclusion

This work in progress study identified evidence of improved DFW rates among students participating in three sets of connected courses in the first semester of the freshman year for engineering and computer science students. The success of students in the introductory level courses corresponds to a better outcome in the first semester for first-year students. The initial results suggest that larger class sizes might not realize the same benefit of this format as smaller classes sizes. Initial results indicate that more than one connected course in the first semester may also improve student performance in first semester classes. Further investigation will demonstrate the longer-term retention outcomes of these cohorts.

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Work-In-Progress: An Updated Peer Mentorship Strategy for First Year Engineering

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Abstract

Undergraduate peer mentorship provides an effective strategy for allowing first-year students to adjust to a college setting by providing a connection with established students and increased access to institutional knowledge and resources. Previous work developed a peer mentorship strategy for a first-year engineering course at Anderson University and reported encouraging results for initial retention and student success outcomes. In particular, short-term retention was increased, and participants felt better engaged with the engineering program and university.

After the initial study, the peer mentorship strategy was refined to improve mentor accountability and structure. In this paper, the refined strategy is presented, along with updated retention data including medium-term retention information. In addition, retention and survey data from the second cohort of students are presented which attempt to measure outcomes for two research questions:

RQ1: Do students feel that peer mentorship was valuable in connecting to the engineering program and community?

RQ2: Does peer mentorship lead to better retention outcomes?

Results from this ongoing study are encouraging in demonstrating the efficacy of engineering-specific peer mentorship.

Introduction

Significant research has demonstrated that peer mentorship is an effective method for improving retention outcomes for engineering students [1,2,3,4]. The motivation to grow effective peer mentorship programs corresponds with the important efforts to improve retention, particularly at enrollment-driven institutions. Although peer mentorship has been studied widely, the challenges associated with these programs are still a relevant topic, particularly coming out of the COVID-19 pandemic [5,6]. The 2022 ASEE Annual Conference included 9 papers on the topic [7,8,9], including an entire session in the First-Year Programs Division called "Peer Mentoring/Learning, Teaching Assistants, and Career Mentorship," which included three papers on peer mentorship [5,6,10].

Within this atmosphere of enrollment pressures and promotion of student success, previous work was carried out at Anderson University, a small enrollment-driven institution, to develop a peer mentorship program for first-year engineering students [2]. This work adapted lessons learned from other, much larger engineering programs into a cohesive peer mentorship program in this smaller context [11,12,13,14,15]. The results of this previous work indicated promising

results in short-term retention and an increased feeling of connection with the engineering program. In the current work, an updated peer mentorship model was developed to strengthen mentor accountability and expectations, and updated assessment was conducted including measuring medium term retention results for the original peer mentorship cohort.

Peer Mentorship Strategy

In previous work [2], peer mentoring volunteers were employed by the department and paid for about 5 hours of work over the course of the semester, split across three mentorship meeting times. Recognizing the benefit of peer mentorship to both the students being mentored and those serving as mentors, the mentorship strategy was adjusted this year to make peer mentorship a required curricular activity. This peer mentorship requirement was added to the upper-level Control Systems course, making up 3% of the grade for the course. This course was chosen because it is required for most engineering majors at Anderson University. Peer mentorship training and expectations were provided as part of the Control Systems course.

Individual peer mentors were assigned to first-year engineering project groups completing a project in their Intro to Engineering course. This course has no TA support, making it a good choice for leveraging student peer mentors. The groups each consisted of four students who were tasked with designing, constructing, and documenting mini-golf holes for a campus event [2,16]. In this project, students are given a strict material budget, constraints on storage space, and several requirements for 3D-printed and laser-cut objects with the objective of making a hole that is interesting to play with an expected par less than six strokes. At the campus event, participants vote on their favorite hole, awarding bonus points to the winning teams. The project is split into well-defined milestones spaced two to three weeks apart in the second half of the semester which require the application of the engineering design process. Each peer mentor completed a project with similar milestone and documentation expectations in their first-year engineering course, resulting in experiential knowledge of project requirements.

Peer mentors were required to meet with their groups a minimum of three times over the course of the semester and report the meeting attendance after each meeting by email. In order to specify timing, it was required that mentors meet with their students before each of the first three milestones for their mini-golf project. The following expectations were provided to these peer mentors:

- Provide a reliable primary and backup contact method to the group
- Provide review/feedback/project management support to groups on their design and project progress
- Ask group members about their adjustment to coursework
- Ask group members about integration to campus life, residence life, clubs, etc.
- Provide aid and support if there are student questions about scheduling courses
- Be positive about the engineering program
- Be professional in communication with groups and group members

Table 1 shows the rubric provided to the peer mentors demonstrating grading standards.

Requirement	Value
Student group rating of peer mentor	10
Attendance at Meeting 1	5
Attendance at Meeting 2	5
Attendance at Meeting 3	5
Communication with Faculty	5
Total	30

Table 1 Peer Mentor Rubric

In addition to requirements for the peer mentors, each student team had a requirement to report back to the responsible faculty member and communicate with their peer mentor. As part of their project grade, they were required to reach out by email to set up an initial meeting with their peer mentor; a minimum of three student-mentor meetings were required, including the student-initiated first meeting. Failing to attend all three required meetings resulted in a 2.5% deduction from the final grade for first-year students participating in the mini-golf project. This allowed the burden of responsibility for scheduling and holding meetings to be shared across both the peer mentors and the student teams which they mentored.

Assessment Methods

Indirect and direct assessment methods were applied to measure the efficacy of this updated peer mentorship model, specifically to answer the research questions:

RQ1: Do students feel that peer mentorship was valuable in connecting to the engineering program and community?

RQ2: Does peer mentorship lead to better retention outcomes?

As a mode of indirect assessment, a 5 point Likert scale survey was delivered to students using Google Forms, containing five prompts. In this survey, a rating of 1 corresponded to 'Strongly Disagree' and a rating of 5 corresponded to 'Strongly Agree'. The particular prompts were:

- 1. I found my peer mentor to be a useful resource for completing my design project.
- 2. How would you rate your peer mentor (1-5).
- 3. I had an easier time adjusting to college life thanks to my peer mentor.
- 4. My peer mentor helped me connect better with the engineering program community.
- 5. I plan to continue studying engineering at Anderson University next semester.

Questions 1 and 2 were aimed at assessing the peer mentors and were used as part of the grading criteria as displayed in the rubric shown in Table 1. Questions 3 and 4 addressed the usefulness of peer mentors in connection to campus and adjustment to college life (RQ1), and Question 5 addressed retention (RQ2).

To directly assess retention outcomes for RQ2, retention to semester 2, 3, and 5 year graduation rate are used. Data are reported for three years prior to implementing peer

mentorship (2018-2020) and for both years that peer mentorship has been used (2021 and 2022).

Updated Results

Results of the Likert scale survey are shown in Table 2. Results from the same survey delivered to the previous cohort are included for comparison. Of the 39 students enrolled in the course, 34 responded for an 87.1% response rate. In the previous cohort, 30/32 responded (93.8% response rate).

Survey	2021 (<i>n</i> ₁ = 30)		2022 (/	n ₁ = 34)	Mann-Whitney Test Results	
Question	Average	Std. Dev.	Average	Std. Dev.	U	р
1	4.33	0.80	3.88	1.03	386	0.095
2	Not Measured	Not Measured	4.06	0.95	N/A	N/A
3 (RQ1)	3.63	1.22	3.32	0.98	407.5	0.168
4 (RQ1)	3.77	1.04	3.29	0.91	363.5	0.049
5 (RQ2)	4.73	0.78	4.62	0.78	435	0.313

Table 2: Average responses to the Likert scale survey with 1 being 'strongly disagree', and 5
being 'strongly agree'.

The averages reported all skew towards the 'agree' side of the scale, but every result is lower than the previous cohort. To compare the difference between results, the Mann-Whitney test was used. Only Prompt 4: "My peer mentor helped me connect better with the engineering program community" saw a statistically significant change between the cohorts (Mann-Whitney U = 363.5, $n_1 = 30$, $n_2 = 34$, p<0.05 two-tailed). It is unclear what caused this change, and this result should be studied further. The question which had the smallest change between cohorts was Prompt 5: "I plan to continue studying engineering at Anderson University next semester" (Mann-Whitney U = 435, $n_1 = 30$, $n_2 = 34$, p=0.313 two-tailed). To uncover the source of the differences in the data sets, Figure 1 shows the survey results in a stacked bar graph comparing the two cohorts. Table 3 contains the numerical data from this bar graph. From these, it can be seen that in 2022, Prompt 4 had a far lower percentage of positive responses and a greater percentage of neutral responses, meaning that many students did not feel that the peer mentors harmed their connection to the engineering program, but they did not help it either. It is also possible to see that Prompt 5 actually had a higher percentage of positive responses in 2022 than in 2021, so even though there was a lower average value, a greater percentage of students intended to retain. These results suggest that retention is positively impacted by engineering peer mentorship, but direct assessment results are needed to further evaluate that finding.





Figure 1: Stacked bar chart showing comparative Likert scale responses between the 2021 and 2022 cohorts, both of which had peer mentorship.

Prompt\Response	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q1 (2021)	0.0%	0.0%	20.0%	26.7%	53.3%
Q1 (2022)	2.9%	5.9%	23.5%	35.3%	32.4%
Q3 (2021)	10.0%	3.3%	26.7%	33.3%	26.7%
Q3 (2022)	5.9%	8.8.%	41.2%	35.3%	8.8%
Q4 (2021)	3.3%	6.7%	26.7%	36.7%	26.7%
Q4 (2022)	2.9%	11.8%	47.1%	29.4%	8.8%
Q5 (2021)	0.0%	6.7%	0.0%	6.7%	86.7%
Q5 (2022)	2.9%	0.0%	0.0%	26.5%	70.6%

Table 3: Numerical results from the stacked bar chart in Figure 1 showing comparative Likert scale responses between the 2021 and 2022 cohorts, both of which had peer mentorship.

In addition to the indirect assessment of research questions, retention outcomes can be directly measured. Figure 2 shows the retention outcomes of cohorts pre- and post-peer mentorship, reported with respect to the original class enrollment size. Cohorts from 2018-2020 did not have engineering peer mentors, while cohorts from 2021 and 2022 did.



Figure 2: Retention results for continuation in engineering majors in semester 2 and 3, as well as 5 year graduation rate in engineering both with peer mentorship (2021-2022) and without it (2018-2020).

Evaluation of Mentor Performance

In addition to studying the effect of peer mentorship on first-year student retention and success, some discussion of the performance of the peer mentors themselves is useful. Of the 10 student peer mentors, 100% attended all three meetings. Each individual first-year student identified and rated their peer mentor through the survey tool, and mentors were rated an average of 7.97/10 by the teams they mentored, with a standard deviation of 1.56. Ratings for each peer mentor by members of their groups were fairly consistent, with an average variance of 1.45.

A few comments were provided by first-year students when evaluating their peer mentors. On one hand, a commenter stated "[Our mentor] was helpful in navigating our project and laying out a solid work plan." In contrast, one particular mentor was not rated as effective and precipitated commentary from group members, shared here: "I wish our peer mentor was more helpful. They really provided no mentorship in engineering and just talked to us about what was going on in general with each of us, and even in that they provided little to no mentorship regarding college life." A similar sentiment for that same mentor was echoed by another group member. These comments (good and bad) suggest that more training is needed for peer mentors on exactly

what role they should take in helping students plan and execute their projects in addition to providing community connection support.

Discussion of Results and Future Work

While results on both the survey and short-term retention are lower than in the first year of the program, the peer mentorship strategy appears to positively impact retention. It is notable that retention to semester 2 is highest for the two cohorts with peer mentorship. Another notable difference is that the variation in the semester 2 retention results is much smaller from year to year with peer mentorship than without. Although only one year of retention to semester 3 with peer mentorship is available, these results are also higher than cohorts without mentorship.

When considering survey results, it is also important to consider the differences between the two cohorts. The average incoming high school GPA for the 2022 cohort was 3.69 while the incoming high school GPA for the 2021 cohort was 3.58. However, the majority of the 2022 cohort's high school experience was directly impacted by the COVID-19 pandemic, so high school GPAs may not be comparable or may not hold as much weight as comparing previous cohorts. Standardized tests such as the SAT were also less common among the 2021 and 2022 cohorts than those prior to 2021, as many universities, including Anderson University, moved to test-optional admissions models. Another factor that is difficult to account for is the change in enrollment size between cohorts, as enrollment grew from 19 students in 2020 to 39 in 2022.

One area that can be easily measured is the comparative performance of the 2021 and 2022 cohorts to those of the cohorts from previous years. Table 4 shows the average semester 1 GPA and average Calculus 1 GPA for students participating in this study. It is difficult to compare the two peer mentorship cohorts with each other based on the difference in first semester performance. The 2022 cohort is much closer in performance to the 2020 cohort. The primary conclusion is that, despite similar performance in the first semester, the 2020 cohort had a short-term retention rate of 55.0%, while the 2022 cohort with peer mentorship had a short-term retention rate of 87.2%. This is both a significant improvement and an encouraging result for the peer mentorship program.

Year	n	Semester 1 GPA	Std. Dev.	Calc. 1 Average	Std. Dev.
2018	19	2.70	1.0	1.91	1.28
2019	18	2.76	0.97	2.77	0.99
2020	20	2.52	1.29	1.93	1.65
2021	32	2.84	0.83	2.48	0.98
2022	39	2.69	0.83	1.93	1.26

Table 4: Average semester 1 GPA and average Calculus 1 GPA for students participating in this study, shown by year of course offering.

Further engagement with the results leads to the following questions that require future research, thought, and discussion, listed here with commentary as appropriate:

- What are the primary benefits and drawbacks of a course-grade-enforced peer mentorship program?
 - When paid volunteers were sought in the first year of the peer mentorship program, only the high-achieving students who were more organized and motivated chose to serve as mentors. When mentorship is required of students in a course, a wider range of achievement levels is expected, which may impact the success of the peer mentorship program.
 - If serving as a peer mentor is retained as a curricular component for upper-level engineering students, this can be used to highlight and assess ABET Student Outcome 5: an ability to function effectively on a team and Student Outcome 3: an ability to communicate effectively with a range of audiences.
 - Careful selection of the best class for the training and recruiting peer mentors is required. Control Systems may not be the optimal course for this. Senior Design was considered as an alternative possibility, as peer mentors are intended to help guide the first-year students towards successful project management.
- If peer mentorship moves away from a curricular component, what is the best way to motivate and incentivize peer mentors and hold them accountable?
- Should more than one peer mentor be assigned to each student group to smooth variance in peer mentor performance?
- Is there a correlation between project grades and peer mentorship ratings?
- With the retention results provided, where do students who do not persist in engineering go? What is the retention rate to the institution, and what majors do they change to?
 - Many students in the past two years have changed their major to Engineering Management, which is housed in the School of Business. This major allows students to use some credits from completed engineering courses towards their degree program.
 - It is not clear what majors are declared by other students who stay at the institution, and this will be explored further.

In addition to these questions, some important changes will be implemented in future iterations of the peer mentorship program:

- In the future, student groups will be required to meet together with the course faculty member and their peer mentors early in the semester to reaffirm expectations for the peer mentorship program and the project. Currently, apart from initial training and end of project assessment, the course faculty takes no role in the mentoring program.
- An additional small, short time-frame project will be added to give students multiple experiences using the engineering design process and interacting with their mentors.
- Students will complete the MUSIC Model of Student Motivation inventory in order to measure the impact of course design and peer mentorship on student motivation and provide additional feedback on improvements to peer mentorship and teaching strategies [17, 18, 19].

Conclusions

The updated engineering peer mentorship program shown in this paper provides clearer guidelines and accountability for peer mentors and first-year students engaged in the program. After two years of peer mentorship in the Intro to Engineering course, retention outcomes have been improved in short- and medium-term, even though academic performance was vastly different between the cohorts. In addition, students in both cohorts indicated general agreement that peer mentors helped them better connect with the engineering program and campus community.

The next step for this project is to continue the engineering peer mentorship program for several more years to assess longer term retention data before reporting again, including key changes highlighted in the previous section. Future work will provide a more comprehensive view of the subsequent career of students who are not retained by the engineering program and will investigate the relationship between project performance and peer mentor rating.

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Work-in-Progress: Transformation of a School of Engineering Technology Gateway Experience

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ABSTRACT

This work-in-progress (WIP) paper begins to 1) describe the transformation of a School of Engineering Technology (SoET) gateway experience and 2) explore students' outcomes and perceptions in the general areas of preparedness for success, satisfaction, learning preference, and competency development. In the Fall of 2022, the SoET gateway experience was transformed from two unintegrated/decoupled courses to a single course, based in part on observational problems with course design, curriculum, instructional methods, grading, assessments, integration, and documentation. Overall course objectives aimed to introduce students to foundational engineering technology (ET) knowledge, skills, and abilities (KSAs) needed for success in future SoET courses remained unchanged. Transformational elements included the refinement and expansion of learning outcomes, prioritization of instructional scaffolding, incorporation of stakeholder input, full integration of a learning management (LMS), new instructional methods, and the creation of a significant amount of new curriculum that covered a breadth of ET topics (e.g., electrical, industrial, manufacturing, and mechanical). This paper reports on a single cohort of twenty-seven Purdue Polytechnic New Albany students who voluntarily completed an end-of-semester anonymous three-part online survey analyzing their demographics, perceptions, and the extent to which they believe they had or had not made progress in a variety of engineering related competencies (i.e., cluster of related KSAs). Twenty five (92.59%) students agreed that the new gateway course had prepared them for future academic success in their selected major(s) (59.26% strongly agreed), but results show an imbalance of perceived preparation across all engineering-disciplines. Multiple course elements (e.g., modality, structure, depth, breadth, etc.) were perceived to be satisfactory and results show favor for lab-based learning over project-based learning (PBL). Finally, results indicate positive self-reported progress in four general competency areas: design, problem-solving,

communication, and group/teamwork. A second cohort will take the transformed gateway experience in the Fall of 2024 to strengthen the overall sample power, and data from the four years (Fall 2018-2022) preceding the transformation will be collected and analyzed in comparison to groups involved in the revised course.

Key Words: Engineering Technology (ET), Gateway, First-year, Competency, Freshman

INTRODUCTION

Gateway (or barrier, weed-out, killer, introductory) courses, which have remained largely untouched and understudied for decades, are simply characterized by being foundational, high risk, and high-enrollment (Koch, 2017; Weston, Seymour, Koch, & Drake, 2019). They are typically a subset of credit-bearing college-level introductory and/or foundational courses taken during the first and second years, have large enrollments (in context to the situation), and generally use a lecture with recitation and/or labs class structure (Koch, 2017). Research by Weston et al. (2019) also characterizes gateway courses as established (i.e. longstanding and offered frequently), required and/or prerequisite for most majors, and have been linked to a high degree of course grading severity (i.e., percentage of students withdrawing or receiving a D, F, or incomplete grade). Commonly offered physical science-based (e.g., chemistry and physics) and mathematics-based (e.g., calculus) courses are often labeled or recognized as gateways; however, the development of department specific gateway courses (e.g., gateway to engineering technology) has occurred.

"Students who are otherwise in good academic standing who earn a D, F, W, or I (DFWI) grade in a STEM gateway course are at high risk of not returning to their institution for the subsequent year" (Weston et al., 2019, p. 198). Other negative outcomes include course repetition, change of degree objective (major change), or existing college completely. It has also been reported that "students who do not succeed in gateway courses disproportionately come from lower-income, first-generation, and underrepresented minority groups" (Koch, 2017, p. 14; McGowan, Felten, Caulkins, & Artze-Vega, 2017). In recent work, the majority of the issues can be linked to "an intensive cluster of encompassing problems with (gateway) curriculum design and teaching methods, and with assessment and grading practices" (Weston et al., 2019, p. 198).

With gateway courses being a universal part of the undergraduate experience in the United States, their impacts cannot be understudied, mistaken, and/or ignored. As the number of traditional-aged students going to college continues to decrease in part from declining 21st century birth rates (Bransberger, Falkenstern, & Lane, 2020; Koch, 2018), the retention and preparation of all students for future academic success, especially in context to gateway courses, must grow in importance. If not, all stakeholders will continue to be negatively impacted but none more than the students, as Koch (2017) clearly states "they (students) leave with their dreams diverted if not extinguished and frequently with debt that they might never be able to repay" (p. 14).

A School of Engineering Technology Gateway Experience

Starting in the Fall of 2016 all incoming School of Engineering Technology (SoET) students at Purdue Polytechnic New Albany (PPNA) were required to take a new freshman gateway experience consisting of a component titled Engineering Technology Foundations (ENGT18000) and a component titled Engineering Technology Applications (ENGT18100), see Table 1. The two components were listed independently in the course catalog and had different instructors of record, who specialized in different engineering fields (electrical and mechanical). In general, the purpose of the new experience was to introduce SoET students to the resources and skills needed to define and solve technical problems, which would help them be successful in their future studies and ultimately in their careers. The original intention from stakeholders when developing the experience was that the two courses would be strongly integrated (i.e., coupled) across all dimensions. For example, instructors would collaborate on course design and curriculum, the material students received passively in lecture would be applied actively in lab, and instructional scaffolding would be prioritized (Kanu, 2017).

From the Fall of 2016 through the Fall of 2022 (six instances), ENGT18000 was taught by a Mechanical Engineering Technology (MET) associate professor (now Emeritus) and ENGT18100 by an Electrical Engineering Technology (EET) associate professor at PPNA. The archival of course syllabi and end-of-semester assessment of course learning outcomes (CLOs) is required each semester for all courses. In reviewing archived departmental records over the six years, syllabi from one semester of ENGT18000 was found and zero for ENGT18100. CLOs were assessed and archived in ENGT18000 twice and never in ENGT18100. Over the six year

period an array of problems with course design, curriculum, instructional methods, grading, assessments, integration, and documentation were observed. Many were aligned with the seven negative characteristics of gateways as identified by Weston et al. (2019):

- 1. Assessments misaligned w/content and understanding (including curved grading)
- 2. Heavy volume and pace
- 3. Level too high/abstract for introductory class
- 4. Rote learning/dull content in lecture mode
- 5. Teacher indifferent whether students learn
- 6. Incoherent organization, missed steps, or explanations
- 7. Competitive class culture

In the Fall of 2022, the SoET gateway experience was transformed into ENGT182000, Gateway to Engineering Technology (see Table 1). The overall course objective to introduce students to foundational knowledge, skills, and abilities (KSAs) needed for success in future SoET courses remained unchanged. However, elements of the course redesign included the complete integration/coupling of lecture and lab periods, addition of a weekly recitation period, refinement and expansion of learning outcomes, intensive and robust utilization of a learning management (LMS), use of a modified mastery of learning method for homework, and the creation of a significant amount of curriculum (22 lectures, 10 labs, 22 assignments, 300+ LMS questions, and three exams) covering a breadth of electrical, industrial, manufacturing, and mechanical engineering technology (ET) topics. It was assigned to a different MET associate professor, who prioritized instructional scaffolding and stakeholder (e.g., curriculum committees, downstream faculty, etc.) input during course design and preparation.

ENGT Course	Structure (#/week)	Credits	LMS Use	Weekly Contact Hours	CLOs
18000	Lecture (2)	3	No	4 (1:50 lectures)	Select the most appropriate degree program Apply algebraic and trigonometric skills to solve ET problems Apply computational tools to address ET problems Identify professional issues in ET Plan and execute a strategy for success in a chosen degree program
18100	Lab (2)	1	No	4 (1:50 labs)	Operate safely in a lab environment Use standard lab instrumentation to take measurements accurately Communicate relevant experimental results Complete an ET team project
18200	Lecture (2) Recitation (1) Lab (1)	4	Yes	5 (0:50 lectures 0:50 recitation 1:50 lab)	Develop an academic pathway for success in the student's selected major Select appropriate strategies and technologies to solve technical problems Apply foundational principles and tools of electrical, industrial, manufacturing, and mechanical engineering technology to address technical problems Apply computational tools to address technical problems Work in a team to solve an ET problem Demonstrate awareness of professional standards, practices, culture, and issues in engineering technology

Table 1 ENGT18000/18100/18200 Details

Purpose

The purpose of this work-in-progress (WIP) paper is to begin 1) describing and analyzing the transformation of a School of Engineering Technology (SoET) gateway experience, 2) prepare for additional data collection, 3) elicit feedback on possible quantitative and qualitative data analysis methods, and 4) explore students' outcomes and perceptions in the general areas of self-preparedness, satisfaction, learning preference, and competency development from the first cohort of ENGT18200 students.

METHODS

The convenience sample data (N = 27) for this paper comes from one cohort of Purdue University students located at PPNA, of which eighteen (66.67%) were freshmen, five (18.52%) were sophomores, and four (14.81%) were juniors. Grade classification was determined by credit

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hours, which included transfer credits. Twenty-four (85.19%) were new beginners (i.e., incoming) students at PPNA. Nineteen (77.78%) students majored in MET, six (22.22%) in EET, and two (7.41%) double majored in MET and EET. One (3.70%) student identified as female, 24 (88.89%) as male, one (3.70%) as gender variant/non-conforming, and one (3.70%) as non-binary/third gender. Four (14.81%) were >25 and twenty-three (85.19%) were between 18 and 23 years of age, respectively. Twenty-seven identified as white or Caucasian and one also as American Indian/Native American or Alaska Native, one also as Black or African American, and one also as Other. Finally, students were asked if they had ever enrolled in a Project Lead the Way (PLTW) program in high school (any amount of time) and twelve (44.44%) had participated in the engineering pathway of PLTW.

Students voluntarily completed an end-of-semester anonymous three-part online (Qualtrics) survey distributed via the LMS (n = 25). The first part collected demographic data, the second part collected students' perceptions of preparedness for future academic success, satisfaction with specific course elements (e.g., modality, structure, depth, breadth, etc.), and learning preference (lab-based vs project-based). The final part measured the extent to which students believe they had or had not made progress in a variety of engineering related competencies (i.e., cluster of related KSAs), as a result of taking the course. These questions came from part three of the Classroom Activities and Outcomes Survey (CAOS), originally funded by the National Science Foundation (NSF) (Bjorklund, Parente, & Sathianathan, 2004; Bjorklund, Terenzini, Parente, & Cabrera, 1998; Terenzini, Cabrera, Colbeck, Parente, & Bjorklund, 2001). Terenzini et al. (2001), preformed a factor analysis on the original 27 survey items which produced four factors, which they labeled to reflect four general competency areas: design, problem-solving, communication, and group competencies.

RESULTS

Overall, twenty five (92.59%) students agreed that the new gateway experience had prepared them for future academic success in their selected major(s) (59.26% strongly agreed). Students also indicted favorably that ENGT18200 had generally prepared them for future ET discipline specific courses and the perceived associated topics and activities (see Table 2). However, results show an imbalance of perceived preparation across all ET disciplines. On average, students felt

most prepared for future mechanical-based courses, activities, and/or topics and least prepared for programming-based.

Prepared for future course, topics and/or activities:	Strongly Disagree (%)	Disagree (%)	Neither Disagree nor Agree (%)	Somewhat Agree (%)	Strongly Agree (%)
Electrical-based	0	7	7	48	37
Industrial-based	0	0	26	63	11
Manufacturing-based	0	0	15	41	44
Mechanical-based	0	4	4	37	56
Programming-based	4	15	26	37	19

 Table 2 Student Perceived Preparation Data

Twenty-six of the students identified as either already completed or were currently taking TECH12000, Design Thinking in Technology, which is the cornerstone course for SoET students. As a cornerstone course it differs significantly to ENGT18200, in context to the course structure (lecture only) and active learning method used: project-based learning (PBL) vs. lab-based. Fifteen (57.69%) students responded that they preferred a lab-based method over PBL and one responded neither. A future study will analyze the students' written responses on why they preferred a specific method.

Overall, students expressed satisfaction with the new gateway course (see Table 3). Many of the new course elements were in stark contrast to ENGT18000/181000, which in general relied less on technology and followed traditional approaches for assessment (e.g., paper-based, closed-book, etc.). Of note is some students were displeased with the actual depth (extent) and breadth (range) of the course topics. Currently, the course would not allow for deeper coverage of a topic without reducing the number of topics covered. Finally, there is significant satisfaction for the inclusion of a modified mastery of learning approach for homework, a contemporary approach to test taking (e.g., individually taken but open resource and technology), and the complete utilization of a LMS, which was significantly lacking in the previous gateway experience.

Results also indicate positive self-reported progress in four general competency areas: design, problem-solving, communication, and group/teamwork (see Table 4). On average, the students believed that they had slightly to moderately improved their design (M = 2.99), problem-solving (M = 2.90), communication (M = 2.94) competencies and moderately to greatly improved their group/teamwork competencies (M = 3.11), as a result of taking the course. As

expected, the average scores on each general competency area were lower than past research from a upper-level (junior/senior) and lower-level (second semester freshman and sophomores) engineering graphics and design-based courses previously taught by one of the authors (Webster, 2019, 2022), as they both included intensive and challenging 16-week long team-based engineering design projects (semi-open-ended). Of note is that eight of the ten labs in ENGT18200 were team-based and a significant cause for the students perceived positive improvements in group/teamwork competencies.

Generalizations shall be limited due to the sample size (n = 25) and dominant homogenous demographics, which were majority white males majoring in MET. Additional limitations to note include multiple uncontrollable variables (e.g., heterogeneous KSAs of each student at entry, course attendance and participation encouraged but not required, etc.), participants came from a convenience sample (not randomized), the use of indirect over direct assessment methods, inherent concerns with descriptive research (e.g., participants' truthfulness, researchers' bias, no manipulated variable, etc.), and the author being an instructor of record and researcher.

Satisfied with the following elements:	Strongly Disagree (%)	Disagree (%)	Neither Disagree nor Agree (%)	Somewhat Agree (%)	Strongly Agree (%)
Course modality (on-campus / in-person)	0	0	0	33	67
Course structure (lecture, recitation, and lab)	0	0	4	37	59
Breadth (i.e. wide range) of course topics	0	15	22	30	33
Breadth (i.e. wide range) of software and hardware technologies	0	0	19	44	37
Depth (i.e. extent) of course topics	0	15	22	30	33
Depth (i.e. extent) of software and hardware technologies	0	19	15	30	37
Multiple homework attempts (max 3 attempts if restrictions were satisfied)	0	4	0	0	96
Open resource exams (notes, lecture slides, Internet, etc.)	0	4	0	4	92
Use of a Learning Management System (Brightspace)	0	0	0	22	78

Table 3 Student Perceived Satisfaction Data

Competency Area	M (SD)
Design:	
• Understanding of what engineers "do" in industry or as faculty members	3.07 (0.62)
• Understanding of engineering as a field that often involves non-technical considerations (e.g., economic, political, ethical, and/or social issues)	3.04 (0.76)
• Knowledge and understanding of the language of design in engineering	3.04 (0.76)
Knowledge and understanding of the process of design in engineering	2.96 (0.81)
Your ability to "do" design	2.85 (0.66)
Problem-Solving:	
• Ability to solve an unstructured problem (that is, one for which no single "right" answer exists)	2.85 (0.82)
• Ability to identify the knowledge, resources, and people needed to solve an unstructured problem	2.85 (0.72)
• Ability to evaluate arguments and evidence so that the strengths and weaknesses of competing alternatives can be judged	2.81 (0.74)
• Ability to apply an abstract concept or idea to a real problem or situation	3.07 (0.73)
Ability to divide unstructured problems into manageable components	2.89 (0.80)
Communication:	
Ability to clearly describe a problem orally	2.93 (0.78)
Ability to clearly describe a problem in writing	2.96 (0.81)
Group/Teamwork:	
Ability to develop ways to resolve conflict and reach agreement in a group	3.04 (0.85)
• Ability to pay attention to the feelings of all group members	3.04 (1.06)
• Ability to listen to the ideas of others with an open mind	3.30 (0.78)
• Ability to work on collaborative projects as a member of a team	3.30 (0.72)
• Ability to organize information into categories, distinctions, or frameworks that will aid comprehension	3.11 (0.85)
• Ability to ask probing questions that clarify facts, concepts, or relationships	2.85 (0.66)
• After evaluating the alternatives generated, to develop a new alternative that combines the best qualities and avoids the disadvantages of the previous alternatives	3.11 (0.80)
Other, Unscaled Items:	
• Ability to develop several methods that might be used to solve an unstructured problem	2.89 (0.80)
• Ability to identify the tasks needed to solve an unstructured problem	2.96 (0.81)
• Ability to visualize what the product of a project would look like	3.07 (0.87)
Ability to weigh the pros and cons of possible solutions to a problem	3.19 (0.74)
• Ability to figure out what changes are needed in prototypes so that the final engineering project meets design specifications	3.11 (0.64)

Table 4 CAOS Data:	Grouped by	y General Con	npetency Area
		/	

Notes. 1 = none at all, 2 = a slight amount, 3 = a moderate amount, and 4 = a great deal

CONCLUSION

In conclusion, this WIP paper begins to describe and analyze the transformation of a SoET gateway experience and explore students' outcomes and perceptions in the general areas of self-preparedness, satisfaction, learning preference, and competency development from the first cohort of ENGT18200 students at PPNA. MET and EET undergraduate students perceived that the new time/work intensive SoET gateway experience, that covered a large breadth of topics in

little depth, prepared them for future general academic success, but not equally across all engineering disciplines (mechanical the most, programming the least). Students strongly supported the instructors overall class structure, modality, and design that included a strong use of various technologies and contemporary assessment methods. Via student self-reported data, it was also shown that the general competency areas of design, problem-solving, communication, and group/teamwork were improved.

A second cohort of students will take the same gateway experience in the Fall of 2024 which will provide a larger and more powerful sample for analysis. Additionally, the authors are requesting historical data concerning assessments (e.g., CLOs), documentation (syllabi, schedules, etc.), grades (e.g., DFWI), and retention rates from the four preceding ENGT18000/181000 courses in an attempt to better justify and understand the impacts of the transformation. All conclusions will be further explored in follow-up research along with analysis of why the majority of students identified as preferring lab-based learning over PBL. Finally, the authors are eliciting feedback on proper future data (quantitative and qualitative) analysis methods and study types.

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Paper Session 3: Beyond Boundaries: Exploring the Intersection of Access, Pedagogy, and Technology in Engineering Education

Location: Engineering Building 1033

Session Chair: Sinan Onal

10.15 10.20	The mailting in a last second of the second size '1		
10:15 - 10:30am	I ransitioning between a flipped civil		
	engineering classroom and fully online		
	learning: Lessons learned before, during, and		
	after the COVID-19 Pandemic		
	Ryan Fries and Chaya Gopalan (Southern		
	Illinois University Edwardsville), Ravali		
	Vennu, (Bechtel)		
10:30 – 10:45am	System Design, Evaluation and Applications		
	of Domain Term Extraction from Engineering		
	Videos		
	Jiaxi Li, Ninghan Zhong, Rob Kooper,		
	Lawrence Angrave (University of Illinois		
	Urbana-Champaign		
10:45 – 11:00am	Exploring the Potential Benefits and Risks of		
	ChatGPT in Engineering Education		
	Sinan Onal (Southern Illinois University		
	Edwardsville)		
11:00 – 11:15am	Improving Access to Engineering Education:		
	Unlocking Text and Table Data in Images and		
	Videos		
	Uchechukwu Uche-Ike, Lawrence Angrave		
	(University of Illinois at Urbana Champaign)		

Transitioning between a flipped transportation engineering classroom and fully online learning

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Abstract

Flipped teaching is a rising pedagogy, but limited information is available about how it can prepare students for a transition to fully online teaching. The COVID-19 pandemic caused Universities to shift instruction to online modes in Spring 2020. The purpose of this study was to examine how flipped teaching prepared civil engineering students to transition to full online instruction and vice-versa. Data included student survey and test scores from an Introductory Transportation Engineering course each spring from 2019 to 2022. Preliminary results suggest that students taking flipped courses during or before the pandemic felt more prepared for success when courses shifted to online formats. Results also support previous research that flipped teaching of road design concepts improved student's ability to meet the stated learning objectives. Last, this study also provides new knowledge about the application of flipped teaching for traffic signals and public transit.

Introduction

Flipped learning, also known as the inverted classroom, has been gaining momentum for more than a last decade. The number of studies focusing on flipped teaching has dramatically increased since 2010 and ASEE is one of the most frequent venues for these publications [1].

Flipped learning is generally considered to include four key parts [2]. First, the learning environment should be reorganized so that time in-class is flexible to the learning needs of students. Second, learner-centered activities should be adopted to match the students served. Next, the difficulty of material should be monitored and active learning strategies leveraged to improve student understanding of key concepts. Last, the faculty should track student performance and provide timely feedback [3].

Overall, the design of flipped learning shifts more responsibility to students for their own learning [4]. Although this pedagogy provides student the opportunity to become more engaged, deep learning will only occur for students who put in the work. This teaching mode simply motivates students, through various incentives, to dedicate adequate time to learn and master the material [5]. Others agree that the success of flipped teaching is closely related to students embracing the completion of pre-class work [6].

Previous Work

Studies of flipped teaching are numerous. The following section summarizes the findings from previous studies as they relate to student performance, the perception of flipped teaching from students and faculty, flexibility, and student professional skills. Although some evaluated flipped teaching throughout the curriculum [7], the majority of studies focused on one class.

When studying student performance, previous studies found that flipped teaching helped students achieve greater overall learning [8]. Evidence included improved performance on exams [9, 10], 5-6% better overall success passing an engineering mechanics/statics class [6, 11, 12], and increased comprehension of the material [13].

Several studies examined how student learning changed between traditional lecture and flipped methods. The latter enabled students to better-achieve higher-order learning objectives [14, 15, 16, 10, 17] but not lower-order objectives. Some found better student performance on all questions at or above Bloom's level three [10] and other found improved performance, "specifically for the middle two quartiles of students (25-75% percentile)" [18]. Based on these findings, some researchers recommend that classroom time in flipped classes be focused towards solving, particularly problems targeting higher-order learning objectives [16] and courses focusing on Bloom's application-level skills [18].

Blooms taxonomy is a method of categorizing understanding into different levels of complexity. The Vanderbilt University Center for Teaching created the following summary of these levels (Figure 1).



Figure 1. Blooms Taxonomy (Adapted from [19])

Previous research has also examined the perceptions of students and faculty, with respect to flipped teaching. The majority of students (69%) agreed that flipped teaching was a good use of their time [11], and (55%) would recommend flipped teaching to a friend, instead of traditional face-to-face lecture [11, 20]. Several studies have found that students enjoyed work sessions

during class time, where they worked with peers on problem solving [21, 22, 23, 24, 25, 26] and found that time well-spent [6]. One study found that the vast majority of students (79%) also agreed that the problem solving sessions helped them master the material [5] or improve their conceptual understanding and critical thinking abilities [18]. This study also reported that half of students (50%) agreed that answering classmates' questions helped them learn the material [5]; and more than half (56%) agreed that their classmates' guidance helped them understand the material [5]. The majority of students (58%) agreed "they learned best in small groups and/or with the instructor" after experiencing flipped teaching; whereas only 14% of students in a traditional class agreed [16]. Several studies of student perspectives about flipped teaching have concluded that the students appreciated having more direct interactions in class with the faculty [27, 21].

Regarding activities before class, the vast majority of students reported that the pre-class work was helpful in learning the material (slightly 56%, very 23%) [5]. Overall, students felt more supported in a flipped class environment [28].

Not all students agree that flipped teaching is better than traditional lecture. Evidence suggests that students who preferred traditional lecture over a flipped class did so for time management reasons [16]. Other studies concluded that students perceive flipped teaching to place greater demands on them, but acknowledge benefits such as deeper learning [26] and that students with higher GPAs were more likely to prefer flipped teaching [29].

Student opinions were also found to change during a semester. For example, as course materials became more difficult towards the end of the semester, students in one study expressed that flipped teaching made it more difficult to learn on their own [30]. Another study found that students' perceptions of learning in a flipped classroom is not always accurate, especially in the beginning part of a flipped class [31].

Previous studies on flipped teaching have also considered the perceptions of faculty. Overall, faculty perceived better student engagement with flipped teaching [32, 28], better student questions at office hours and discussions during class [6], and increased class attendance [33].

In addition to evidence of student performance, student perceptions, and faculty perceptions, studies have found that flexibility and professional skills are also benefits of flipped teaching. Students appreciated the flexibility to watch pre-class videos again [1], to solve problems multiple ways [18], and feel they are "treated more individually" [28]. Faculty have noted that flipped teaching allows weaker students to learn at a slower pace [34] and an analysis of the video analytics suggested that students were watching videos just-before class, to review for tests, and watch at multiple locations [35].

Several studies have noted that flipped teaching can help students build their professional skills. Most commonly, studies have found that students can improve their autonomy or ability for self-learning [36, 37, 38, 29, 39] and lifelong learning [40, 29]. Individual studies have noted that students can improve their critical thinking [41] and interpersonal skills [42]. Autonomy, lifelong learning, critical thinking, and interpersonal skills are all important to the careers of engineers.

Other studies of flipped teaching found no evidence of changes. Several studies measuring student test performance between flipped and traditional, found no significant difference [43, 22, 32, 38, 23, 24, 25]. Another study between flipped and blended courses across multiple Universities found no significant change [26].

Flipped teaching has been studied in lower-level Civil Engineering courses such as Statics [44, 45], Mechanics of materials [46, 22, 8, 47], and Dynamics [29]; as-well-as upper-level courses such as Geotechnical Engineering [16], Structural Design [18], and Transportation Engineering [20, 48]. Specific findings included that most students preferred flipped over traditional [47] and that students learned better in flipped class than an online class [48].

The objective of this study was to evaluate changes in student perceptions and performance in a partially-flipped transportation engineering course. These results were compared to a face-to-face lecture format, a virtual synchronous partially-flipped format, and the Spring 2020 semester that began as face-to-face partially-flipped then abruptly transitioned to virtual asynchronous because of the COVID-19 pandemic.

Methods

This study evaluated student perceptions and performance in a junior-level introductory transportation engineering course in two methods 1) Final Exam performance and 2) Student surveys. The class was offered in three 50-minute sessions each week for 16 weeks. The number of lectures on each topic remained the same for all years of the study. This study included two surveys. One survey containing a list of questions about the student experience with flipped teaching compared to lecture-based traditional teaching and was collected every semester. The second survey was a questionnaire on student experiences with flipped teaching after COVID-19 and was specific to Spring 2020.

During Spring 2018, the course was taught in a traditional face-to-face format, with a moderate inclusion of active learning. Most lectures included a group problem for 5-10 minutes. The course did not include a specific lab component, but students participated in a group project to analyze and assess the performance of a transportation facility.

During Spring 2019, the course was taught in a partially-flipped format. The flipped topics first included a 5-class sequence on geometric road design (stationing, elevations, vertical and horizontal curve lengths and considerations, and superelevation transition), similar to Hayes 2015 [48]. The next flipped topic included a 3-class sequence on intersection performance analysis and traffic signals (terms and formulas in video, activities in our traffic signal lab during class meetings). Last, the class included a 2-class sequence on public transportation (definitions in video, in-class group discussions and problems to solve during class meetings). This offering included a group project, similar to 2018. The flipped modules included a short video before each week. Based on the recommendations of previous research that the videos are best kept short [7, 16], the videos were approximately 20 minutes or less. The videos introduced the terminology and formulas for each model. Students were given strong encouragement to watch and take notes on the pre-class videos. Based on the recommendations of other studies [18], the students were informed that there would be a quiz to confirm their video completion. At start of the next class, faculty allowed for a 5-minute question/answer session, then administered a short

quiz. These assessments usually had 2-3 questions, were closed book, but open notes. This offering also included a group project, similar to the previous year.

During Spring 2020, the COVID-19 pandemic caused an unexpected change in the course format. The initial plans were identical to Spring 2019. Instead, the course was a partial flip for first half, then online asynchronous the second half of the semester. This included a 5-class flipped sequence on geometric design of roads and a 3-class flipped sequence on intersection performance analysis and traffic signals. Students were not required to complete a group project, instead the value of homework was doubled. Student feedback was solicited about this change and no students expressed dissent.

In Spring 2021, the course was taught in an online synchronous format. The flipped topics were implemented using break out rooms in Zoom. The lecture topics were the same as previous semester, but the group project did not require all members to visit the study site.

Last, in Spring 2022 the course was taught face-to-face using a partially-flipped format. This offering was the same format as Spring 2019, except that the students were primarily taking online-courses the previous two years. Table 1 compares the instructional formats included in this study, where a dash (-) indicates traditional face-to-face instruction.

Topic/Module	2018	2019	2020	2021	2022
Introduction and Vehicle Characteristics	-	-	-	Virtual Synchronous	-
Geometric design	-	Flipped	Flipped	Flipped Virtual	Flipped
Pavement design	-	-	-	Virtual Synchronous	-
Traffic flow	-	-	-		-
Intersections and signals	-	Flipped	Flipped	Flipped Virtual	Flipped
Transportation planning	-	-		Virtual Synchronous	-
Traffic safety	-	-			-
Public transit	-	Flipped		Flipped Virtual	Flipped
Airport design	-	-	Virtual Asynchronous		-
Freight and curb management	-	-		Virtual Synchronous	-
Sustainable and intelligent transportation	-	-			-

Table 1.	Summary	of Instructional	Methods
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Student survey feedback and their performance on the course final exams were utilized to compare a variety of course offerings. The test performance was separated by topic and classified using Bloom's levels of cognition. The following learning objectives were assessed for each topic, with the associated Bloom's levels in parentheses.

- Geometric Design or Roads
 - Calculate the required length of crest curves (Apply)
 - Recommend solutions for providing adequate horizontal curve sight distance (Analyze)
- Traffic Signals
 - Apply common signal terms (Understand/Apply)
- Public Transit
 - Classify types of public transit (Understand)

When possible, statistics were applied to measure differences between offerings. The survey instruments, student disclosures, and research practices were reviewed and approved by the University's Institutional Research Board. These findings are described in the next section.

Analysis

This section will first describe the findings from student surveys each semester. These surveys asked students for their perceptions of flipped teaching and their learning in both flipped and traditional classrooms.

Student perceptions

The survey asked students if they would, "take another flipped course" and, "recommend a flipped course to another student." The results indicate student's opinions of flipped teaching are increasing over time. In addition, the students were less satisfied during the Spring 2020 course when the instructional mode was shifted from flipped to online (Figure 2).



Figure 2. Student Overall Opinion of Flipped Classes

Next, students were asked about their engagement, time spent, and attendance in flipped classes. Students reported more engagement over time, suggesting that continuous improvement in the activities and the shifts to synchronous (Spring 2021) and face-to-face (Spring 2022) course formats are important to student engagement. Students reported the highest out-of-class time during the Spring 2020 semester, compared to other offerings. Last, students reported better class attendance when a virtual option was available. Figure 3 shows the results and trends.



Figure 3. Student Engagement, Time Spent, and Attendance

Students were asked several questions about their learning in each class. Students were slightly positive that they learned more from flipped teaching and were more confident with the course material. Answers to these questions were nearly identical and showed an increase over time, with the low point in 2020. Also, the survey asked students about their ability to connect course content to the real world. Responses to this last question were the most positive and also showed increase over time.



Figure 4. Student Perceptions of Learning

The surveys also gathered feedback about student's perception about their learning in a flipped classroom. The responses indicate improvement over time for the activities and class atmosphere. For pre-class activities, the responses were mixed. It is noteworthy that pre-class activities were not present in the second half of Spring 2020 because of the asynchronous format of the course (Figure 5).



Figure 5. Student Perceptions of Flipped Teaching

Student performance

The authors next compared student performance on the final exam. The cumulative performance is shown in Figure 6 and indicates similarities among semesters with virtual classes and more consistent student performance over time. During 2020 and 2021 when the course was at least 50% online, the final exam performance was very similar, which may be a result of using virtual tests. The results also suggest that students performed the worst during the first implementation of flipped teaching in Spring 2019. The performance could be caused by student resistance to complete pre-class work or the design of the activities. The overall trend indicates that flipped teaching methods can improve final exam performance when implemented in-person or online synchronous.



Figure 6. Student Final Exam Performance

Student Performance on Flipped Topics

To learn more about student performance on specific topics that were taught using a flipped method, final exam performance was analyzed for problems on these topics. This course included flipped modules on geometric design or roads, public transit, and traffic signals. The authors compiled student performance on final exam problems focusing on each topic. When multiple problems existed, a weighted average was calculated, considering the point value of each problem. The results indicate that performance did not improve for all topics. The topic of geometric design showed improvement after implementing flipped teaching activities, which supports the findings of others [48]. The trends were unclear for the other topics, but could be related to the learning objectives assessed. Other studies found improvements only for higher-order learning objectives [10, 14, 15, 16, 17], such as Bloom's level three (apply) or higher [10]. These results require further investigation to identify nuances that could have caused these trends the last two offerings of the course.



Figure 7. Student Performance on Flipped Teaching Topics

Flipped Teaching Transition to Online

To learn more about using flipped teaching could have prepared students for the shift to online learning researchers reviewed how student perspectives shifted between the flipped format (Spring 2019) and the flipped-to-online format (Spring 2020). The comparison revealed a decrease in several key factors, from 2019 to 2020. First, students were less confident in the content (Figure 4). Students also reported that the classroom environment was less conducive to learning in 2020 (Figure 5). Most notably, the students were also less confident that the in-class activities helped them learn in 2020. This change in responses was significant at the 95% level (Figure 8).



Figure 8. Student Responses to, "The in-class activities helped me learn."

To learn more about how students were adapting to the changes during the spring 2020 semester, an additional survey was conducted. Although the response rate to this additional survey was low (9 responses from 48 enrolled), the feedback provides some valuable insight into their ability to

adapt. Overall, few students found the transition from flipped to online difficult. Specifically, 45% rated the transition easy, 45% rated it medium, and 10% rated it difficult. In addition, 75% of students reported being confident (30%) or very confident (45%) in their ability to complete the course in an online format. Most students (78%) had some experience with online teaching before COVID-19, but many (67%) were still adjusting to the shift to online.

Conclusions

This study demonstrated how flipped teaching effected the transition of students to online teaching during the COVID-19 pandemic of 2020 and also provided examples of student perceptions of flipped teaching across semester. Flipped teaching improved student's ability to transition to an online format in Spring 2020.

The overall study results suggest that student perceptions of flipped teaching are improving over time and their ability to connect content to the real world was one of the highest rated benefits.

Results for specific topics showed unclear trends. Students tended to improve their performance on the geometric design of roads, but not on public transit or traffic signals. These findings support the assertion that flipped teaching is a better investment for topics that are higher-order in Bloom's taxonomy.

Future work could examine if flipped teaching provides better gains for higher-level learning objectives. For traffic signals these could include, "calculate green times for a two-phase intersection" and "construct and interpret time-space diagrams." For public transit, learning objectives could include, "Describe how transit design and planning can address the seven elements of good service."

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System Design, Evaluation and Applications of **Domain Term Extraction from Engineering Videos**

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Abstract

Understanding the meanings of domain-specific terms is essential to academic success in college-level STEM courses. However, it can be challenging for students to obtain correct spellings and precise definitions of domain-specific terms from lecture videos, given the limited lecture time, rarity of the terms, and possibly confusing pronunciations. To provide accurate speech-to-text transcription, and enable students to search for domain-specific terms and obtain term definitions in real-time, we designed, implemented, and evaluated the PhraseHinter tool, a text analytics pipeline that efficiently extracts domain-specific terms from engineering educational videos. The tool is lightweight and adaptable to online instruction platforms.

In our approach, a series of key scenes are initially extracted from a lecture video using a novel scene detection algorithm. The algorithm employs a support vector machine to classify image differences based on pixel, face, and text similarity information [2]. A domain corpus is built by using the optical character recognition (OCR) technique to extract text from the scenes. A sequence of text-cleaning algorithms is applied to the domain corpus to filter out invalid characters, punctuation, and stop words. Frequent phrases are identified using standard text mining algorithms including PrefixSpan [15]. Using the TF-IDF metric [16], we compare the cleaned corpus to the background corpus to determine domain-specific terms and phrases.

The proposed PhraseHinter tool has been successfully integrated into ClassTranscribe [4, 11, 3, 19, 2, 10], a web-based video lecture platform, for multiple purposes: 1) Improve the Microsoft Azure Speech-to-Text accuracy by preparing a list of domainspecific terms with high confidence of occurrence in the audio, 2) Provide the input for the glossary tool, another text analytics service in ClassTranscribe that automatically generates the explanation for the domain-specific terms, and, currently in progress, 3) Provide search capability in order to locate the moments in the video when a domainspecific term is visually presented.

In this paper, we evaluate the performance and accuracy of the PhraseHinter system based on a representative corpus of videos from different engineering disciplines with domain-specific terms and phrases correctly pre-identified. We share the evaluation dataset to the education community for further research. In addition, we present the source code and provide guidance for instructors who would like to adopt the tool.

1 Introduction

Domain-specific terms refer to words or phrases that are primarily used within the context of a specific field of study. Domain-specific terms often involve abstract and sophisticated meanings e.g., "hybridization" in chemistry or "backpropagation" in machine learning. A large amount of domain-specific terms are introduced and taught in college-level STEM lectures and textbooks, which serve as the building blocks for advanced courses. Consequently, understanding the meanings of those terms plays an important role in achieving success in the curriculum. Yet, due to the varied learning outcomes from students' high schools, college freshmen without sufficient prerequisites may face obstacles when learning domain-specific terms because not all of them are covered in the classroom due to the limited lecture time and the scope of the course.

Computer-based learning platforms can provide new learning tools and features that help mitigate this problem. For example, a web-based dictionary where every student is able to access and edit content would be a valuable platform for students to share, learn, and consolidate knowledge in domain-specific terms. However, in order to implement and adopt these features into online education, the first step is to generate a glossary of domain-specific terms for each course, because instructors may not have provided one for each course they teach. Today, advances in Text Mining and related algorithms make it possible to extract and present domain-specific terms and definitions in an efficient and accurate manner.

In this paper, we introduce "PhraseHinter", an automated text analytic service that extracts domain-specific terms from the text-based course modality including text presented visually, which, based on empirical experiments, achieves a reasonable accuracy within a reasonable time frame. The PhraseHinter service is open source and is available at https://github.com/classtranscribe/pyapi. We present how the tool was integrated into a web-based learning system and present three features that were created using the service. These include more accurate closed captioning, a glossary tool, and a query system for domain-specific terms.

The paper is organized as follows. In section 2, we introduce the background of our work including the guiding methodologies and the integration of the service into an existing learning platform. In section 3, we present a formal description and motivation of the problem. We discuss the challenges encountered during the research and related works. In section 4, we present the system in detail using a data-flow diagram and explanations of the text processing procedures. In section 5, we report on the accuracy and processing time requirement of the service. In section 6, we discuss the applications of the tool within ClassTranscribe. We conclude the paper with an overview of the contributions of the paper and discuss the remaining challenges.

2 Background

2.1 Universal Design for Learning

Universal Design for Learning (UDL) refers to a set of guidelines or principles that addresses the development of flexible learning environments that are suitable for all stu-

dents [17]. In other words, UDL seeks accessibility and inclusiveness when implementing educational frameworks. A UDL-guided course should provide students with multiple learning pathways and modalities toward academic success. For instance, students could absorb the course content by attending traditional lectures, watching lectures through online platforms, reading course notes and lecture transcriptions, or a combination of all methods. Under the UDL guidelines, a strong emphasis is placed on inclusiveness. Educational technologies should be able to deliver widely accessible contents that benefit all students, regardless of their backgrounds and physical conditions [12]. Adhering to the principles under UDL, the PhraseHinter system was designed to assist course glossary creation and improve automatic speech-to-text transcriptions. These modalities provide alternative learning options for all students and are particularly valuable for students who are Deaf or Hard-of-Hearing (DHH).

2.2 ClassTranscribe

ClassTranscribe is a web-based video learning platform designed to offer accessible educational content, developed at the University of Illinois. ClassTranscribe has been previously described in ASEE Conferences [11, 3, 19, 2, 10]. Designed to provide accessible education to engineering college students, ClassTranscribe is equipped with user-friendly features such as automatic transcriptions and digital book generation [10]. ClassTranscribe also allows students to easily search through the automatically generated transcriptions and fix transcription errors [19]. ClassTranscribe has been used as an educational platform for Computer Science and other engineering disciplines. Its usage covers multiple large-enrollment classes with over 300 students, and its videos have been watched by over 6,200 students.

One feature of ClassTranscribe is automatic speech-to-text transcription, which allows students to understand the oral content of the lectures more efficiently. Further, to be an effective learning modality, the transcriptions need to be accurate, which is challenging in engineering classes that include domain-specific terms. Thus, a robust speech-to-text transcription system that can precisely capture the domain-specific terms for a wide range of engineering disciplines is valuable.

2.3 SceneDetection

SceneDetection is a tool that has been implemented in ClassTranscribe, which enables efficient identification and removal of similar and repetitive frames from a lecture video. It compresses a lecture video into a few unique scenes that include the equivalent visual content to the full lecture video. Though SceneDetection primarily processes pixel differences from one frame to the next, to further improve the accuracy, an Optical Character Recognition (OCR) step is included to extract text data from visual images. The detailed algorithm design, evaluation, and implementation of the SceneDetection system are described in [2]. This OCR text data is used as the initial source of the PhraseHinter.

3 **Problem Description**

3.1 Motivation and Goals

With the goal of providing students with web-based interactive tools to effectively fulfill the knowledge gap in domain-specific terms for college-level STEM education, our first task was to build a text analytic service that efficiently discovered domain-specific terms from text-based lecture modalities. Domain-specific terms refer to terms that are primarily used in a specific academic context and rarely used in general English. In our approach, domain-specific terms refer to words e.g., "binomial" and phrases e.g., "inner product". As a computational performance target, the service should be able to process within a minute the text extracted from a 50-minute lecture.

3.2 Challenges

The task of domain-specific term extraction is non-trivial. First, to ensure students an effective learning experience, the domain-term extraction system should not add significant additional latency into the lecture video processing pipeline. Second, the domain term identification should reach an acceptable accuracy, allowing students to read the correct words. Further, the domain-term extraction system should be robust enough to adapt across all engineering disciplines. Lastly, in STEM subjects, domain-specific terms do not only imply single words but also technical phrases, e.g., "support vector machine" in machine learning and "forward kinematics" in robotics. These phrases occupy a large proportion of the domain-specific terms in engineering disciplines and are non-trivial to identify. Thus, to ensure helpful domain term extractions, the system should identify not only single keywords but also technical phrases for completeness.

3.3 Related Works

Early works on domain-specific term extraction utilized rule-based approaches, in which the structural characteristics of the domain-specific term were first identified. Then, strings that matched these characteristics were extracted [8, 6]. These approaches were focused on a specified language or domain. Later works developed statistical and distributional approaches. In [14], term co-occurrence patterns were analyzed to extract terms that referred to specialized concepts. In [9], an unsupervised domain-term extraction method was proposed, based on Term Frequency and Inverse Document Frequency (TF-IDF, Section 4.3), a common weighting technique for keyword extractions. If the TF-IDF value of a term is greater than a specified threshold, the term is considered domainspecific. More recent methods employed machine learning approaches. In [18], a set of seed terms were first extracted using rule-based approaches. Then, the seed terms were used to train an LSTM-CRF model to extract extended terms from technical documents. In [13], domain-term identification was considered as a binary classification, where each word was classified as either a domain-term or not. A deep neural network with a pretrained word-embedding layer was used to perform the classification. Existing methods of domain-specific term extraction focused on the natural language processing tasks. To the best of our knowledge, few have considered processing time requirements and did not evaluate their approaches within an educational context.



Figure 1: PhraseHinter System Overview.

4 System Design

Figure 1 provides an overview of the data-flow of the PhraseHinter system. The system was implemented in Python and used the Natural Language Toolkit (NLTK) [5] and the PrefixScan library [15].

4.1 Text Cleaning

The raw text input from the text-based lecture modality contains punctuation and invalid characters due to OCR errors. Further, high frequency (common) stop words (e.g., a, an, the) are not domain-related. Consequently, the following words or characters were removed to provide a more representative and meaningful data set for later processing.

- Punctuation
- Characters that are neither alphabets nor numbers
- Stop words
- · Words with less than 2 characters
- · Words that only contain digits

As indicated by Figure 1, punctuation, digits, and stop words were removed from both sentences after text-cleaning.

4.2 Canonical Word Map

The same word can be written in different styles, such as in the plural form, uppercase, titlecase, lowercase, etc. Without accurate matching and conversion, the dataset may not precisely represent the frequency of each word. Therefore, a canonical word map was created to record the number of occurrences of each word independent of style. Words written in other styles were converted to the style that has the most number of occurrences in the dataset, which was assumed to be the most representative style of the word. For example, in Figure 1, "property" and "properties" were referring to the same word. Since "property" appeared twice, "properties" was converted to "property" in the output.

4.3 TF-IDF Filtering

TF-IDF, or term frequency-inverse document frequency, is a statistical index that measures how a word is relevant to a document or a text corpus [16]. We compared the TF-IDF value of the words inside the course-specific dataset to those inside the Brown Corpus [7], a background corpus that collected English text from everyday language use. Words that were important in the course-specific dataset but unimportant in the background corpus were determined to be domain-specific. For example, as shown in Figure 1, words that were often used in daily life e.g., "question", "have", and "property" were removed from the final output.

4.4 Sequential Pattern Mining

Instead of generating only single words, OCR retained the sentence structure and contextual relationship between individual words, which enabled the Sequential Pattern Mining algorithms[1] to discover multi-word phrases. Sequential Pattern Mining is a data mining process that extracts important sequential patterns from the dataset and was used to extract frequent phrases from the dataset.

Considering the processing performance requirements, a PrefixSpan algorithm [15] was selected to extract frequent phrases because of its minimal processing time requirement and efficient memory utilization. We specified the minimum support to be 2 instances, which removed all phrases that only appeared once in the text and built a bagof-words model for the remaining phrases. TF-IDF filtering was applied to the model to remove the common phrases e.g., "different from" and incomplete phrases e.g., "is a". For example, as shown in Figure 1, the multi-word phrase "correlation coefficient" was extracted using the PrefixSpan algorithm.

The Sequential Pattern Mining is the final processing step of the PhraseHinter. An example output of the PhraseHinter after processing a Bioengineering video is "convective, stagnant, gas, initial concentration, concentration, surface, evaporating, liquid, convective stream, stagnant liquid, mass transfer, solid, moisture, diffusivity (100 more phrases not shown)."

Recall (%)	Full Corpus Processing Time (seconds)	Single Lecture Time (seconds)
71.36	1.55	0.14

Table 1: Performance metrics of the PhraseHinter service; Recall accuracy and processing time requirements of the PhraseHinter system for all 10 lectures and one 50 minute lecture.

5 Evaluation

5.1 Dataset

We tested the performance of the PhraseHinter system using a dataset of (N = 10) lecture videos from multiple STEM disciplines offered at the University of Illinois. The total length of the videos in the dataset was 5 hours and 30 minutes. A testing dataset with 3,928 lines of text that accompanied the lecture videos was generated using the SceneDetection system, which served as the source input for the PhraseHinter service. With the help of students with related engineering experience, 398 valid domain-specific terms were identified from the testing dataset.

5.2 Recall Accuracy

Our approach was able to achieve high accuracy (71%) by successfully extracting 284 target domain-specific terms as indicated in Table 1.

Recall, the ratio of the number of domain-specific terms correctly extracted to the number of domain-specific terms that appeared in the videos, measures the robustness in completely discovering all target domain-specific terms in the testing set. It is an important accuracy metric because we wish to present as many domain-specific terms as possible. Providing too many terms, though distracting, is unlikely to significantly impact learning outcomes. Students could simply ignore the extra terms that they were already familiar with. However, missing a term in the learning environment may cause students to assume that the term is not relevant to the context and hence skip the important content.

5.3 Time Requirement

The service was tested using a laptop with an Intel Core i7-6920HQ CPU. We chose this testing configuration because we want to ensure that our system has acceptable latency in general hardware environments, especially in systems without powerful GPUs. As shown in Table 1, it required only 1.55 seconds for our system to process the text of all 10 lecture videos in the dataset (around 0.14 seconds for a 50-minutes lecture). This was within our desired processing time.

6 Applications

6.1 Improving Speech-to-Text Accuracy

Domain-specific terms can improve the accuracy of some automated speech-to-text services, including the Microsoft Azure Speech-To-Text Service. Most online learning



Figure 2: Improving Speech-to-Text Accuracy.

platforms provided accessible closed captioning for DHH students by transcribing the lecture audio into text using speech recognition systems. However, speech recognizers have difficulty in accurately transcribing domain-specific terms. The technical terms may be absent or incorrectly transcribed into phonetically-similar words. The PhraseHinter tool can provide a list of potential phrases as an a priori set of hints to the speech recognizer to improve the likelihood of correctly identifying domain-specific terms. For example, the technical word "byte" (see Figure 2) might be transcribed as the common word "bite" by a speech recognizer. But after providing the domain hint "byte", the speech transcriber will increase the probability likelihood of selecting the word "byte" during the transcribing process. In the next section, we discuss a Glossary Tool, which is another application of the PhraseHinter service.

6.2 Glossary Tool

When students are confused about a domain-specific term, additional time and effort is required searching for meanings. To improve the learning experience, we created an automated workflow that efficiently collected definitions and explanations of the domain-specific terms from a variety of open-source sites including Wikipedia and WordNet. An interactive glossary tool was created and implemented in ClassTranscribe, which presented the definition, domain, affiliated course, and external link for each domain-specific term (see Figure 3). Both instructors and students can upvote or edit the information for each term. We propose that this new approach will encourage knowledge exploration in domain-related concepts and help learning outcomes. The detailed system design, data flow, and user experience of the glossary tool are beyond the scope of this paper and will be presented as a full paper at the main 2023 ASEE Conference. In the next section, we present text-based visual search; a third application of the PhraseHinter.

6.3 Domain-Specific Term Search

In addition to extracting the text from video frames, the SceneDetection system also recorded the timestamp for each scene. Therefore, it is possible to create a map between the domain-specific terms and visual time of their appearances in each video. This

Glos	Glossary										
University	University / Department / Course Number / Seméstér										
Search	Page: 1/2 P	rev Next	Go								
TERM T	LINK		DEFINITION	SOURSE	LIKE	1					
variable	http://en.wkipedia.org/wki/Variable_(m	athematics)	In mathematics, a variable (from Latin variabilis, changeable) is a symbol that represents a mathematical object. A variable may represent a number, a vector, a matrix, a function, the argument of a function, a set, or an element of a set. Algebraic computations with variables as if they were explicit numbers solve a range of problems in a single computation. For example, the quadratic formula solves any quadratic equation by substituting the numeric values of the coefficients of that equation for the variables that represent them in the quadratic formula. In mathematical logic, a variable is either a symbol representing an unspecified term of the theory (a meta-variable), or a basic object of the theory that is manipulated without referring to its possible intuitive interpretation. Jess	Wikipedia	1	like					
probability	https://en.wikipedia.org/wiki/Probability		Probability is the branch of mathematics concerning numerical descriptions of how likely an event is to occur, or how likely it is that a proposition is true, more	Wikipedia	5	like					
logistic regression	https://en.wkipedia.org/wki/Logistic_reg	ression	In statistics, the logistic model (or logit model) is a statistical model that models the probability of an event taking place by having the log-odds for the event be a linear combination of one or more independent variables. more	Wikipedia	6	like					
linear combination	https://en.wikipedia.org/wiki/Linear_comt	anation	In mathematics, a linear combination is an expression constructed from a set of terms by multiplying each term by a constant and adding the results (e.e. a linear combination of x and v would be any expression of	Wikipedia	5	like					

Figure 3: The Glossary Tool.

functionality creates opportunities for new functionality in ClassTranscribe video playback system; students will be able to directly search and seek to the exact moments in a video where the the query term is first presented or re-used.

7 Conclusion and Future Works

We presented the value and a method of extracting domain-specific terms and phrases within the context of engineering education. Student understanding of domain-specific terms is an important step for students to comprehend course materials. Under the principles of Universal Design for Learning, this paper proposed PhraseHinter, a system that was designed for domain-term extraction from engineering lecture videos. We presented the design of the system pipeline, which included text pre-processing, TF-IDF Filtering, and Sequential Pattern Mining. We analyzed the performance of the proposed system with a dataset of (N = 10) lecture videos from multiple engineering disciplines. Our evaluation indicated that the PhraseHinter system achieved a sufficient performance with reasonable accuracy. Finally, we presented three learning-focused applications of the PhraseHinter service; improving Speech-to-Text transcriptions, a Glossary Tool, and search of visual text.

This work introduced additional opportunities to the engineering education community. For example, with the domain-specific terms identified, test questions can be automatically included based on the terms. It is an open question if domain term information could be used to understand dependencies and relationships across lecture videos. We encourage the engineering education practitioners who are interested in adopting new approaches into their course, to contact us for more information. Finally, we hope our system and its initial results will inspire additional innovation in inclusive and accessible education.

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Exploring the Potential Benefits and Risks of ChatGPT in Engineering Education

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Abstract

This paper examines the potential benefits and risks of using ChatGPT, an AI-powered chatbot developed by OpenAI, in engineering education by generating sample questions and answers and solving sample mathematical problems related to course subjects in the industrial engineering curriculum. The generated questions and answers were evaluated using multiple criteria such as accuracy, relevance, precision, depth, and breadth. The examination found that ChatGPT has the potential to be a useful tool for generating questions and answers in various contexts. However, the study also raises concerns about the potential risks of using ChatGPT in engineering education, such as over-reliance on the chatbot leading to a decline in critical thinking and problem-solving skills, and the potential for academic dishonesty and misinformation, as well as confusion among students due to the generation of wrong answers to mathematical problems which can negatively impact students' learning experience. The author emphasizes the importance of educators being aware of these potential risks and developing strategies and policies to ensure ChatGPT is used as a supplement, not a replacement, for traditional teaching methods. **Keywords**

"ChatGPT", "engineering education", "teaching strategies", "technology in engineering education", "faculty paper"

1. Introduction

The use of online and digital learning platforms has become increasingly prevalent in higher education to increase access and flexibility for students [2]. This has led to the development of new tools and technologies, such as AI-powered chatbots and virtual reality simulations, which can be used to enhance teaching and learning in a number of ways, including by providing personalized learning materials, interactive exercises and assessments, and instant feedback and support. These benefits can help to improve student engagement, retention, and performance, making chatbots a valuable resource for both instructors and students [3].

Chatbots are computer programs designed to simulate conversation with human users, especially over the Internet. There have been a number of studies done on the use of chatbot technology in education, focusing on a variety of applications such as answering students' questions [4-6], teaching computer programming concepts [7, 8], assessing students' performance [9, 10], and providing administrative services [11]. Some studies have also conducted literature reviews to summarize existing knowledge on the topic [12, 13]. The implementation of chatbots in education has the potential to enhance students' learning experiences and increase their satisfaction [14] and there is evidence from multiple research studies that chatbots can be effectively utilized in educational settings [5, 10, 15, 16]. These chatbots are seen to have many advantages for the education system, such as: chatbots can assist in the integration of subject matter by allowing teachers to upload information such as class topics, schedules for assignments, tests, and exams to an online platform for easy access by students [17, 18]; maximize student learning abilities, and achievement [4, 19]; chatbots can help to keep students motivated and engaged by providing an interactive and comfortable learning environment resulting in increasing student engagement [20, 21]; and chatbots can quickly provide students with support, allowing both students and teachers to get fast answers to their questions and tasks. The use of Chatbots in education allows for efficient and quick communication[22, 23].

Despite the potential benefits of using AI-powered chatbots in education, there are also potential risks that educators and students should be aware of. One concern is the possibility that students may rely too heavily on chatbots for assistance with assignments and projects, leading to a decline in critical thinking and problem-solving skills and a decline in the quality of education. Another concern is the possibility that chatbots could be used to encourage academic dishonesty, such as by providing answers to assignments or exams. Some researchers have argued that chatbots have the potential to facilitate plagiarism by providing students with ready-made answers to assignments and assessments [24]. In [25], the authors presented the potential for chatbots to be used to cheat on online exams. The author in [26] also addressed this issue. These studies highlight the need for careful consideration of the ethical implications of using chatbot in education.

The recent release of ChatGPT in November 2022 (<u>https://openai.com/blog/chatgpt/</u>) by OpenAI (<u>https://openai.com/</u>), an AI-powered chatbot, has marked a significant advancement in artificial intelligence involving natural language processing and reasoning. This publicly available technology is capable of engaging in complex conversations, providing information on a wide range of topics, and generating accurate answers to challenging questions that require advanced analysis, synthesis, and application of information. It can even generate critical questions that educators in various disciplines might use to assess students' competencies. It is therefore necessary to examine the capabilities of this AI agent.

The purpose of this paper is to investigate the consequences and advantages of using ChatGPT in the field of engineering education. Despite being a new technology, ChatGPT hasn't been widely studied in the context of engineering education. The paper aims to explore the potential risks and benefits of ChatGPT in depth, with a specific focus on courses within the industrial engineering program. Additionally, it aims to establish methods and policies to ensure that ChatGPT is used in a way that upholds academic standards and improves the teaching and learning experience.

2. Experimental Design

Before discussing the method of creating tasks and evaluations using ChatGPT, it's beneficial to provide background information about the higher education setting. The author, who is a professor of industrial engineering, teaches various courses at both the undergraduate and graduate level. A significant duty of his is leading a course on project management, covering the concepts and methods used in planning, executing, and monitoring projects in various contexts. Alongside the project management class, he also teaches a class on the techniques and technology used in manufacturing, including subjects like choosing processes, ensuring quality, and implementing efficient manufacturing methods.

The potential benefits and risks of utilizing ChatGPT in an engineering education context were explored by identifying two fundamental courses in the industrial engineering curriculum. Sample questions and answers were generated using ChatGPT, and sample mathematical problems relevant to the manufacturing processes course provided by the author were also solved by the model. The generated questions and answers were then analyzed.

2.1. Sample Course-1: Engineering Project Management

The purpose of this course is to furnish students with a socio-technical perspective on the management of projects. The curriculum covers the essential aspects of project management, including planning, scheduling, organizing, and implementing various types of projects such as product development, construction, information systems, new business ventures, and special events. To evaluate students' comprehension of the course material and their ability to apply it in practical situations, the course includes multiple choice and discussion assessments. One of the topics that is covered in this course is "Organization Strategy and Project Selection".

Discussion questions are an important aspect of a project management course as they provide students with an opportunity to engage in active learning and collaboration. They allow students to share their own experiences, perspectives, and insights on the course material, which can deepen their understanding of the subject matter. Additionally, discussion questions can help students develop critical thinking skills, as they are required to analyze and evaluate information and ideas presented by their peers. However, preparing discussion questions for a project management course can be difficult for instructors for several reasons. One reason is that preparing discussion questions requires instructors to have a good understanding of their students' learning styles and abilities in order to create questions that are appropriate for their level of understanding and that challenge them to think critically. This can be challenging as students come from diverse backgrounds with varying levels of experience and understanding of the subject matter.

Multiple choice questions are also an important assessment tool in this course. They provide a quick and efficient way for instructors to assess students' understanding of the course material. They can quickly assess a large number of students in a short amount of time, making them a useful tool for formative and summative assessments. Multiple choice questions can be used to test students' knowledge of specific facts, concepts, and terminology related to project management, which helps instructors to determine if students have a basic level of understanding of the subject matter. Finally, they can be utilized as a diagnostic tool to identify areas where students need additional support or clarification. This can be particularly useful in a project management course, which covers a wide range of concepts, tools, and techniques. To create reliable and valid multiple-choice items, instructors have to ensure that the stem of the question is clear and concise, the choices are written in the same grammatical structure and length, the correct answers are randomly placed across the items in the exam, and the distractors are challenging for item discrimination purposes, among others [28].

2.1.1. Questions Generation

To assess the capacity of ChatGPT to generate thought-provoking questions in this field, ChatGPT was initially given a prompt requesting five difficult multiple-choice and discussion types of questions that were suitable in the Organization Strategy and Project Selection topic for undergraduate and graduate students. The multiple-choice and discussion types of questions were achieved by typing the following command on ChatGPT respectively:

"Generate five difficult **multiple-choice** questions in the field of Project Management with Organization Strategy and Project Selection topic targeting both undergraduate and graduate industrial engineering students"

"Generate a **discussion** type of question in the field of Project Management with Organization Strategy and Project Selection topic targeting both undergraduate and graduate industrial engineering students which involves a hypothetical scenario"

2.1.2. Answers Generation

Answers to both types of questions were generated typing the following commands on ChatGPT respectively:

"Select the best answers to the questions above"

"Answer the question above in at least four paragraphs with justification"

Ge	nerated multiple-choice questions by ChatGPT	Ge Ch	nerated answers to multiple-choice questions by atGPT
1.	Which of the following is NOT typically a factor considered in the project selection process?	1.	Which of the following is NOT typically a factor considered in the project selection process?
	 a. Alignment with organizational strategy b. Potential return on investment c. Feasibility 	2.	b. Potential return on investment Which of the following is NOT one of the common approaches to selecting projects?
2.	 <i>a.</i> Number of people required <i>e.</i> Personal preference of the project manager <i>Which of the following is NOT one of the common</i> <i>approaches to selecting projects</i>² 	3.	c. Critical path analysis How does a stakeholder analysis fit into the project selection process?
	a. Weighted scoring model		and needs of stakeholders

Table 1: Generated multiple choice and discussion types of questions and answers by ChatGPT

	<i>b</i> .	Portfolio management	4.	Whi	ch of the following is NOT a benefit of project
	С.	Critical path analysis		port	jouo managemeni?
	<i>a</i> .	Resource allocation	5	e. It	reduces the risk of project failure
2	e. Loui	SWOI unulysis doos a stakeholden analysis fit into the	5.	In w	inal ways can a project charter help with
5.	nnoi	ades a stakenoider analysis ju into the		proj	It defines the second and objectives of a project
	proje	t is used to determine the forsibility of a		а. ь	It identifies the scope and objectives of a project
	и.	project		D.	and responsibilities
	<i>b</i> .	<i>It is used to determine the potential return on</i>		С.	It outlines the resources and budget required
		investment of a project			for a project
	С.	It is used to identify and prioritize the		d.	It provides a high-level timeline for the
		interests and needs of stakeholders			project
	<i>d</i> .	It is used to identify the critical path of a		е.	It specifies the project selection criteria
		project			
	е.	It is used to evaluate the alignment of a			
		project with organizational strategy			
4.	Whic	ch of the following is NOT a benefit of project			
	portj	folio management?			
	а.	It allows organizations to align projects with			
		strategic goals			
	<i>b</i> .	It helps organizations prioritize projects			
		based on available resources			
	С.	It helps organizations avoid taking on too			
		many projects at once			
	<i>d</i> .	It allows organizations to easily track the			
	1	progress of multiple projects			
-	е.	It reduces the risk of project failure			
5.	In w	hat ways can a project charter help with			
	proje	ect selection? (Select all that apply)			
	<i>a</i> .	It defines the scope and objectives of a project			
	<i>b</i> .	It identifies key stakeholders and their roles			
		and responsibilities			
	С.	It outlines the resources and budget required			
		for a project			
	<i>d</i> .	It provides a high-level timeline for the			
		project			
	е.	It specifies the project selection criteria			

As can be seen from Table 1 above, the multiple-choice questions generated by ChatGPT appear to be relevant and accurately representing the topic. The question stems are concisely and clearly written in as few words as possible. Question stems do not provide a clue to the correct alternative, and when a negative stem is used (e.g., Questions #1, 2, & 4), the word NOT is capitalized to catch the attention of the test-taker to avoid a reliability concern. Similarly, alternatives for each question in generated questions follow similar grammatical patterns. Moreover, alternatives in each question are written in similar length, and the position of the correct alternative varies and is randomly assigned across the generated questions. Although it is not possible to determine the effectiveness of these items generated by ChatGPT without actually collecting data from test-takers, these aspects of the question stems and alternatives increase the degree of item facility and item discrimination values of each question, resulting in more reliable and valid assessments. In that sense, using ChatGPT as a supportive tool in generating multiple-choice questions would be a good alternative for instructors who want to create such assessment tasks without worrying about typical reliability issues.

The answers to the multiple-choice questions appear to be accurate and relevant to the questions they are intended to address. They are precise in specifying the correct answer to each question. The depth of the answers varies, with some providing more detailed explanations and others simply stating the correct answer. The breadth of the answers is limited to the specific questions being asked. The logic of the answers is sound, as they provide appropriate responses to the questions being asked.

Generated a discussion type of question by ChatGPT	Generated response to discussion type question by
	ChatGPT
Discussion question: Imagine you are a project manager at a medium-sized manufacturing company. The company's leadership team has recently developed a new business strategy that emphasizes sustainability and innovation. You have been tasked with identifying and selecting a new project that aligns with this strategy. You have three potential options: a) implementing a new, more energy-efficient manufacturing process; b) developing a new product line made from recycled materials; or c) creating a digital platform to streamline the company's supply chain. Which option do you think would be the best fit for the company's new business strategy and why? How would you go about evaluating and comparing the potential benefits and risks of each option? What factors would you consider in your decision-making process, and how would you communicate your recommendation to the leadership team?	As a project manager at a manufacturing company, I believe that option b) developing a new product line made from recycled materials aligns best with the company's new business strategy of sustainability and innovation. This option aligns with the sustainability aspect of the strategy by reducing the company's environmental impact through the use of recycled materials, and it aligns with the innovation aspect of the strategy by introducing a new product line that potentially distinguishes the company from competitors. To evaluate and compare the potential benefits and risks of each option, I would conduct a thorough analysis of each option's feasibility, potential return on investment, and alignment with the company's strategic goals. This could include reviewing market research on the demand for recycled materials, analyzing the costs and potential savings associated with implementing a new manufacturing process or supply chain platform, and assessing the potential impact of each option on the company's reputation and brand. In terms of factors, I would consider in my decision- making process, I would prioritize those that align with the company's strategic goals and have the potential to generate the greatest return on investment. This could include the potential market demand for the product or service, the costs and resources required to implement the project, and the potential risks and challenges that may arise. I would also consider the skills and expertise of the team members available to work on the project, as well as the potential impact on stakeholders. To communicate my recommendation to the leadership team, I would present a clear and concise report outlining the benefits and risks of each option, as well as my rationale for why I believe option b) is the best fit for the company's new business strategy. I would also include a detailed plan for how we would go about implementing the project, including a timeline, budget, and key performance indicators to measure success.

Table 2:	Generated a	discussion	type question	and answer	by ChatGPT
			•, ••••••••••		

As illustrated in the Table 2 above, the generated discussion questions an appropriate. However, The question does not provide a clear understanding of the company's background. The tasks given to the students are relevant to their field of study and align with the overall strategy of the company. The students are tasked with selecting a new project that aligns with this strategy. These tasks require the

students to apply the theoretical concepts they have learned in the classroom to a real-world scenario, which is an effective way to evaluate their understanding and ability to apply their knowledge.

The response to the discussion question was also evaluated. The relevance of the response is that it addresses the specific problem of evaluating and comparing options for a new business strategy at a manufacturing company. It provides a detailed and comprehensive approach to addressing this problem, covering a wide range of considerations, and presenting a logical and well-organized approach. The clarity of the answer is noteworthy because it is written in clear and concise language, and it presents the information in an organized and easy-to-follow manner. The accuracy of the answer also stands out, as it appears to be based on sound reasoning and relevant information. The precision of the answer is demonstrated by its inclusion of specific and concrete details, such as the steps involved in conducting a thorough analysis of each option and the factors that should be considered in the decision-making process. The depth of the answer is impressive, as it covers a wide range of considerations and provides a detailed approach to addressing the problem. The breadth of the answer is notable because it touches on a variety of relevant topics, including market demand, costs and resources, team skills and expertise, and stakeholder impact. The logic of the answer is strong, as it presents a logical and well-organized approach to evaluating and comparing the options, including a clear rationale for why one option is recommended over the others. The persuasiveness of the answer is also notable, as it presents a strong case for why one option is the best fit for the company's new business strategy and includes a detailed plan for implementation, which could be persuasive to the leadership team. It is not clear whether the answer is original or draws on existing approaches or frameworks, but it does provide a unique perspective on the problem and how to address it.

However, one potential shortcoming of the response is that it does not provide any specific examples or details to support its argument for why option b) is the best choice for the company. It does not address any potential drawbacks or limitations of option b). Finally, it does not include detailed information on the implementation plan, including the specific steps and resources required to execute the project successfully.

2.2. Sample Course-2: Manufacturing Processes

This course focuses on fundamental and applied sciences in the processing of materials. Specifically, the effects of processing on the manufactured parts, selection of processing methods, and their relationship with material properties will be discussed. Contemporary and non-traditional processes used in manufacturing are also covered.

Mathematical problems are an important aspect of a manufacturing processes course as they provide students with an opportunity to apply the mathematical concepts they have learned to real-world situations. They help students to understand how mathematical concepts are used to analyze and optimize the performance of manufacturing systems, such as production rates, material usage, and energy consumption. Furthermore, mathematical problems can also help students to develop their critical thinking skills, as they are required to analyze and evaluate information, make decisions, and justify their solutions (Große 2015). Creating mathematical problems for a course can be challenging for instructors (Daroczy et al. 2015). One reason is that manufacturing processes are constantly evolving, and instructors need to stay up to date with the latest developments and trends in order to create problems that are relevant to current industry practices. Furthermore, preparing mathematical problems requires a lot of time and effort, as instructors need to create a variety of problems that are appropriate for different levels of understanding and that challenge students to think critically. Therefore, many instructors potentially avoid creating mathematical problems, are not able to create effective problems, or keep using the same items every year, which may lead to increased cheating.

2.2.1. Questions Generation

To assess the capacity of ChatGPT to generate mathematical problems in the "Sheet Metal Working" topic for undergraduate students, the problems were achieved by typing the following command on ChatGPT respectively:

"Generate two mathematical problems in the field of Sheet Metal Working for undergraduate students"

To evaluate ChatGPT's problem-solving abilities, the author tests it by giving it two problems created by the author.

2.2.2. Answers Generation

Answers to both types of questions were generated typing the following commands on ChatGPT respectively:

"Provide solution for these two problems"

For this course, mathematical problems and their corresponding solutions are created as follows:

Ge	nerated mathematical problems by ChatGPT	Generated solutions to mathematical problems by
		ChatGPT
1.	A sheet metal part is to be formed using a	Solution/ Problem 1:
	hydraulic press brake. The part is made of	To calculate the required force to form the part, we can
	aluminum with a thickness of 5 mm and a tensile	use the following equation:
	strength of 200 MPa. The part has a length of	Force = (Thickness * Width * Tensile Strength) / (Bend
	250 mm and a width of 100 mm. The part is to be	Radius * K-Factor)
	bent to a 90° angle with a bend radius of 25 mm.	Where the K-Factor is a factor that depends on the
	Calculate the required force to form the part.	material, the type of bend, and the degree of the bend.
2.	A sheet metal part is to be formed using a deep	For a 90° bend in aluminum with a bend radius equal to
	drawing process. The part is made of cold rolled	the material thickness, the K-Factor is approximately
	steel with a thickness of 3 mm and a tensile	0.33.
	strength of 550 MPa. The part has a blank	Substituting the given values into the equation, we get:
	diameter of 100 mm and a punch diameter of 75	Force = (5 * 100 * 200) / (25 * 0.33) = 800/0.33 =
	mm. The part is to be drawn to a depth of 25 mm.	2424 N
	Calculate the required drawing force and the	Solution/Problem 2:
	maximum allowable blank holder force.	To calculate the required drawing force, we can use the
		following equation:
		Drawing Force = (Blank Diameter^2 - Punch
		Diameter^2) * Blank Thickness * Tensile Strength / (4 *
		Punch Diameter)
		To calculate the maximum allowable blank holder force,
		we can use the following equation:
		Blank Holder Force = Drawing Force / (1 - (Buckling
		Factor * Blank Holder Force) / (Drawing Force * K-
		Factor))
		Where the buckling factor is a factor that depends on
		the material and the blank holder force, and the K-
		Factor is a factor that depends on the material and the
		punch radius.
		Substituting the given values into the equations, we get:
		Drawing Force = $(100^2 - 75^2) * 3 * 550 / (4 * 75) =$
		2925 N
		Blank Holder Force = $2925 / (1 - (0.21 * Blank Holder))$
		Force) / (2925 * 0.7))
		Solving for the blank holder force, we get:
		Blank Holder Force = 1293 N

Table 3: Generated mathematical questions and answers by ChatGPT

These problems presented in Table 3 are effective to test of students' knowledge of sheet metal forming using a hydraulic press brake. The first problem provides a realistic scenario and requires students to apply their understanding of material properties, geometry, and mechanics to calculate the required force to form the part. However, the problem doesn't specify if the part is a single bend or a series of bends, and what is the final shape of the part after the bend. The second problem also presents a relevant scenario for a sheet metal part that is to be formed using a deep drawing process. In addition. It also provides specific information about the material properties and dimensions of the part, which is good as it makes the problem more realistic.

The solution of the mathematical problems was achieved through the utilization of clear and precise solutions. The solutions presented were well-written and effectively conveyed all the necessary information and tasks required to address the questions at hand. The solutions provided clear and detailed descriptions of each step, making the calculations accurate and easy to follow. It is also worth noting that the questions utilized a variable value that can be obtained from a table. The ChatGPT model demonstrated its capability by successfully identifying and utilizing this variable value in its solution process.

Ge	nerated mathematical problems by instructor	Solutions to mathematical problems generated by
		instructor
1.	A blanking operation is performed on $3/32$ -in- thick cold-rolled steel (half hard). The part is circular with diameter = 2.500 in. Determine the appropriate punch and die sizes for this operation A bending operation is performed on 4.0-mm- thick cold-rolled steel sheet that is 25 mm wide and 100 mm long. The sheet is bent along the 25 mm direction, so that the bend axis is 25 mm long. The resulting sheet metal part has an acute angle of 30° and a bend radius of 6 mm. Determine (a) the bend allowance, and (b) the length of the neutral axis of the part after the bend.	Solution/ Problem 1: From the table $Ac = 0.075$. Thus, $c = 0.075(3/32) = 0.007$ in Punch diameter = Db - $2c = 2.500 - 2(0.007) = 2.486$ in Die diameter = Db = 2.500 in Solution/Problem 2: (a) Given that $\alpha' = 30^\circ$, R = 6.0 mm, and t = 4.0 mm $\alpha = 180 - \alpha' = 150^\circ$. $A_b = 2\pi(\alpha/360)(R + K_{ba}t)$ $R/t = 6/4 = 1.5$, which is less than 2.0; therefore, $K_{ba} = 0.33$ $A_b = 2\pi(150/360)(6.0 + 0.33 \times 4.0) = 19.164$ mm (b) Due to stretching, the neutral axis of the final part will be greater than 100.0 mm. The amount of stretching will be the difference between the bend allowance and the length of the bent section, which is computed as $2\pi(150/360)(6.0 + 0.5 \times 4.0) = 20.944$. The difference = $20.944 - 19.164 = 1.780$ mm Thus, the final length of the neutral axis will be L = $100 + 1.78 = 101.780$ mm

Table 4: Generated mathematical questions and answers by instructor and GPT

Generated solutions to mathematical problems generated by ChatGPT

Solution/ Problem 1:

To determine the appropriate punch and die sizes for a blanking operation on 3/32-in-thick cold-rolled steel (half hard) with a circular diameter of 2.500 inches, the following calculations should be done:

- 1. The punch size should be equal to the finished part size, which in this case is 2.500 inches in diameter.
- 2. The die size should be equal to the finished part size plus the desired clearance between the punch and die. The typical clearance for a blanking operation is around 10% of the material thickness, so for 3/32-in-thick material, the clearance should be 0.003 inches. Therefore, the die size should be 2.500 + 0.003 = 2.503 inches in diameter.
- 3. It is also necessary to consider the material type and the desired edge finish when selecting the punch and die size. For example, if a sharp edge finish is desired, a smaller clearance may be used and for a rougher edge finish a larger clearance may be used.

Note: This is a general explanation and specific calculations may vary depending on the material, desired edge finish, machine and tooling capabilities, and other factors. It is always recommended to consult the manufacturer's guidelines for specific recommendations.

Solution/ Problem 2:

A bending operation is performed on 4.0-mm-thick cold-rolled steel sheet that is 25 mm wide and 100 mm long. The sheet is bent along the 25 mm direction, so that the bend axis is 25 mm long. The resulting sheet metal part has an acute angle of 30 degrees and a bend radius of 6 mm. To determine the bend allowance and the length of the neutral axis of the part after the bend:

a. The bend allowance can be calculated using the following formula: Bend allowance = $(\pi/180) * R * (90 - angle) * T$ Where R is the bend radius (6 mm), angle is the acute angle of the bend (30 degrees), and T is the sheet thickness (4 mm). (4 mm).

 $(\pi/180)6(90-30)*4 = (\pi/3)*4 = 4.188mm$

b. The length of the neutral axis can be calculated using the following formula: Length of neutral axis = $T * (1 - (\cos(angle)/(1 + (R/T)^2)))$ where angle is the acute angle of the bend (30 degrees), R is the bend radius (6 mm) and T is the sheet thickness (4 mm) Length of neutral axis = $4 * (1 - (\cos(30)/(1 + (6/4)^2))) = 4 * (1 - (\sqrt{3}/5)) = 4 * (1 - 0.6) = 1.6mm$

Note: This is a general explanation and specific calculations may vary depending on the material, desired edge finish, machine and tooling capabilities, and other factors. It is always recommended to consult the manufacturer's guidelines for specific recommendations.

The results of the evaluation of ChatGPT's ability to solve mathematical problems provided by the author were not entirely successful. When the answers provided by ChatGPT were compared to the instructor's solution manual, it was found that the answers were not accurate. The model had difficulty interpreting the questions correctly, which led to incorrect answers. ChatGPT provided a step-by-step explanation for each question, and a note after the solutions, "*warning that specific calculations may vary depending on the material, desired edge finish, machine and tooling capabilities, and other factors. ChatGPT also recommends consulting the manufacturer's guidelines for specific recommendations.*"

3. Discussion

In this paper, the use of ChatGPT in two industrial engineering courses, Engineering Project Management and Manufacturing Processes, were investigated and analyzed by generating different types of questions and answers. The goal was to determine whether the incorporation of ChatGPT into engineering education is beneficial or risky. Through our analysis, we aimed to provide insights into the potential impacts of ChatGPT on teaching and learning as well as any potential risks or challenges associated with its use in engineering education.

The finding of the analysis is that the use of ChatGPT in project management and manufacturing processes courses has the potential to greatly benefit both students and instructors. One potential benefit is the ability for ChatGPT to assist with generating and answering multiple choice questions, providing students with instant feedback, and allowing them to quickly assess their understanding of the material. This can be seen in the study " Effective learning of tax regulations using different chatbot techniques" by Mellado-Silva et al. [27], which found that the use of AI in education led to improved student performance on multiple choice assessments. Furthermore, ChatGPT can potentially facilitate more dynamic discussions. As a language model, ChatGPT can generate thoughtful and nuanced responses to discussion-type questions, encouraging deeper engagement among students. This aligns with the findings of " Chatbots: History, technology, and applications " by Adamopoulou et al. [21], which found that AI-assisted discussions led to increased student engagement and improved learning outcomes. Another benefit of using ChatGPT in these courses is the ability for it to assist instructors in creating engaging and interactive course materials. Finally, ChatGPT could potentially save time for instructors, allowing them to focus on other aspects of the course or to provide more individualized attention to students.

Another benefit of using ChatGPT in project management and manufacturing processes courses is the ability for it to assist students in solving mathematical problems. Although its answers to problems that were provided by the instructor were not accurate, ChatGPT can be used to generate step-by-step solutions for complex equations, providing students with a better understanding of the problem-solving process. This can be a valuable tool for students who may struggle with mathematical concepts, as it allows them to work through problems at their own pace and with the assistance of ChatGPT.

However, it's also important to consider the potential risks of using ChatGPT in these courses. One potential risk is the potential for ChatGPT to perpetuate bias, particularly in regard to mathematical problems as it relies on the data it was trained on. Also, if the same mathematical problems are run multiple times or ChatGPT is used to solve problems provided by instructor and compare the answers, it is possible that the answers may differ slightly due to variations in the way that the problems are interpreted or calculated. This can happen for a variety of reasons, including differences in the algorithms or processes used to solve the problems, as well as variations in the input data or initial conditions. It is generally a good idea to carefully evaluate the results of any mathematical calculations to ensure that they are reasonable and accurate. Another risk is the potential for ChatGPT to discourage critical thinking and creativity among students, as they may become overly reliant on the assistance provided by ChatGPT. Instructors should be mindful of this risk and take steps to promote independent thinking and creativity among students, such as encouraging them to come up with their own solutions to problems and to think critically about the responses generated by ChatGPT.

There are several potential risks that instructors may face when using ChatGPT in educational settings. One risk is the possibility that students may use ChatGPT in an unethical manner. This aligns with the findings of [24]. For example, a student might use ChatGPT to generate answers to questions that they are not able to solve on their own, or to write papers or complete assignments without doing the necessary research or understanding the material themselves. This can be difficult for instructors to detect and can undermine the integrity of the educational process. The author also raises a concern that if ChatGPT generates incorrect answers, it may lead to confusion among students. This is a problem for instructors because it can lead to confusion among students, which can negatively impact their learning experience. Additionally, if students are given incorrect answers, they may not fully understand the material and may not be able to complete the coursework or exams correctly.

It is important for students to be aware of the potential risks and consequences of using ChatGPT in this way. Cheating is considered a serious breach of academic integrity and can have serious consequences, including failing grades, academic probation, and even expulsion from school. Additionally, using ChatGPT to complete assignments or exams without understanding the material can undermine a student's education and long-term career prospects. Students should always be honest and transparent about their use of any tools or resources and should seek out help and support from their teachers and peers when needed. It is always better to ask for help and learn from one's mistakes than to cheat or cut corners in order to get ahead.

The strategies that instructors might consider when developing a class policy about the use of ChatGPT in educational settings: Help students understand that ChatGPT is not a substitute for human expertise or understanding, and that they should not rely solely on ChatGPT for their learning. Encourage students to use ChatGPT as a starting point for further research and exploration: ChatGPT can be a useful tool for generating ideas and starting points for further research, but students should always verify the accuracy and reliability of any information they use in their studies. Be transparent about the use of ChatGPT in the classroom: Let students know when and how you plan to use ChatGPT in your teaching and make it clear that they should not rely solely on chatbots for their learning. Clearly communicate the expectations for academic integrity: Make it clear to students that cheating, including the use of ChatGPT to complete assignments or exams, is not tolerated and will have serious consequences. Educate students about the limitations and potential biases of ChatGPT. By following these strategies, instructors can help students understand the appropriate and responsible use of ChatGPT in an educational setting, while also protecting the integrity of the learning process.

There are several ways that future research could be conducted to further investigate the potential benefits and risks of utilizing ChatGPT in engineering education. Some potential areas of research could include: 1) Effectiveness of ChatGPT for teaching and learning: Research could be conducted to assess the effectiveness of ChatGPT in teaching and learning specific engineering concepts or skills. This could involve comparing student outcomes when using ChatGPT to when using other teaching methods or resources. 2) Student perceptions of ChatGPT: Studies could be conducted to understand how students perceive and engage with ChatGPT in an engineering education context. This could include surveys or interviews with students to understand their attitudes towards ChatGPT and their experiences using it in their studies. 3) Ethical considerations: Research could be conducted to explore the ethical implications of using ChatGPT in engineering education, such as the potential for cheating or the risk of relying too heavily on automated tools. 4) Comparison with other teaching methods: Studies could be conducted to compare the effectiveness of ChatGPT to other teaching methods or resources, such as traditional lectures or problem-based learning, in teaching engineering concepts or skills.

4. Conclusion

The examination found that ChatGPT was able to generate relevant and appropriate questions and answers for multiple choice and discussion types of questions for given topics. It performed well when tested on various topics, producing accurate and on-topic responses. Additionally, ChatGPT was able to come up with unique questions, showing its ability to be creative. However, it's possible for answers to vary slightly when given the same problem multiple times or when used to solve problems provided by instructors. Overall, ChatGPT has the potential to be a useful tool for generating questions and answers in various contexts. Further research is needed to evaluate its performance and potential applications. Educators should communicate the limitations and potential biases of ChatGPT, encourage students to use it as a starting point and verify information, and be transparent about their use in the classroom. By doing so, students can learn to use ChatGPT responsibly and appropriately while maintaining academic integrity.

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Improving Access to Engineering Education: Unlocking Text and Table Data in Images and Videos

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Abstract

Accessibility of media, including visual media, is a significant concern in creating engineering education that is inclusive and accessible; without access, students who are blind or have low vision are unable to learn from today's engineering materials. This project presents a new accessibility tool, implemented as a user-friendly browser extension to extract and create accessible structured text — with a focus on tables of information — when embedded within web-based images and video media. The app can extract information to be used in a speech-to-text output of a screen reader; or text-to-braille device; pasted into a programming editing environment (e.g., Matlab, Jupyter notebook, Microsoft Code, or text editor); and further, used as the initial source input for manual or automated construction of audio descriptions to accompany the original media for future dissemination. In addition to improving access to engineering education, this project is a productivity tool for students seeking more access to textual data presented in image form. For example, it serves as a tool for all engineers and student engineers who seek to extract and re-use tabular information embedded inside an image or video that otherwise would require manual entry. The system uses the React.js framework and Tesseract Optical Character Recognition (OCR) engine. The tool preserves privacy because it runs entirely inside the browser: no image data leaves the client. It can extract information from any web page on any website supported by the Chrome browser. Users can screenshot images and videos, extract text and numbers in scientific notation, determine the tabular structure, and meaningfully extract text from tables in tabular form (separated into rows and columns). We describe its design: the user interface features that allow its use by people with low-vision and access specialists. Upon initiation, the user selects a media HTML element to process; the user can choose to extract text from this frame or change the focus to another object on the page. The extraction area is adjustable by keyboard or pointer/touch interaction. Finally, the user chooses to either screen-capture the area and download the image, extract text from the area, or extract tabular information. To make the tool intuitive, interaction is structured as a wizard where users are guided along the stepwise process but can go back to previous steps. We provide examples of the best and worst output of our accessibility tool when applied to engineering education content and evaluate its accuracy and performance to extract tabular information from image samples from engineering disciplines.

Introduction

Engineering content consists of a wide variety of forms - including but not limited to prose, images and figures, equations, charts and visualizations, programming code, and tabular information. A challenge of the inclusive education approach is to provide accommodations for students with disabilities and use technology to unlock access to these information-rich items. Unfortunately, textual information is frequently embedded in images or video, which is inaccessible to students who are blind or have low vision.

In this research paper, we introduce a new Chrome-based tool that can extract information from an image. Using an Optical Character Recognition (OCR) library, plain text can be machine-recognized from an image area. This work extends this text extraction to the extraction of structure and text of tabular information. This aspect is challenging because table layout and visual presentation can vary significantly. For example, there may be border lines between rows and columns, and column headings may span several lines.

Background

Optical Character Recognition (OCR) technology is a fundamental component of Text extraction tools. OCR operates by identifying text in an image, comparing the identified characters to a model of character features, and finally translating those recognized features into machine-encoded text. Popular OCR tools include Google Drive OCR, Tesseract, Transym, and OmniPage. Regardless of OCR application, they all share six principal steps in text extraction: **Image Acquisition, Pre-Processing**, Segmentation, Feature Extraction, Classification, and **Post Processing**.

Image Acquisition, the first stage, involves acquiring the picture and demarking the light from dark areas of the image. The light areas are treated as the background, while the dark areas are text. Pre-Processing follows this step. It takes the acquired picture and transforms it to ease character recognition in later stages. It includes several subprocesses including: binarization of the image: making it black and white; rotating the picture for improved horizontal alignment; noise removal: removing digital image spots and smoothing out edges; thresholding: cropping out unnecessary parts of the image.

Segmentation crops the pre-processed image to focus on the text portion of the photograph. The first part of Segmentation, Page Segmentation, removes parts of the image not containing text. Character segmentation then isolates individual characters for classification in the later stages, and the Image size normalization substage takes those separated characters and resizes them for the Feature Extraction stage.

In the Feature Extraction stage, the OCR application analyzes the isolated characters for distinguishing features: the tail of a capital Q, the stem of an L, and other minute details. The OCR software records these details for the penultimate stage: Classification. Classification uses several machine learning algorithms: K- Nearest Neighbor (K-NN) classifier, Support Vector Machines (SVM) classifier, and Probabilistic Neural Network (PNN) classifier to classify the segments of the image into characters. The extracted text is then output to the user during the Post-Processing phase. During this phase, the machine-encoded text could be placed in a file and edited for grammatical or spelling errors.

Implementation [Research design]

Our application uses Javascript, the React.js framework and the Tesseract.js OCR engine. The React.js framework allows for a simplistic, dynamic, state-driven user interface without interacting directly with the DOM of a webpage. Tesseract.js is a free, open source OCR tool with customizable features for text extraction, including character allow lists/deny list, Page Segmentation Modes, and adjustable borders for text extraction.

In our text extraction application, the user right-clicks on a webpage and is prompted with a context menu to open the application. Upon clicking "open," the application window becomes visible and selects the first video/image HTML element on the screen. The user is guided through a wizard where they can choose whether or not to change the text extraction focus, adjust the frame of the focus to extract text from, screenshot the frame, and extract tabular information or text from the image. Finally, the wizard prompts the user to repeat the text extraction on the same HTML element or pick a new extraction focus.

Our Text Extraction Application follows this general flow chart (Figure 1): it uses the Javascript Canvas API to screenshot the extraction focus: a video or image. The application then crops the screenshotted image based on the user's input. The cropped image is reduced to two colors, given padding, and borders are placed around the image. These three techniques improve text accuracy. For tabular extraction, this additional preprocessing is omitted for performance sake, and an edge detection algorithm processes the image and returns the dimensions of the table and the dimensions of the individual table cells. The tesseract engine is used on each cell individually. For normal extraction, the app forwards the entire preprocessed image to the Tesseract OCR engine.





In the case of numerical text extraction, an allow list orders Tesseract to recognize exclusively characters standard numerical notation: "0123456789e*^." For normal text extraction, an allowlist is not used. The app then displays the extracted text. Tabular text can be displayed as an HTML table, CSV file, or JSON table.

Development began with linking Tesseract.js functionality with React.js. Tesseract allows users to insert several object types as parameters for OCR text extraction: Image URLs, filenames, and HTML canvas objects, among others. HTML's Canvas object is a convenient medium for text extraction as React.js can take a "screenshot" of an image or video in the website DOM. React.js can directly send that screenshot to Tesseract.js.

After linking React.js' functionality to Tesseract's functionality, the next concern became the tabular extraction feature. The principal issue was table formatting. Table formats vary wildly: cell boundaries, cell arrangements, and color schemes can all affect how an algorithm can interpret a table from an image. For the application's early stage, we assumed that tables have a uniform layout with a black-and-white color scheme.

Our initial implementation of a tabular extraction used a K-means clustering algorithm to find areas in the image with the most amount of black pixels. The intuition was black clusters on the image would be where cell entries reside. Cell dimensions could be interpreted from the relative position of those clusters along the X and Y axes. We abandoned this approach after experiments found that the clustering algorithm required a significant amount of time and often misidentified the table edges as cell entries.

The improved methodology uses an edge detection algorithm that records into an array the number of times the pixel color changes significantly while scanning horizontally and then vertically across an image. The logic of this approach is that text in an image would cause a row of pixels to have more "edges" detected than space or cell borders on the table. The mode number of edges is found. Any rows/columns in the image that have more edges than the mode are treated as text subsections; those with a less or equal number of edges are non-text subsections. The app interprets the horizontal and vertical subsections as the rows and columns of the table; these subsections determine the position of the table cells in the image. The application sends the table cells' coordinates to Tesseract.js.

After solving the tabular extraction issue, the last major challenge with the "Extract Text as Numerical Value" functionality. Ideally, the feature would extract text in Scientific notation from images and return the value of the number in standard form as text. For example, the text "3.02e2" on an image would translate to "302" in the application output. However, initial versions of the application had text extractions for mathematical expressions such as 3.02^5 be recognized as 3.02M5 or 3.0275. The problem was Tesseract's default OCR model did not recognize the caret ("^") character. To rectify this issue, a new training model was created based on the existing Tesseract model for English with additional training data to help recognize the caret symbol.

Preliminary Testing

For testing, we looked into the accuracy of the tabular extraction feature of our proposed out. We ran our proposed text extraction app on several STEM-related course books. Screenshots were taken of the tables in these course books with generous amounts of whitespace around the tables. We then classified the screenshots into two main groups: Regular and Irregular. Regular tables contain a fixed number of rows and columns and do not have missing table entries. An example of a regular table is shown below in Figure 2.

Obs.	X_1	X_2	X_3	Y
1	0	3	0	Red
2	2	0	0	Red
3	0	1	3	Red
4	0	1	2	Green
5	-1	0	1	Green
6	1	1	1	Red

Figure	2
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Irregular tables are tables that do not conform to the specifications of Regular tables: asymmetrical table dimensions, empty table entries, multiple header rows/columns, etc. An example of an irregular table can be shown in Figure 3.

		True default status			
		No	Yes	Total	
Predicted	No	9320	128	9448	
default status	Yes	347	205	552	
	Total	9667	333	10000	

Figure 3

The Regular table group further divides into two subgroups: Alphanumeric and Numeric. Alphanumeric tables contain both alphabetic and numeric characters. Likewise, alphabetic tables only have alphabetical characters in the table contents - alphabetical characters include greek letters.

To measure our app's word accuracy, we recorded four metrics. The word accuracy, the header accuracy, the data accuracy, and the extracted dimensions of the table. We calculate the word accuracy as the difference between the number of correct characters extracted by the number of incorrect characters extracted divided by the total number of characters in the original image. For numerical figures, a single-digit error results in the entire number being incorrect. Other artifacts from extraction, such as newline characters ("\n"), are ignored for accuracy measurement. Header accuracy and data accuracy are similarly defined but only consider text in the header and data sections of a table.

Table Type	Word Accuracy	Header Accuracy	Data Accuracy	Expected Dimensions	Extracted Dimensions	
	•	Alpha	betical			
Table 5	89.66%	0%	91.57%	5x2	5x2	
Table 8	52.41%	42.55%	52.96%	10x6	2x11	
Table 4	0%	0%	0%	4x4	N/A	
	•	Alphan	umerical			
Table 2	86.66%	84.61%	100%	3x5	1x1	
Table 3	18.64%	12.82%	75%	3x5	2x2	
Table 4	73.13%	69.49%	100%	3x5	2x2	
Irregular						
Table 2	83.09%	90.32%	37.5%	N/A	7x1	
Table 1	13.73%	4.65%	37.5%	N/A	7x1	
Table 8	0%	0%	0%	N/A	1x1	

Results

These are some highlights of the results of running our app on tables of each type of table from the college coursework.

Discussion

Overall, while our proposed app was sometimes accurate at deducing table dimensions, the accuracy of the extracted text was poor. We believe this is because the size of the tables from the engineering coursework was significantly smaller than those we used for our preliminary testing. Our edge detection algorithm described previously relies on differences in pixel color while scanning through the image. For tables with a dense amount of text or minute padding between table cells and their entries, our edge detection algorithm often interpreted multiple rows/columns as a single row/column (Figure 4). We furthermore believe this problem was exacerbated by our image binarization algorithm; while effective in improving the quality of larger images, for smaller images, we imagine binarization made deducing table dimensions harder for our edge detection algorithm. In scenarios where our edge detection algorithm accurately deduced table dimensions, the meager padding between the cell borders and contents

hindered the Tesseract OCR software from correctly transcribing the image as text based on empirical data. Tesseract OCR would forgo some of the text altogether or misinterpret characters

libetan terrier	0.56	Old English sheepdog	0.82	jacamar	0.28
xocker spaniel	0.32	Persian cat	0.04	robin	0.12

Figure	4
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The alphabetic tables had the highest accuracy overall. We assume this is because most tables in this category were larger and had ample space between their cells. Predictably, the irregular tables had the worst accuracy overall. Since these tables had merged rows/columns headers, our edge detection algorithm would erroneously split the headers into two among the aforementioned issues. The alphanumeric tables were a peculiar case because the Tesseract OCR technology would moderately accurately transcribe the text; however, because these tables were the smallest out of all groups, our edge detection algorithm had its worst performance deducing the table dimensions.

Conclusion

A means of extracting text embedded in media is crucial in creating a more accessible world for people in all educational disciplines. In this research paper, we proposed our application for extracting text from videos and images with several features such as screenshotting, text extraction, and tabular extraction. We furthermore tested the application on several real life instances of text and found some insightful results.

Further Work

Although our application's accuracy was disappointing, the results of our testing revealed opportunities for future potential improvements to our application. The critical step in our application's table extraction process was determining the table dimensions; any errors in this step propagate to the other stages in table extraction. To improve the issues with table dimension detection, we will evaluate a new algorithm that combines edge detection and cell border detection to deduce the table dimensions. The general strategy of this algorithm is to use the edge detection algorithm for larger tables where ample padding exists within cell dimensions and utilize cell border detection for smaller images. This proposed cell border detection algorithm will seek elongated horizontal and vertical lines in an image that is identical in the pixel color and assume those are the borders between cells.

Beyond automated dimension detection, our application could employ user input in finding table dimensions. The app would first run the previously described algorithms on an image and prompt the user to adjust the rows and columns using an interface similar to Microsoft Word (Adding Rows/Columns, Splitting Cells, etc). The application would then forward these dimensions to Tesseract.

To improve pre-processing of cells for Tesseract, we propose the idea of using each cell's contents and adding upscaling, padding, and other pre-pro-cessing effects to the cells similarly to how we described the general pre-processing. We had forgone these for table extraction as a compromise for performance; however, these tests have shown that for smaller images this pre-processing may prove indispensable for Tesseract to transcribe the text correctly.

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Paper Session 4: Innovations in STEM Education: Strategies for Sustainable and Transformative Learning

Location: Engineering Building 1150

Session Chair: Saad Ullah

10:15 – 10:30am	Building a Sustainable Institutional Structure
	to Support STEM Scholars – Scholar Survey
	Data
	D. W. Mueller, Jr, Josué Njock Libii, Donna
	D. Holland, O. David Momoh, Peter A. Ng,
	Reynaldo M. Pablo (Purdue University Fort
	Wayne), Suleiman Ashur (Eastern Michigan
	University)
10:30 – 10:45am	Work-in-Progress: Sustainability Education in
	Law and Engineering
	Tyler J. Smith (Bradley University)
10:45 – 11:00am	Curricular Priority and Transformation of
	Construction Engineering Capstone Design
	Course
	Brandon Fulk, Kyubyung Kang (Purdue
	University)
11:00 – 11:15am	Work-In-Progress: Can We Create a Model
	Program: Insights into the Effectiveness of a
	Research Experience for Undergraduates
	La'Tonia Stiner-Jones (The Ohio State
	University)

Building a Sustainable Institutional Structure to Support STEM Scholars - Scholar Survey Data

D. W. Mueller, Jr.*	Josué Njock Libii	Donna D. Holland	O. David Momoh
Purdue University	Purdue University	Purdue University	Purdue University
Fort Wayne	Fort Wayne	Fort Wayne	Fort Wayne

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Abstract

This paper describes activities and preliminary findings from a five-year, NSF-sponsored project (Award #1565066) at Purdue University Fort Wayne to increase the number of students who complete engineering, engineering technology, and computer science degrees. Purdue University Fort Wayne is a metropolitan, non-selective, public institution with a high percentage of underprepared, first-generation, low-income, commuter students, many of whom work. The objectives of this project are to (a) increase graduation rates of the STEM cohorts; (b) build the foundation for a sustainable institutional structure and support STEM scholars and other students; (c) carry out research designed to advance understanding of the factors, practices, and curricular and co-curricular activities that affect the retention of students and their degree completion; and (d) integrate the best practices into the educational culture of the institution.

Funding from this grant was primarily used to support twenty-six (26) junior- and senior-level students. Students were recruited in three cohorts consisting of eight, eight, and ten students from 2017-2019. The topic of this paper is the personal data, survey responses, completion rates, and student success from the grant-funded students. Areas of focus for which data are collected include: (a) learning how commuters prioritize the three aspects of their lives (home, work, and school); (b) understanding how commuters use the financial assistance that they receive and its impact on the progress they make towards completing their degrees; (c) identifying the support practices and interventions that enhance the academic success of commuter students from among the many that are provided by universities and colleges; and (d) identifying the challenges that commuters face with juggling responsibilities and obligations from home, work, and school. Significant findings from the first two cohort groups indicate that grant funds and activities reduce financial stress, give students hope and structure, and shorten time-to-degree. High-performing commuters, a majority that are employed, have developed efficiencies in the use of their time and how to they do their academic work.

Introduction

Nationwide, engineers, technologists, and computer scientists are needed to meet the demands of the current economy, and even more will be needed to meet the demands of the economy of the

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future. According to the Bureau of Labor Statistics [1], the job outlook for engineering and computer scientists is growing, e.g.

- employment of software developers, quality assurance analysts, and testers is projected to grow 25% from 2021 to 2031, much faster than the average for all occupations;
- employment in computer and information technology occupations is projected to grow 15% from 2021 to 2031, much faster than the average for all occupations;
- employment in architecture and engineering occupations is projected to grow 4 percent from 2021 to 2031, with some areas of engineering, such as industrial and biomedical growing at rates of 10%.

In northeast Indiana [2], engineering and computer science graduates support economic development in the broad sectors of manufacturing and health care, as well as specifically targeted, growth industries such as defense & aerospace, distribution & e-commerce, medical devices, specialty insurance, and vehicles. A continuous and steady supply of engineers, technologists, and computer scientists is necessary to sustain economic growth [3].

Purdue University Fort Wayne (PFW) is a public institution serving northeast Indiana. PFW is a metropolitan, non-selective, institution with a high percentage of under-prepared, first-generation, low-income, commuter students, many of whom work. The mission of the PFW College of Engineering, Technology, and Computer Science (ETCS) is to provide a comprehensive education that will prepare career-ready graduates for a variety of roles in engineering, polytechnic, computer science, and leadership, serving the needs of northeast Indiana and beyond.

In 2016, PFW (then IPWF) was awarded an NSF grant (Award #1565066)—the overarching goal of the project is to increase the number of students who complete degrees in engineering, technology, and computer science. Like many similar institutions, PFW struggles with graduation rates [4]. For example, in 2020, the overall 6-year graduation rate for first-time, full-time undergraduate students who began seeking a bachelor's degree at 4-year degree-granting institutions in fall 2014 was 64% [5]; at PFW that rate was 37% [6]. Improving graduation rates and reducing time-to-completion is a priority for the Indiana Commission of Higher Education [4].

This paper briefly describes some of the activities associated with the NSF project [7] with a focus on the personal data, survey responses, completion rates, and student success of the grant-funded students. Areas of attention for which data are collected include: (a) learning how commuters prioritize the three aspects of their lives (home, work, and school); (b) understanding how commuters use the financial assistance that they receive and its impact on the progress they make towards completing their degrees; (c) identifying the support practices and interventions that enhance the academic success of commuter students from among the many that are provided by universities and colleges; and (d) identifying the challenges that commuters face with juggling responsibilities and obligations from home, work, and school.

Rationale and Approach of the Project

The objectives of this project are to (a) increase graduation rates of the STEM cohorts; (b) build the foundation for a sustainable institutional structure and support STEM scholars and other students; (c) carry out research designed to advance understanding of the factors, practices, and curricular and co-curricular activities that affect the retention of students and their degree completion; and (d) integrate the best practices into the educational culture of the institution. More details on the overall structure of the project are given in [7].

Most programs to enhance retention in the STEM fields focus on first- and second-year students [8,9]. Many retention-enhancement programs [10,11] form communities of learning to support first- and second-year students academically, socially, and professionally.

This project focuses on rising juniors; there are two reasons for this. First, the nature of nonselective institutions such as PFW is that a very wide variety of students is admitted. Their readiness for, interest in, and commitment to a given major vary widely as well. These issues are generally not sorted out until the end of their sophomore year. As juniors, these students will have demonstrated commitment to their ETCS majors as well as to satisfactory levels of academic performance. Financial aid at this point rewards them for what they have achieved-making it to the halfway mark. Second, beyond the stipend, this project also encourages, supports, and assists STEM scholars to complete their degrees earlier than they would otherwise. On residential campuses of very selective universities, where graduation rates are very high (88-96%), once a student reaches the junior level of an undergraduate curriculum, it is practically a certainty that the student will graduate with a bachelor's degree. Unfortunately, that is not the case at PFW. A review of institutional data regarding the graduation rates of rising juniors in the College of ETCS from 2006 to 2015 reveals that only 27.5% of new juniors completed their degrees in two years; 58% completed their degrees in three years; 64% in four years; 72% in five years; and 82% in six years. The ranges of percentages within the college and the corresponding weighted averages are shown in Table 1. Some of these students get discouraged and quit altogether. Therefore, the significance of this project is that it will shorten the time it takes students to graduate, thereby, increasing their graduation rates. With this project, the expectation is that rising junior-level students who would have taken three or four years to graduate will do so in two years. This would increase the twoyear graduation rate of STEM scholars (rising juniors) from the current 27.5% to about 60% for each of the two cohorts of this project. The data in Table 1 is generated by considering all students who attained 60 credit hours in a given semester as juniors. Thus, it includes students with transfer credits fulfilling general education requirements and students who need to retake a single sophomore-level course to satisfy a pre-requisite requirement.

For this project, three types of data were collected and analyzed: (1) survey data from the scholars in the program that received funding, (2) college-wide surveys to ETCS students, primarily firstand second-year students, (3) institutional data such as retention, persistence (student success), progression-in-major, and graduation rates.

years to graduate once a junior	2 years	3 years	4 years	5 years	6 years
range (%)	18% - 32%	43% - 84%	50% - 86%	50% - 90%	67% - 92%
average (%)	27.5%	58%	64%	72%	82%

Table 1. Years taken by new juniors to graduate with bachelor's degrees in ETCS (2006-2015).



Figure 1. Types of data collection

Description of Grant Activities

Funding from this grant was primarily used to support twenty-six (26) junior- and senior-level students. Students were recruited in three cohorts consisting of eight, eight, and ten students from 2017-2019.

S-STEM Scholars Program

Twenty-six (26) rising junior-level students were selected to participate in the S-STEM Scholar Program (SSP). Demographic data is given in Table 2. The application process consisted of an application form, personal essay, and letter of support from a faculty member. Applicants also had to satisfy residency requirements in accordance with NSF guidelines and demonstrate financial need as determined by the office of financial aid. Students selected received \$4166 per semester or \$8332 per year. The period of funding was two years, although adjustments could be made. The scholars participated in a comprehensive program designed to improve student retention, promote academic success, and build preparedness for professional careers and graduate studies. The program was built upon student support structures that existed previously at PFW.

cohort	number	engineering	computer science	polytechnic	male	female	white	not white
2017	8	4	1	3	7	1	5	3
2018	8	3	3	2	5	3	6	2
2019	10	4	3	3	9	1	7	3
total	26	11	7	8	21	5	18	8
total		42.3%	26.9%	30.8%	80.8%	19.2%	69.2%	30.8%
ETCS*		33.1%	27.1%	39.8%	87.6%	12.4%	76.3%	23.7%

Table 2. Demographic information about the three cohorts.

*fall 2019 and includes computer science, engineering, and polytechnic majors (excludes non-resident)

The S-STEM Scholar Program consists of required elements and optional elements. The following elements are required: program orientation, Student Learning Communities (SLC), academic and professional development workshops, STEM colloquia series, reports of academic progress on a weekly basis (RAP), and exit interviews. A program orientation was given to the scholarship recipients in late August of the fall semester during which they received the award and the following fall. During this orientation, the students are given a timetable of activities and other program requirements. It was emphasized that the honor and recognition that they receive as STEM Scholars comes with distinct responsibilities and that the program requirements must be completed in a timely manner for each student to continue participation in the program.

A team consisting of teaching faculty, mentors, academic advisors, and peer mentors has been created to support the NSF S-STEM scholars. These teams are organized and do their work using the well-established concepts of faculty and student learning communities and follow the recommendations from the well-known study by the National Research Council (NRC): *How People Learn*, which identifies four interrelated perspectives of effective learning environments: *Learner-centered environments, Knowledge-centered environments, Assessment-centered environments*, and *Community-centered environments*. Together, these environments work to create and sustain the mutual support and encouragement of students and the active involvement of all faculty, staff, administrators, fellow students, and employers of the graduates of STEM academic programs [12].

Faculty Learning Community

A Faculty Learning Community (FLC) is a cross-disciplinary group of faculty that engages in an active, collaborative, multiyear program that focuses on sharing experiences, learning from the literature, other campuses, and each other.

An FLC was formed, and the group participated in a comprehensive program designed to increase interactions between faculty and students, support student retention, promote academic success, and build career preparedness through such activities as faculty advising and mentoring; and cooperative learning [12,13]. Six to eight members of the FLC met regularly to discuss the data collected and develop tools and recommendations to promote student success.

Student Learning Community

A Student Learning Community (SLC) was created to enhance academic achievement, personal growth, and career & employment success [10,11]. The SLC consists of a small group of students and a faculty member in the same, or closely related field, and a student assistant (peer mentor). The faculty member served as the top-tier mentor and liaison for the cluster and performed the following duties: advising (e.g., helping students with course selection and monitoring their academic progress); assisting them in identifying and evaluating academic and career opportunities; evaluating job offers or preparing for graduate school, whichever is appropriate; coordinating various activities for the cluster (e.g., research seminars, trips, etc.); and being the group's liaison with the FLC. The student assistant served as a "near-peer" mentor for the STEM Scholars, helping them with issues related to available resources and connecting them with a variety of services, professionals, and other students, as needed. Whereas some students find it intimidating to work with the faculty, in the mentoring cluster, when needed, the peer advisor provides a less intimidating resource. Three SLCs were formed: one for engineering majors,

another for polytechnic majors, and the third for computer science majors. Building such learning communities is a way to implement a research-proven and time-tested pedagogy on *How People Learn* [12].

Results: Weekly Activity Reports

Members of the STEM Scholars Program were required to fill out activity reports detailing their time use and academic progress (attendance, grades, etc.) The reports contained weekly data and were submitted monthly via email. In addition, students filled out reports describing how they spent their stipend from the grant. The monthly data was complied, analyzed, translated to semester data, and reported to the S-STEM scholarship reporting site (www.s-stem.org).

The topic of this section is personal data and survey responses from 15 scholars in the first two cohorts.[†] Results from the fall 2018 individual time use surveys are shown in Figure 2, while the average values are shown in Figure 3. The data indicates that the scholars spent the majority of their time sleeping or with home life. Twelve of the scholars worked, while three did not. For the students that worked, the average number of hours reported working per week is 17.1 (SD = 10.0). One student reported working 36 hours in a given week, while one student reported working only 2 hours per week.

The relationship between GPA and time use is investigated using Pearson's correlation coefficient. Despite the small sample size, three relationships stood out as potentially significant, viz., a 63% positive correlation between GPA and time spent on paid work, a 46% negative correlation between GPA and home life, and a 57% positive correlation between GPA and sleep. For all correlations, r(13) and p < 0.01.



Figure 2. Allocation of time—individual student responses fall 2018.

[†] The data presented in this section is pre-COVID-19 pandemic disruption.



Figure 3. Allocation of time—average student responses fall 2018.



Figure 4. Allocation of funds—individual student responses fall 2018.



Figure 5. Allocation of funds—average student responses fall 2018.

Figures 4 and 5 show how the SPP participants spent their stipend. The majority of the funds were used for tuition and housing. Three scholars reported spending all of the funds on tuition, while two students reported not spending any of the funds on tuition.

Results: End-of-Semester Surveys

End-of semester Qualtric surveys were given to all S-STEM scholars in the program. The surveys consisted of 10 questions as shown in the Appendix. The survey was developed and administered at the end of each semester starting in the fall 2017 semester. To make sure that students provided complete and honest answers without any bias, the survey was conducted by the PFW Assessment Office. Results from the fall 2017 – spring 2019 were aggregated and analyzed by the assessment coordinator of the grant.

Students were asked to evaluate the extent to which participation in the S-STEM Scholars Program (SSP) helped them in the following areas:

- a) Increased their interactions with other engineering students
- b) Increased their interactions with faculty members
- c) Increased their interaction with professionals in the community
- d) Increased opportunities to participate in research projects

Students were asked to evaluate each element on a five-level Likert scale with responses of *none*, *not much*, *a little*, *quite a bit*, or *a lot*.

Students were asked to evaluate the extent to which participation in the S-STEM Scholars Program (SSP) helped them achieve learning gains in the following areas:

- a) Participating in an externship
- b) Participating in an internship
- c) Participating in Fort Wayne Engineers' Club Tours
- d) Retired Engineers and Engineering Managers Seminars
- e) Immersion Excursions
- f) Monthly Leadership Meetings
- g) Monthly Seminar with Scholars

Students were asked to evaluate each element on a five-level Likert scale from *no gains*, *a little gain*, *moderate gains*, *good gains*, or *great gains*.

A summary of the results from the fall 2017 - spring 2019 is shown in Table 3. The fall 2017 and spring 2018 data are solely from the first cohort, while the fall 2018 and spring 2019 data are from cohorts 1 and 2. Table 3 contains the percentage of respondents, juniors and seniors, which selected the top two responses on the Likert scale, either *quite a bit* and *a lot* or *good gains* and *great gains*. Values greater than 50% are indicated with bold and are deemed to be significant.

Both junior and senior students felt that the SSP helped to increase interactions with other students. Junior-level students felt that the SPP helped to increase interactions with faculty, while senior-level students felt that the program helped to increase interaction with professionals in the community.

Participation in some SPP activities was optional and not required. Students, however, were encouraged to participate in these activities. In general, there were very few responses to some questions in this part of the survey. Due to the low participation in these areas, observations should be considered with caution.

Extent SSP helped to	junior (N = 16)	senior (N = 21)	
Increase interactions with other engineering students	75.	0%	76.	2%	
Increase interactions with faculty members	56.	3%	42.	9%	
Increase interaction with professionals in the community	25.	0%	61.	9%	
Increase opportunities to participate in research projects	12.	3%	23.	23.8%	
Extent SSP helped to achieve learning gains by	Ν	%	Ν	%	
Externship Participation	2	0%	4	25%	
Internship Participation	10	80%	13	69%	
Fort Wayne Engineers' Club Tours	2	0%	3	0%	
Retired Engineers and Engineering Managers Seminars	3	33%	5	40%	
Immersion Excursions	3	33%	4	0%	
Monthly Leadership Meetings	12	67%	10	70%	
Monthly Seminar with Scholars	16	69%	20	60%	

Table 3 End-of-semester survey responses fall 2017 – spring 2019—% favorable responses.*

* top two favorable responses: *quite a bit* and *a lot* (top) or *good gains* and *great gains* (bottom)

With regards to SSP activities that helped achieve learning, both junior and senior students felt that internships contributed to their learning. In addition, both junior and senior students felt that monthly meetings and seminars were beneficial to learning.

Note the survey was also given each semester from fall 2019 to spring 2021, and subjects included the third cohort and members of the first two cohorts that were still in the program. Due to the COVID-19 pandemic, program activities were modified, priorities were shifted, and data collection was problematic. Before presenting the 2019 - 2021 data, further analysis and a nuanced interpretation are needed.

In addition to the rating of activities, students were asked to provide comments as to what they achieved over the course of a semester, e.g. one student commented:

Because of the scholarship assistance, I was able to achieve a good semester GPA while still being able to spend some quality time with my family. It is important to me that I be able to attend my stepchildren's events and activities, as well as help them with their homework and spend some free time with them, and the scholarship funds allowed me to discontinue one of my two jobs, allowing me extra time. In all, I achieved a balanced work, school, and family schedule.

and another:

I divided my semester into four compartments: school, work, family, and personal life. I achieved enough of a balance to succeed in my courses and still have time to devote towards my professional development.

These comments indicate that the SPP offers a healthy work-life balance for students that allows them to succeed academically. Another student commented:

I went to school full time and worked at Regal Beloit part time. At school, I was able to get great grades on tests while managing my time accordingly. At work, I've been developing a new product using skills I learned in school and experience from past co-op sessions.

This comment indicates that the SPP allows students to make personal and professional changes to their lives that empower and equip them with new skill sets.

Students were also asked how the stipend helped, e.g.

The scholarship money helped tremendously with tuition payments and it gave me peace of mind when budgeting for food, bills, transportation, etc.

The main way the scholarship money helped me was by allowing me to take time to focus on my academics and not have to stress much about fitting in time to work. Being able to concentrate so heavily on my academics allowed me to achieve very good grades and still maintain a healthy lifestyle i.e. time to exercise and sleep a healthy amount.

Feeling more financially secure reduced tremendous amounts of stress that could have detracted from my ability to focus on my current goals and course completion. I feel that not having worries related to money allowed me to relax and approach university work with a clearer head and optimism. It also made affording materials for class much easier.

Almost every student remarked how the provided funds reduced stress and allowed them focus on their schoolwork.

Results: Time-to-Graduate and Student Success

The overarching goal of this study is to increase the graduation rates or decrease the time to graduate for juniors in the College of ETCS. Twenty-six students received funding from the program—25 of the 26 students or 96% of students in the program graduated. One student from the 2017 program left the university. Seventeen of the students in the program or 65% graduated in 4 semesters or fewer and after five semesters, that percentage rose to 73%. The average number of semesters-to-graduate is 4.8 (SD = 1.51) and the average graduation GPA is 3.50 (SD = 0.37).

Two students graduated nine semesters after becoming a junior—both of those students changed majors. One student changed their major from mechanical engineering technology (polytechnic) to mechanical engineering and the other changed from mechanical engineering to mechanical engineering technology (polytechnic). These data points are included in the analysis.

The data reveals a negative correlation of 0.40 between semesters-to-graduation and GPA (Pearson's correlation r(23) = -.40, p < 0.01). Figures 6-8 present the semesters-to-graduate and GPA data highlighting three different aspects, i.e. program, cohort year, and work/no work. A linear regression analysis of the data, showing the general trend, is indicated on the graphs with a dotted line.

On average, computer science students in the program graduated in 4.3 (SD = 0.76) semesters, polytechnic students graduated in 4.8 (SD = 1.75) semesters, and engineering students graduated in 5.1 (SD = 1.73) semesters.







Figure 7. Relationship between semesters-to-graduate and GPA—effect of year entering the program.





Students in the 2017 cohort took the longest to graduate—taking an average of 5.5 (SD = 2.20) semesters. However, note that two students in the first cohort changed majors and took 9 semesters after entering the program to graduate—without those two data points, the average number of semesters to graduate drops to 4.3 (SD = 0.52). Students in the second and third cohorts graduated in 4.3 (SD = 0.76) and 4.5 (SD = 1.08) semesters. It appears that there is no significant difference in time-to-graduate between the cohorts.

81% percent of the students reported that they work, while 19% reported no work. Over the entire reporting period, the average number of hours students reported working is 17.7 (SD = 7.86). Students who work had higher GPAs compared to students who reported not working (3.53 to 3.37), but, on average, took slightly longer to graduate than students that did not work (5.2 semesters to 4.7 semesters). Other studies found student work often results in a longer time to graduation and less academic success [14,15].

Lessons Learned

When you have met one PFW, ETCS student, you have met *one* PFW, ETCS student. Every student is different and every student has different interests and challenges to overcome. Time is limited and engineering programs do not allow much flexibility. A more flexible curriculum could potentially improve retention [16] and time-to-graduation.

A common theme related to the financial aspects of the grant is that scholarship money greatly reduces *stress*. Stress affects students and learning communities and mentoring give student structure and advice to help them cope with stress.

The SSP helped students *interact with other students*, especially those outside of their discipline.

Students in the SSP benefited greatly from *internships*, as well as the *meetings* and *seminars*. To make these aspects *sustainable*, permanent structures need to be put in place. Programs to help students obtain internships should be continued by university career services. Student chapters of professional societies can help to sustain meetings and seminars, and the college has implemented a peer and alumni mentoring program.

A majority of PFW students *work*. Surprisingly, a majority of the students that participated in the grant also worked. It appears that PFW ETCS students who work take slightly longer to graduate, but are slightly more successful academically. This appears to contradict other studies involving student employment.

While the COVID-19 pandemic disrupted many aspects of society including academia, it appears that the disruption did not affect timely graduation for upper-level ETCS students in good academic standing.

Future Work

Analysis of the other two data sources, i.e. ETCS student survey data and PFW institutional data [17], is ongoing and being used to complement and confirm the data and findings reported in this paper. Based on these findings, three tools to enhance student success were developed by a faculty learning community: (1) Success Assessment Tool, (2) Risk Indicator Survey, and (3) Engineer Your Success [17].

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Appendix

Exit Survey

Thank you for taking the time and effort to respond to this survey. Please feel free to give your most candid response to the following questions. Your response is confidential, will not affect your scholarship, and most importantly will help us to improve the university's NSF Scholarship Program.

Q1	When	did you	enter	the NSF	Scholarship	Program?
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O Fall 2017	
O Fall 2018	
O Fall 2019	
O Fall 2020	

Q2 What is your current class standing?

O Freshman
O Sophomore
O Junior
O Senior

	N/A	None	Not Much	A Little	Quite a Bit	A Lot
Increased your interactions with other engineering students	0	0	0	0	0	0
Increased your interactions with faculty members	0	0	\bigcirc	\bigcirc	0	0
Increased your interaction with professionals in the community	\bigcirc	0	\bigcirc	\bigcirc	0	0
Increased opportunities to participate in research projects	0	0	0	0	0	0

Q3 Please evaluate the extent to which participation in S-STEM Scholars helped you in the following areas:

Q4 Describe the learning gains you achieved as a result of participating in the following activities:

	N/A	No Gains	A Little Gain	Moderate Gain	Good Gain	Great Gain
Participating in an externship	0	\bigcirc	0	0	0	\bigcirc
Participating in an internship	0	\bigcirc	0	\bigcirc	\bigcirc	\bigcirc
Fort Wayne Engineers' Club Tours	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc	\bigcirc
Retired Engineers and Engineering Managers Seminars	0	0	0	0	0	0
Immersion Excursions	0	0	\bigcirc	0	0	0
Monthly Leadership Meetings	0	0	0	0	0	0
Monthly Seminar with Scholars	0	0	0	\bigcirc	0	0

In the following section, describe your semester.	
Q5 What did you achieve?	_
Q6 What did you hope to achieve but did not?	
Q7 What did you plan to achieve but did not?	-
Q8 How did the scholarship money help you?	
Q9 How did the scholarship money not help you?	
Q10 Please share any additional information and questions.	
Question added in fall 2020	
Q11 How has COVID-19 affected your studies?	

Work-in-Progress: Sustainability Education in Law and Engineering

Abstract-Numerous surveys indicate that younger generations (Millennials and Gen Z) increasingly care about the actions of companies when it comes to sustainability and ethics. Nearly 9 in 10 (88%) of consumers say that sustainable and ethical practices are key factors in determining whether or not they will purchase from a particular company. Furthermore, two-thirds of consumers (66%) say that they would not purchase from a company that does not have plans in place to address issues of climate change and DEI (diversity, equity, and inclusion), as well as ethics. Organizations, such as the American Society for Engineering Education, understand the importance of sustainability with respect to engineering. Many engineering undergraduate and graduate programs have responded to the demand for sustainability in engineering education by creating programs that primarily aim to focus mainly on design and environmental impacts. While those are critically important considerations, engineers must also consider the social, legal, and future impacts of their professional actions. With the input of experts from academia and industry, the ASEE's Engineering for One Planet (EOP) initiative developed a framework to guide faculty that incorporates OP curricular modules into engineering education programs. The framework includes topic areas that contain theories and concepts that are of great importance in the development of competent and environmentally sustainable engineers. As a business law faculty member of the Foster College of Business at Bradley University, this paper will describe my experience as a recipient of the EOP's Mini-Grant Program that allowed me to develop Learning Management System (LMS) modules using three topic areas from the EOP framework related to environmental literacy, responsible business and economy, and social responsibility

Work-in-Progress: Sustainability Education in Law and Engineering

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Introduction

An overwhelming amount of evidence exists to support the notion that our planet is in peril in numerous ways. From greenhouse gasses causing global warming to the destruction of natural resources, and from microplastics to radium, the use of materials for the benefit of humankind has done damage that in many instances is hard to measure. However, organizations, corporations, and higher educational institutions have developed ways to combat several of the issues facing our world today. Pressure has come from younger generations who generally demand more from those in power, both in government and in the corporate world. Millennials, the digital generation, are perceived to be the most diverse and largest generation with a higher awareness of business activity.¹ Companies are recognizing the importance of Corporate Social Responsibility (CSR) as a valuable business strategy.² Studies have indicated that if a business's CSR activities are in alignment with a consumer's, the likelihood that consumers take those CSR activities into account while making a purchase increases.³ CSR has been defined as a "company's commitment to practice environmental and social sustainability and to be good stewards of the environment and the social landscapes in which they operate."⁴

Organizations such as the American Society for Engineering Education (ASEE), with input from academia and industry experts developed the Engineer for One Planet (EOP) framework for use in integrating sustainability into engineering education (Engineering for One Planet). As a business law faculty member at Bradley University, I was afforded the opportunity to participate in the ASEE's EOP Mini-Grant Program to develop Canvas (LMS) modules to supplement engineering education. The first section of this paper will discuss the injection of law into engineering education via the ASEE EOP framework. The next section will discuss the specific content of the Canvas modules, and the last section will discuss results and the next steps in scaling up the use of the modules.

Injection of a Legal Perspective

¹ Chatzopoulou, E., & Kiewiet, A. *Millennial's Evaluation of Corporate Social Responsibility: The Wants and Needs of the Largest and Most Ethical Generation, JOURNAL OF CONSUMER BEHAVIOR, 20*(3), 521–524 (2020). ² *Id.* at 524.

³ Id.

⁴ *Ethics Unwrapped*, MCCOMBS SCHOOL OF BUSINESS, https://ethicsunwrapped.utexas.edu/subject-area/sustainability-csr (last accessed Jan. 26, 2023).

While nearly every educator would most likely say that their courses and their topics are the most important in a given curriculum, the forward-thinking educator, not trapped in their academic silos, is likely to embrace an interdisciplinary mindset. This can be facilitated through an interdisciplinary degree program specifically designed to allow students to study in multiple disciplines (perhaps across colleges) and by faculty that run those interdisciplinary classes, as well as by conducting research with colleagues in different disciplines.

The National Science Foundation defines convergence as the "deep integration of knowledge, techniques, and expertise from multiple fields to form new and expanded frameworks for addressing scientific and societal challenges and opportunities." (National Science Foundation).⁵ Though not new, the idea of "convergence" in education has become central to how some universities seek to enhance the educational experience for students — so much so that Bradley University built the "Business and Engineering Convergence Center" academic building to house both the Foster College of Business and the Caterpillar College of Engineering under one roof to help facilitate convergence activities between the two colleges.

One of the many challenges related to the ASEE EOP Mini Grant Project as expressed by many in the first cohort as well as those facilitating the project, relates to getting so-called "buy-in" from other faculty members, to include deans and department chairs and administrators. The "silo effect" and its consequences has been well studied, but is still of concern even in an age of "convergence." Fortunately, faculty members and administrators at Bradley University see how differing academic perspectives can benefit students all across campus.

As one of three faculty members with a law background actively teaching in law (one faculty member with a law degree teaches in accounting), we are able to offer a unique perspective to a variety of disciplines. Students with an introduction to law, either through a mandatory legal environment type of course or through guest lectures or other one-off activities, could benefit from exposure to a legal perspective. Not only is this because of the very fact that learning about different perspectives is one of the foundational benefits of seeking higher education in the first place, but for a more pragmatic reason that engineers are not immune from legal liability resulting from negligence.

Canvas Modules

As mentioned above, the EOP Framework is made up of nine topic areas and because my academic discipline is business, I chose three of the topic areas with an orientation toward business. I used

⁵ Learn About Convergence, NATIONAL SCIENCE FOUNDATION, https://beta.nsf.gov/funding/learn/research-types/learn-about-convergence-research (last accessed Jan. 26, 2023).

the topic areas to form the basis for each Canvas module. Each topic area in the EOP framework contains numerous "core" and "advanced" learning outcomes. From there, I developed numerous learning objectives from each outcome. Then, I created learning materials that met each objective. These learning materials consisted of text, videos, assignments, and a variety of assessment types.

Figure 1

The Engineering for One Planet Framework



Note. Engineering for One Planet, n.d., (<u>https://engineeringforoneplanet.org/wp-content/uploads/eop_engineering-for-one-planet_framework.pdf</u>)

A. Environmental Literacy

For the first topic area of "environmental literacy," I chose two learning outcomes:

1) Demonstrates knowledge and basic facts and ability to quantify data about important (past/current/future and local/regional/global) environmental issues (e.g. climate

change, water use, scarcity and pollution, air quality, waste management, toxicity, etc.)."

2) Is aware of key environmental laws, ethics, and policies at the regional, national and global levels and ability to consider ethical implications beyond current compliance and political boundaries.

Within each outcome, I developed learning objectives that would meet each outcome from the EOP framework. In order to meet each objective, I developed a variety of learning materials, assignments and assessments. With Bloom's Taxonomy in mind, I developed the following objectives (in italics) and content for the first outcome⁶:

1(a) *Be able to locate legitimate sources of facts and data about environmental issues.* The learning materials for the first outcome include content about information literacy and evaluation. Information evaluation is a skill critical for engineers to develop as students when the stakes are much lower, as in a classroom setting. Evaluative frameworks are often helpful in providing guiding questions that will help with each state of the evaluation. RADAR (Relevance, Authority, Date, Appearance and Accuracy, and Reason) as well as CRAAP (Currency, Relevance, Authority, Accuracy, and Purpose) are two such frameworks.⁷ My university employs a librarian who specializes in information literacy. She was instrumental in helping me to find content that would be beneficial for engineering students. Other universities may have similar library resources.

1(b) Be able to identify and explain key environmental issues at global, national, and local levels. This objective is met by three assignments designed to give students the ability to put to use what they learned in the previous objective with respect to locating legitimate sources of facts and data about environmental issues. For the global level assignment, students were asked to complete a fill-in-the-blank assignment from a United Nations website detailing facts on the impact of plastics that are polluting our environment. For the national level assignment, students were asked to apply RADAR or CRAPP to evaluate two to three sources and summarize a national environmental issue they identified. For the local level, students needed to identify a specific example of a local environmental problem. They were not to choose something vague such as air or water pollution, but something specific, like perhaps a leaky faucet, a memorial balloon - release, lights left on, or a clogged storm water drain, which could all be appropriate choices. They were then given a generalized template for writing a letter or email to the particular person responsible for the identified problem. The students were able to decide whether or not they actually wanted to send the letter or email.

⁶ See A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives (2001), https://www.uky.edu/~rsand1/china2018/texts/Anderson-Krathwohl%20-

^{%20}A%20taxonomy%20for%20learning%20teaching%20and%20assessing.pdf.

⁷ See Evaluating Sources: The CRAAP Test, BENEDICTINE UNIVERSITY (Jan. 23, 2023),

https://researchguides.ben.edu/source-evaluation, and EVALUATING SOURCES: USING THE RADAR FRAMEWORK, LOYOLA MARYMOUNT UNIVERSITY (Aug. 16, 2022), https://libguides.lmu.edu/aboutRADAR.

For the second learning outcome, I developed the following learning objectives and content with respect to law and ethics:

2(a) Be able to understand the basic structure and role of government agencies (to include federal agencies, such as the EPA, FDA, and OSHA, as well as their state counterparts), legislatures (Congress and state), and courts (federal and state). The learning materials for this objective contain pages on basic American legal principles, sources and types of laws, administrative law, environmental law, and environmental statutes. Each page also contains videos I recorded providing short explanations of the law topics. In order to better understand the role of important environmental laws and regulations, the pages containing legal principles, sources, and administrative law provide context and the basic background that is not typically provided to engineering students.

2(b) *Be familiar with the NSPE Code of Ethics for Engineers (as well as others as applicable and understand how ethical codes are integrated into everyday life.* Links to the NSPE Code of Ethics for Engineers and the American Society of Civil Engineers Code of Ethics are provided.⁸ A discussion prompt is also provided for the professor to engage in conversation about ethics in engineering with students. The discussion prompt is: After reading the engineering ethics codes, what role do you think the codes should play in your professional career? Should there be legal ramifications for violating the codes? Should there be professional consequences for violations?

The learning materials also provide essentials to business ethics. While engineers are bound to follow their professional codes of ethics, engineers ultimately provide a service to businesses, as well as working for a business in the form of a firm or other type of business entity.

B. Social Responsibility

For the next topic area, "social responsibility," which is the second Canvas module, I chose learning outcomes that would provide students with a general background on how businesses are built and structured traditionally as well as alternatives to those traditional models. This section will discuss those materials.

- 1. Is familiar with alternative business, revenue and entrepreneurship models (e.g., B Corps, product service systems, sharing economy platforms, cooperatives, indigenous practices/ sensibilities, etc.).
- 2. Demonstrates high-level understanding that different business models can positively or negatively influence environmental and social systems as a result.

⁸ *NSPE Code of Ethics for Engineers*, NSPE, https://www.nspe.org/resources/ethics/code-ethics (last accessed Jan. 27, 2023), and *ASCE Code of Ethics*, ASCE, https://www.asce.org/career-growth/ethics/code-of-ethics (last accessed Jan. 27, 2023).

Learning materials on the nature of business, how business and economics work, traditional types of business models, business structures, and the corporate structure are provided to meet the learning objectives for each outcome. Many of the pages of text provided in each module are derived from several OER (Open Educational Resource) sources to include Business Law I Essentials, Introduction to Business, and Business Ethics. While these textbooks from OpenStax are open-source materials licensed under a Creative Commons Attribution license, they undergo a rigorous review process much like traditional textbooks.⁹ But the main benefit of using these OER materials is that they can be used as is, modified, or used in other ways with attribution.

C. Responsible Business and Economy

For the third and final topic area covered in the developed Canvas modules, I chose the following learning outcomes from the EOP framework:

- 1. Understand the role of social responsibility in the engineering profession (i.e., policies, laws, social justice, etc.).
- 2. Be familiar with the United Nations Sustainable Development Goals.
- 3. Is able to articulate and understands how engineering activities directly and indirectly cause positive and negative social/cultural impacts throughout the design life-cycle, both to workers producing the products (i.e., labor practices, livelihood, health, etc.) and to communities and society (i.e., resources acquisition, waste production and management, traditional/cultural methodologies, etc.), and is aware that some communities have historically been negatively impacted and/or minoritized.

For the first learning outcome, I provided learning materials that speak on how social responsibility is defined and how social responsibility is a win-win for business and consumers. For the second learning outcome, I provided learning materials on the United Nations Sustainable Development Goals. The 17 sustainable development goals form the heart of the 2030 Agenda for Sustainable Development, adopted by all United Nations member states in 2015.¹⁰ These goals are an urgent call to all countries to work together in developing policies that tackle the most pressing issues facing our world today. The goal of this module is to help engineering students to recognize that they play a vital part in creating solutions to these challenges.

⁹ OPENSTAX, https://openstax.org/subjects/business (last accessed Jan. 24, 2023).

¹⁰ The 17 UN Sustainable Development Goals are: 1) No Poverty, 2) Zero Hunger, 3) Good Health and Well-Being, 4) Quality Education, 5) Gender Equality, 6) Clean Water and Sanitation, 7) Affordable and Clean Energy, 8) Decent Work and Economic Growth, 9) Industry, Innovation and Infrastructure, 10) Reduced Inequalities, 11) Sustainable Cities and Communities, 12) Responsible Consumption and Production, 13) Climate Action, 14) Life Below Water, 15) Life on Land, 16) Peace, Justice and Strong Institutions, and 17) Partnerships for the Goals. *See Transforming Our World: The 2030 Agenda for Sustainable Development*, UNITED NATIONS, https://sdgs.un.org/2030agenda (last accessed Jan. 27, 2023).

This module and the third learning outcome, in particular, has important historical ties to the state of Illinois and served as an inspiration for my desire to take on this interesting and informative project. A primary learning material for this module is a video I created entitled *Radium Girls: Silent Death.* As a part of the "radium craze," in the 1920's in Ottawa, IL (as well in New Jersey and Connecticut) a group of women worked at a factory painting watch dials using radium paint. Many of the women were taught (though the companies would deny it) to lip, dip, paint, that is to put the brush in their mouths to sharpen the bristles, dip the brushs in the paint laced with radium, paint as many numbers on dials as they could before lipping the brushes again, starting the process over and over again. They would do this day in and day out. Years later the women developed mysterious illnesses to include loose teeth, lesions and ulcers, anemia, bone fractures, and necrosis of the jaw, later known as "radium jaw." Many of the women fighting for their lives, fought for justice and compensation for the medical bills well into the 1930s. Following the closure of the Radium Dial Company, the building became a storage for meat as well as a co-op space. The building was demolished in the 1960s and the radium laced rubble was spread throughout the Ottawa area.

In the 1980s the Environmental Protection Agency declared the 17 areas contaminated by radioactive materials a "superfund" site. As of 2022, 16 of the 17 sites have been cleaned up, with one remaining by a river.¹¹ The lasting, but often forgotten legacy, is that over 100 years later the impact of using radioactive material remains. A memorial for the Radium Girls was constructed in Ottawa in 2011 and the original factory site contains a Subway Restaurant. This example, I hope serves as a reminder to engineers and to us all about the importance of understanding the materials we use and how it impacts the future of the environment and the people who use the material.

Figure 3

Screenshot of YouTube Video Produced for Canvas Module



¹¹ Ottawa Radiation Areas, UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0500634 (last accessed, Jan. 27, 2023).

Note. Radium Girls: Silent Death, https://youtu.be/DqtjZBk4Ink

For this module overall, the discussion prompt includes learning materials about JEDI (Justice, Equity, Diversity, and Inclusion). As universities continue to highlight the importance of JEDI, the sometimes-uncomfortable discussions how prejudiced we can be towards one another play an important role in being able to move forward together to protect ourselves and the planet. The discussion prompt is: After looking at the definitions of JEDI (Justice, Equity, Diversity and Inclusion) in the resource linked above, what role do you think corporations, engineering firms, and governments play in ensuring the principles of JEDI are implemented as humans face unprecedented environmental, economic, and engineering challenges?

Results and Going Forward

Data from surveys sent to students who used the modules will be discussed in this section.

The next steps for this project include taking feedback from the surveys to improve the existing modules. The instructional design model, ADDIE means Analyze, Design, Develop, Implement, and Evaluate.¹² Given the feedback and more time to apply the principles of ADDIE and other online design principles I can improve the content, assignments, and assessments as well as develop new modules based upon other topic areas from the EOP framework.

As a part of the effort to scale up the use and impact of the modules, I will also continue to build relationships with faculty members who may be interested in learning about how the modules and EOP framework can positively impact the educational experience of their students.

- Great examples of injection of law into engineering education. It would be useful to include one or two examples of assignment templates and the assessment techniques or the rubric used to grade these assignments. This will be helpful to other educators who wish to adopt teaching sustainability in their courses.
- Please refer to the formatting guidelines, especially for references. Formatting inconsistencies in document possibly due to .docx submission. Please submit as pdf in the future. Draft papers should omit identifying institution information. The paper will be improved by including more details on the LMS modules. I

¹² ADDIE Model, UNIVERSITY OF WASHINGTON (last updated Feb. 25, 2019), https://www.uwb.edu/it/service-catalog/teaching-learning/hybrid-and-online-learning/instructional-design/addie.

encourage you include excerpts from the learning materials developed. Assignment snapshots, discussion questions, etc. can be included. One discussion prompt is provided in the footnotes - please move this to the body of the text.

• Your paper describes an interesting course and the details will be of interest to the attendees. I had hoped to learn about the results, but understand this is a work in progress.

Redesign of Purdue Construction Engineering and Management (CEM) Capstone Course

2

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5 INTRODUCTION

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4

In large part, the evaluation of construction engineering education has gone untouched 7 since its inception post-WWI (Abudayyeh et al., 2000). More specifically, the curriculum 8 and overall content for the construction engineering education within the Purdue 9 Construction Engineering and Management (CEM) curriculum has remained 10 fundamentally unchanged since its development in the late 1970s. There is a call to 11 reform construction engineering education for students' future development before they 12 enter the construction profession (Bernold, 2005). CEM will be positioned as a leader in 13 the reform because of the resources accessible to the CEM program: 14

- Academia Purdue is home to the first School of Engineering Education (Purdue University, 2022).
- Learners students who must complete 36 weeks of experiential learning as part
 of the degree requirement.
- Profession industry relationships established with an active Industry Advisory
 Board (IAB) and industry partners participating in the experiential learning process.
- 21

CEM is addressing the call for reform through several initiatives. The reform will initially focus on the CEM Capstone course redesign, which will be the benchmarking tool for future reform. The framework of this research utilizes three of the initiatives (1) the 2007 stakeholder analysis, (2) the April 2016 CEM Industry Advisory Board meeting, and (3) the Spring 2018 IMPACT program.

27

In May of 2007, CEM students developed the stakeholder analysis study of construction 28 engineering and management (CEM) at Purdue University. The CEM seniors noted in 29 their analysis that the curriculum of CEM is outdated and needs an overhaul. The analysis 30 discusses the desire of the students to see "more dynamic/comprehensive course 31 32 requirements that include all required skills necessary for the industry." The seniors specifically said that the CEM Capstone course (CEM 425) could be improved and that 33 they need to be "more applicable to current industry practices." Technology is an 34 important tool in the construction industry, especially in scheduling and estimating. While 35 it is essential to get the background and understand how to do things by hand, instruction 36 should include new and current methods because they will provide "better learning 37 opportunities." Structuring the instruction based on the stakeholder analysis's insight 38 39 would allow the students to prepare for the workforce.

40

In April of 2016, the CEM Industry Advisory Board (IAB) convened, and part of the agenda
 for the proceeding involved discussion regarding Engineering Education (ENE)
 recommended practices, specifically CAP and curricular priorities. The discussion

44 provided a significant amount of information that informed CEM of what the profession

- 45 was looking for relative to knowledge the CEM students should have upon graduation.
- 46

In the spring of 2018, the author enrolled in the IMPACT program to redesign the CEM Capstone course. The IMPACT program provided access to scholarly mentors, a community of practice, and a sequential guide to course redesign. These tools allowed the IMPACT Fellows (instructors and faculty) to unpack their course of choice for the redesign and test aspects within their community of practice alongside their cohort's assigned mentors.

53

54 Several limitations existed before the fall of 2019 for the CEM Capstone course. The CEM Capstone course was only offered in the fall semester and the contents covered in the 55 class did not emulate the current trends of the industry. The course did not cover two 56 phases: (1) pre-construction (e.g., business development and feasibility analysis) and (2) 57 post-construction (e.g., facility operation and maintenance). Furthermore, the curricula of 58 the CEM Capstone (CEM 425) did not reflect the skill sets and knowledge that the current 59 industry professionals think the students should gain upon graduation to apply to current 60 industry practices (Bernold, 2005; Hegazy et al., 2013; Schexnayder & Anderson, 2011). 61 Hence, there was a *need* to review and transform the CEM 425 course to better reflect 62 63 the students' and industry professionals' demands. This research aimed to propose and demonstrate a new CEM Capstone course(s) curriculum that can deliver topical content 64 to incubate industry-ready professionals. To achieve the objective, this study (1) 65 conducted a literature review about curricula priority and assessment, (2) mapped 66 learning outcomes of CEM lower-level courses, and (3) designed a preliminary structure 67 of the new two-semester long capstone courses. The anticipated contributions of this 68 69 study are:

- Academia expand the intersection of Engineering Education (ENE) and Construction Engineering Education (CEE) field.
- CEM courses execute the deployment of ENE and CEE recommended practices
 in a CEM course as part of a continuous improvement process to meet the need
 of the learner and the profession.
- Students execute the continuous improvement process on the CEM Capstone course to provide academic experiences that are student-centered and authentic.

7778 LITERATURE REVIEW

79

The literature review provides detail of the ENE recommended practices that the author used in the CEM Capstone course redesign. Each recommended practice blended to ground and inform the author so the course redesign would align with the call for reform.

83

Accreditation for Construction Education: Felder & Brent (2003) identified that engineering educational programs are required for accreditation to meet ABET Criteria relative to curriculum and instruction. Their paper outlined the challenge in doing this but was guided by subscribing to three principles: (1) planning, (2) instruction, and (3) assessment. Planning is merely defining the content and what objectives will be measured. Instruction is simply the pedagogy for which knowledge will be conveyed and

transferred to the student from the instructor, a variety of methods can be applied depending upon the content transfer. Still, ultimately instructors should strive for a deep and authentic learning opportunity. Assessment is an instrument of measurement which comes in many forms, either individually or as a group. Their work is very similar to the Content, Assessment, and Pedagogy (CAP) framework that is used to guide the course redesign (Streveler, 2014). Felder & Brent also stated that if instructors prepare in this manner with awareness and application of the ABET criteria, the challenge is obtainable.

Curricular Priority: Wiggins & McTighe (1998) was one of the more influential literature in 98 99 this research. The introduction of the curricular priorities concept has catapulted this research into course curriculum design and overall construction engineering curriculum 100 redesign. The curricular priorities concept links the backwards design concept previously 101 discussed by providing a support tool and method for structure development. Curricular 102 priorities are defined by the following categories: (1) Enduring understanding, (2) 103 Important to know and do, and (3) Worth being familiar with. Their research expanded 104 upon the illustration of the curricular priorities and links those with assessment tools, an 105 106 essential bridge for instructors to guide learners' knowledge development.

107

108 <u>Student-centered Pedagogy</u>: Chi (2009) documented and explored the philosophy of 109 constructivism (discovery learning), an overt learning activity. The instructor provides the 110 learner with an environment in which the students are inquisitive such that the learner 111 constructs "the rules and relationships." Discovery learning deploys a variety of methods 112 to pursue learning objectives. Methods include but are not limited to concept mapping, 113 taking notes, self-explaining, comparing and contrasting cases, generating predictions, 114 and reflection.

115

Case-based and collaborative learning: The philosophy of community of practice can be 116 intertwined with the collaborative learning discussion provided. Before this research, a 117 generic description was applied to the approach to learning by the researcher that was 118 more likely a characterization-based nomenclature rather than a sophisticated 119 articulation; the author should concede that collaborative learning is: "a situation in which 120 two or more people learn to attempt to learning something together." This is an important 121 distinction because, too many times in team-based (collaborative learning), one member 122 will work in a silo on a topic while yet other members do the same on other topics 123 individually. Dillenbourg (1999) assisted in defining approaches, techniques, and 124 language to describe collaborative learning, which brings guided structure to the concept-125 network development. Fulk et al. (2019) implemented case-based and collaborative 126 learning to CEM sophomores and high school seniors. 127

128

Project-based learning (PBL): Hmelo-Silver (2004) discussed the definition of the PBL approach; the "teacher acts to facilitate the learning process rather than to provide knowledge." The goals of PBL are intended to assist students in developing: (1) Flexible knowledge, (2) Effective problem-solving skills, (3) SDL (self-directed learning), (4) Effective collaboration skills, and (5) Intrinsic motivation. In addition, Hmelo-Silver "discusses the nature of learning in PBL and examines the empirical evidence supporting it." Hmelo-Silver indicated there is a significant gap in the research on PBL because it has

mainly been conducted on high-achieving students in gifted programs and/or medical
programs; therefore, Hmelo-Silver claimed there is little knowledge on how this impacts
learners with less aptitude than those generally found in the gifted education programs
as well as those in medical education. "The evidence suggests that PBL is an instructional
approach that offers the potential to help students develop flexible understanding and
lifelong learning skills" (Hmelo-Silver, 2004).

142

This current state of published engineering education (ENE) and construction engineering 143 and management (CEM) realized that there was an intersection of these fields that would 144 allow one to inform and the other to be grounded. This exercise would bring more 145 146 awareness to the intersection; the contributions of this study would be (1) academic – other CEM-related departments throughout the country to evaluate their curriculum, (2) 147 learner - CEM students are expected to have experience-centered and authentic learning 148 environments, and (3) professional - would employ prepared individuals and allow them 149 to support the continuous improvement of academia and learner experience. 150

151

152 **PROPOSED PURDUE CEM CAPSTONE**

153

154 Determination of the Project Life Cycle and Topics of the Capstone Course

155 From the literature reviews and reviews of peer institutions' CEM Capstone curriculum, the study sees many benefits for students if the capstone course replicates the 156 construction life cycle over two semesters (approximately 32 weeks of academic calendar 157 at Purdue). To replicate concepts of construction project life cycle in CEM Capstone 158 courses, this study classifies a construction life cycle into six phases which are (1) 159 administrative business development and feasibility phase, (2) conceptual design phase, 160 (3) design development phase, (4) final design and pre-construction phase, (5) project 161 execution (or construction) phase, and (6) operation and maintenance phase. The first 162 three phases are covered during the fall semester (first semester), and the other three 163 are addressed during the spring semester (second semester). The four weeks of the first 164 semester will be dedicated to the topics and discussions relating to the administrative 165 development feasibility phase. Both the conceptual design phase and the design 166 development phase have six weeks of the timeline. During the second semester, the final 167 168 design phase, construction phase, and O&M phase will have four weeks, ten weeks, and two weeks of the academic calendar, respectively. The schedule can be modified 169 according to the enrollment of the CEM capstone course and the selected project types. 170 171

172 This study considered the students' two potential career roles (i.e., a contractor and a consultant) to decide what topics and contents needed to be discussed during the two 173 174 semesters. The career paths are becoming contractors who will perform primarily on job sites and consultants (or owner representatives) who will support construction projects 175 remotely. The proposed CEM Capstone delivers these topics and contents at appropriate 176 177 times throughout the two semesters. This study identified six essential topics to be covered during the capstone courses - this can be defined as key learning outcomes 178 (KLO): (1) communication-related topics, (2) engineering economics-related topics, (3) 179 180 engineering ethics-related topics, (4) legal aspects, (5) safety aspects, (6) design-related topics. The following subsection describes how this study determined and prioritized KLO. 181

Figure 1 shows the proposed CEM template replicating six construction project life cycle phases embedded into the two-semester concept for the CEM Capstone course. CEM Capstone instructors can utilize this template to develop detailed capstone course plans.

189 <u>Determination and prioritization of learning</u>

190 <u>outcomes</u>
191 The instruction developed with this capstone
192 transformation will key in on the motivated
193 undergraduate student entering their specific

188

212

professional field upon completing the Bachelor of 194 Science in Construction Engineering. The students 195 can and will enter entry-level positions with various 196 titles. However, as reflected in CEM senior exit 197 198 surveys, most will join on a tract that will steer them into a management or field operations career. How 199 entry-level construction 200 does engineering 201 professional distinguish themselves from their peers? CEM structure aids in this effort with the 202 engineering curriculum. With this study, the author 203 will build upon the construction engineering 204 curriculum and develop an example for future 205 improvements aimed at developing elite builders. 206 The vision is that the elite builders (or master 207 builders) will be prepared in the classroom. The 208 elite builder will encompass the skill sets that 209 embody the management and field operations tract 210 throughout the construction project life cycle. 211

The CEM Capstone course redesign takes the first 213 214 step in preparing learners for the profession. The CEM Industry Advisory Board and the faculty 215 worked to prioritize curricula for the construction 216 engineering program at Purdue, which guided the 217 course redesign during the April 2016 biannual 218 meeting. The IAB consists of more than 20 industry 219 220 representatives that hold positions as owners, executives, or project managers. The IAB members 221 are all Purdue graduates and nearly all CEM 222 223 graduates. The IAB worked in groups, utilized discussion sessions, and documented their output 224 on "white sheets." The output from the educational 225 226 exercise developed a list that quantified and formulated the curricular priorities. The list (Figure 227



Figure 1 The Proposed CEM Template that Replicated Six Construction Project Life Cycle Phases Fitted into Two Academic Semesters (Equivalent to 32 Weeks)

- 228 2 and 3) provides a tabulation of the results, which summarizes the proposed instructional
 229 outcomes and goals, detailed in this section's remaining portions.
- The enduring understanding is the development of work plans to complete day-to-230 day operations for a project that will be integrated into a comprehensive schedule 231 to complete a project safely and economically. In developing the master builder, 232 the ability to cultivate the knowledge base is found to be a work plan that is tangible 233 and deliverable. Some components are similar regardless of the type of 234 construction: schedule, material, labor, and equipment but depending upon the 235 type of construction, the analysis and selections will differ. The enduring 236 understanding of this study is intended to be the catalyst for the development of 237 the new-aged master builder. 238
- What is Important to Know and Do focuses on the assessable components (or subarea) of the enduring understanding, which should allow the instructor to deduce that the learner is accumulating skills. The skills will be developed via sessions and enriched in modules to promote mastery of the enduring understanding using the community of practice theory as the foundation of learning with ideas and learning practices implemented. The session and module concept will be discussed further in this project.
- Various knowledge and topics fall into the "worth being familiar with" category relative to construction engineering. Knowledge worth being familiar with will be used to analyze work and develop work plans. In most cases, the knowledge will consist of material that the student will be responsible for learning outside the classroom in preparation for application in the classroom.

Enduring Understanding	Important to Know	 Industry software basics
- FE/EIT Passed	- Computer Skills	 Communication – oral, written, saf
 Professional, Ready to go 	- Schedule	 Cost Control
 Safety Conscious & Assertive 	- Formwork	 MEP Awareness
 Leadership Skills – Craft Relatable 	- BIM/VDC/Autocad	- Codes/Standards
 Continually improvement focused 	 Unions/Labor Relations 	 Workforce Training
- Problem solver	 Workforce training 	 Sub-contractor situations
- Adaptable	- Equipment usage	 What's next in industry?
- Self-Starter	- Estimating	- Engineering class
 Good communicator 	- Soft skills (teamwork &	- Legal/Contracts
- OSHA Certification	communication	- Budgeting
 Project Planning 	 Spec/Plan Reading 	- Finance
- Budgeting/Cost control	- BIM/Facility Management	- Bracing Design
- Scheduling	- Conflict Resolution	- Cash Flow
- Teamwork	 Stress Management 	 Concrete Construction
 Time management 	- Bidding	 Construction Claims
 Comprehensive problem analysis 	- Scheduling	- Design Process
 Passion for Construction Industry 	- Cost Accounting	- Dewatering
- Integrity	- Problem Solving	- Earthwork
- Personality	- Temp Design	 Equipment costs & Accounting
- Desire to Build	- Safety	- Sitework
 Strong Technical Understanding (pass 	- Document Control	- GIS
FE)	- Leadership/TEAM	- Masonry Construction
 Company & Peer feedback 	- P6	- Leadership
- Always open to learn/curious	 Industry Software 	 Materials performance under load
 Basic Technology/excel/PM software 	- Modeling	- Operational Costs
- Budget/Project Controls	- Team Dynamic	 Project Controls
- Service to Customer	 Construction Vocabulary 	- Quality Concepts
- Critical Thinking	 Excel Spreadsheet 	- Resource Management
- People Skills	- Productivity	- Sheeting Design
	- Basic Terminology	- Shoring Design
	- Excel	- Steel structures
	- Communication Skills	- Unions

Figure 2 Identified Topics of Curricular Priorities ("Enduring Understanding" and "Important to Know") for the Proposed Capstone Course by IAB Members in 2016

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		-	Specific Trades	-	Worker Motivation
Worth	Being Familiar With	-	Design Details	-	Network Diagrams
-	Hydraulics	-	Labor agreements	-	Numerical Methods
-	HR	-	Basic Eng Classes	-	Organization Types
-	Bonds/Liens/RM	-	Site planning/Logistics	-	Professional Liability
-	Facilities Management	-	Contractors obligations	-	Proposal Developme
-	Electrical	-	Cost Reports	-	Schematic Design
-	Insurance	-	Productivity Analysis	-	Strategic Planning
-	Business Plans	-	Claims	-	Timer Construction
-	Technical Writing	-	Misc. Design Related Topics	-	Torts
-	Design Process	-	Insurance Issues	-	Underpinning
-	Labor Relations	-	Earthwork	-	Wind Loads
-	BIM	-	Concrete		
-	Contract Types	-	HVAC		
-	Project Life Cycle	-	Piping		
-	Project Planning	-	Masonry		
-	Safety	-	Codes		
-	Quality Processes	-	Business Writing		
-	Lean Processes	-	Computer Graphics (Technology)		
-	Risk Management	-	Bonds		
-	Temp Str.	-	Bridge Construction		
-	Marketing	-	Business Plans		
-	Estimating	-	Capital Project Analysis		
-	Legal Aspects	-	Career Development		
-	Design (firms, scaffolds, etc)	-	Cofferdams		
-	Project Structure (IPD/Design-Build)	-	Data Analysis & Metrics		
-	Negotiations	-	Database		
-	Finance	-	Facility Management		
-	Accounting	-	Infrastructure Data Mngmt		
-	Bidding	-	Information Modeling		
-	Thermo Equipment	-	Intellectual Property		
-	Arbitration Litigation	-	Mediadtion		
-	Labor Negotiations/Union	-	Monte Carlo Simulation		

256 257

Figure 3 Identified Topics of Curricular Priorities ("Worth Being Familiar With") for the Proposed Capstone 258 Course by IAB Members in 2016

259 Mapping of identified topics and prioritized learning outcomes in CEM

This study investigated where the identified topics are being covered in the low-level 260 courses in CEM at Purdue. The investigation includes the seven CEM courses the 261 students would take before the capstone course. These courses are CEM 201 - Life 262 Cycle Engineering and Management of Constructed Facilities; CEM 280 – Construction 263 Engineering Professional Development I; CEM 301 – Project Control and Life Cycle 264 Execution of Constructed Facilities; CEM 324 - Human Resource Management in 265 Construction, CEM 380; Construction Engineering Professional Development II; CEM 266 455 - Temporary Structures in Construction; and CEM 485 - Legal Aspects of 267 Construction Engineering (the students can take CEM 324, 455, and 485 concurrently). 268 Depending on the course setting, the students will have different opportunities (e.g., 269 traditional lectures, labs, homework, term projects, and/or presentations) to learn these 270 topics in the courses. Hence, this study had individual meetings with the instructors of 271 these courses to survey when and how the identified topics of curricular priorities are 272 discussed in each course. 273

274

For instance, during the 16 weeks of the course CEM 201, the students will learn various 275 topics to the instructor's structure and schedule. After an interview with the instructor of 276 the CEM 201, this study identified that the topic of "budgeting and cost control," which is 277 one of the "enduring understanding" topics, is being covered in the lecture materials in 278 week 8 (lecture topic: construction scheduling and life cycle cost analysis), week 9 279 (lecture topic: project cash flow and project funding) and week 11 (lecture topic: 280

equipment ownership). Similarly, the topic of "equipment usage" of "enduring understanding" is being taught in the lecture materials in week 11 (equipment ownership), week 12 (equipment productivity I), and week 13 (equipment productivity II). The overall course mapping for the topics is shown in Figure 4.

285

At the end of this mapping process, this study counted how many times each topic had 286 been covered throughout the degree program. For example, the topic of "project 287 measurement" has been discussed 14 times (six lectures, six homework, and two 288 projects) in the seven courses. This study, finally, was able to identify what topics are 289 never discussed in CEM courses. The topics that were never discussed are: (1) service 290 to customer, (2) GIS, (3) next in industry, (4) quality concepts, (5) insurance, (6) 291 intellectual property, (7) marketing, (8) schematic design, (9) torts, and these are shown 292 in the second page of Figure 5. 293

294

295 CONCLUSION

296

297 This study proposed a new CEM Capstone course. This course was developed based on industry feedback and inputs of curricular priorities, leading to increased student 298 satisfaction and buy-in on the work. This course provides authentic projects with 299 300 stakeholders mimicking real-world situations (32 weeks of project life cycle) for the students. Some of the challenges that the instructor observes during the first 301 implementation are (1) the success of the project is dependent upon stakeholder 302 engagement and available information, (2) the instructor will encounter more challenges 303 if there are various project types and more available projects for the students, (3) the 304 instructor should cooperate with multiple stakeholders to develop projects and to secure 305 306 space in which the student can work in for the execution phase, and (4) the students had to deal with team members' graduation and transition between two semesters. These 307 challenges will impact the overall students' performance and the success of the projects. 308

			-	CEM .	CE	A 201:	Lectu	re Topi	s and S	chedul	e (from	recent r	vllabus				_	CEM .	CEM	280:Le	cture To	pics and	Schedu	le (from	recent	syllabus)	2					_	CEM	1 301: Le	ecture T	opics and	Schedu	le (from	recent s	(llabus)					CEM 32	CEM 324	E Lecture	Topics	and Sched	le (from	recent syl	labus)		_	-
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Figure 4 Mapping the Identified Topics of Curricular Priorities in Lower Level CEM Course

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Figure 5 Mapping the Identified Topics of Curricular Priorities in Lower Level CEM Course (continued)

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Work-In-Progress: Can We Create a Model Program: Insights into the Effectiveness of a Research Experience for Undergraduates

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Abstract

This study expands on our prior work of the Research Experience for Undergraduates (REU) SITE program to provide data on participant preparation for success in graduate school and their perceptions of the program. In the first two studies from our initial cohort, we summarized that we effectively provided an independent research experience, increased participants perception of preparedness for success in the graduate application process and graduate school and increased their ability to communicate about Biomechanics and Mechanobiology (BMMB)¹. In the follow up study we showed that by the end of the program students believed they were better prepared for success in graduate school, two students co-authored publications from their projects, and the majority were enrolled in a graduate program². Here we share data across our first two cohorts which expands our outcomes associated with graduate school preparation and student perceptions of the REU SITE program. We used our site-licensed online survey tool Qualtrics to administer the surveys for data collection. We used the same pre- and post-survey data to assess changes for both ten student cohorts over the 10-week period. The data were analyzed using a paired t-test from GraphPad Prism 9.3.0 software. This study confirmed the findings from the first two studies while highlighting new information. The new analysis conducted across both cohorts showed participation in the program influenced student interest in applying to graduate school p < 0.05. Additionally, the data show that participants felt more prepared to conduct independent research after participating p < 0.05. Of the twenty participants the twelve students who have graduated or will be graduating before summer 2023 are enrolled in a graduate program or have applied for admission. Six of those yet to graduate reported they plan to pursue a graduate degree after completing their BS degree. Additionally, students felt the program prepared them to find and read research articles p < 0.01 and participate at a conference p < 0.05, skills that will be beneficial for success in a graduate program. Ninety-five percent of the participants indicated the REU SITE met or exceeded their expectations and would recommend the program to others. Similarly, 95% were satisfied with the mentorship of their graduate ambassador and 100% indicated they were satisfied with the mentorship of their faculty. Additionally, we were excited to find that after an adjustment to our program after the first cohort, the second cohort felt prepared to contribute to the field of BMMB p<0.05. This was an objective of the program that was not achieved with the first cohort. Lastly, 85% of participants were from underrepresented minority (URM) backgrounds and 70% were female. Thus, the enrollment of our participants in graduate programs continues to enhance diversity in engineering and the field of BMMB. Going forward we will continue to track the progress of participants and the careers they choose after completion of their graduate degrees. We will also continue to use student feedback to improve the experience for participants.

Introduction

A fundamental value of a REU is the research experience students acquire. By participating students gain the experience many STEM graduate programs seek in their applicants. But the research experience alone is insufficient for admission. Additional professional development could be beneficial in helping students garner success in the admissions process. We set out to enhance the research experience and increase a student's likelihood of success with gaining admission and successfully completing a graduate degree by incorporating targeted professional development.

Our REU SITE has had three main objectives, to increase the number of traditionally underrepresented students pursing a graduate degree and prepare them for success in the application process and graduate school, provide hands-on scientific research experience in BMMB, and develop the participants ability to comprehend, contribute, and communicate advances in BMMB. From our first study we learned that by the end of the 10-week program participants were conducting independent research, felt prepared for success in the application process and graduate school and believed they were better able to communicate about the field of BMMB¹. Additionally, all participants from the first cohort were from underrepresented minority backgrounds, 80% of them are now pursing graduate degrees¹.

In the absence of a REU SITE program in years two and three because of the pandemic we analyzed additional data from cohort one to better understand the effectiveness of the program. We found that students felt better positioned for success in graduate school after participating because of the professional development they received². Specifically, students believed they were better able to prepare and give research presentations, write an abstract and design posters and that their knowledge of applications of BMMB work had increased². Providing students with the requisite skills to be successful after they enroll in a graduate program is essential. According to the Council of Graduate Schools (CGS) PhD Completion Project from 2008, only 57% of PhD students actually complete their degree within ten years³. Unfortunately, students from underrepresented minority backgrounds complete PhD programs at an even lower rate. The 2008 CGS PhD Completion and Attrition study reported 36% of African American/Black and 40% of Hispanic/Latino students completed PhD programs in life science, engineering, and physical and mathematical sciences in seven years⁴. To accomplish our aim of increasing the number of URM students pursuing a graduate degree and preparing them for success in the application process and graduate school, it is imperative to begin to cultivate the skills they will need as they progress through their programs. This will include providing intentional professional development and active mentorship. To ensure our participants were entering an inclusive environment and positioned to receive support and effective mentorship, all faculty mentors completed our 8-hour mentor training workshop. This training was designed to prepare faculty to be more effective at creating inclusive environments and support student/trainee research development. Here we used the data from the first two cohorts to assess additional skills students believed they obtained that would support their success in graduate school and their perceptions of our program over two years. We also investigated whether our program influenced participants to pursue a graduate degree. Based on what we have learned we hope to create a model to facilitate success for others seeking to develop a REU.

Materials and Methods

In preparation for the program all faculty mentors completed mentor training. It was offered within our college or university and was designed to prepare faculty to be more effective at creating inclusive environments and supporting mentee development personally, professionally, and academically, so they become independent researchers. The training is based on the curriculum developed by The Center for the Improvement of Mentored Experiences in Research (CIMER) and facilitated by the REU SITE PI, co-PI, and other trainers within our college and across the university. During both summers we hosted the program we engaged ten students in each of the two cohorts for a 10-week research immersion. Each participant was matched with a faculty mentor based on their research interest. Only one participant was paired with each mentor. Participants were also assigned a graduate ambassador from their faculty mentors research group. Throughout the ten-week program participants engaged in research and professional development activities. The program was structured to expose students to the graduate student experience, how to prepare for success in graduate school, and career opportunities beyond the advanced degree. They all participated in a series of professional development activities. Some activities were integrated into their research activities and others were conducted separately. Structured and unstructured interactions with their mentors, lab members and workshops provided an opportunity for participants to learn how to identify and understand research articles, conduct independent research, prepare for conferences, and ultimately success in graduate school.

Questions
1. Please rate the extent of your interest in applying to graduate school?
2. Please rate the degree to which you feel prepared to conduct independent research?
3. Please rate the degree to which you feel prepared to find research articles?
4. Please rate the degree to which you feel prepared to read research articles?
5. Please rate the degree to which you feel prepared to participate at a conference?
6. Please rate the degree to which the REU SITE program met your expectations?
7. Would you recommend this REU SITE program to others?
8. Please rate the degree to which your graduate ambassador met your expectations?
9. Please rate the degree to which your faculty mentor met your expectations?
10. Please rate the degree to which you feel prepared to contribute to the field of BMMB?
Table 1. Shows an excerpt of the pre- and post- survey questions asked of participants.

Nineteen of the twenty students completed the pre- and post-surveys: nine in cohort one and ten in cohort two. To maintain data integrity, we only used the data from those who responded to both surveys. Since the names were not collected, we mapped the pre-and post-survey data based on the demographic and identifying questions asked in each survey. Table 1 shows the survey questions asked to assess knowledge of and comfort with research, research related activities, the ability to contribute to BMMB and student perceptions of the REU SITE program.

Nineteen students completed the pre- and post- survey. Question 1 asked participants the extent of their interest in applying to graduate school on a scale of 1 (Not at all) to 5 (High). In questions 2-5 and 10 participants were asked to rate how prepared they currently felt with doing each of the following on a scale of 1 (Not at all) to 5 (High). For questions 6-9 participants were asked to rate their perception of each item or provide a recommendation. The data was analyzed using GraphPad Prism 9.3.0 software using a parametric paired t-test.

Results

We provided the participants a ten-week research immersion with professional development opportunities embedded as well as separate sessions. The sum of these opportunities provided students insight into the graduate student experience and how to prepare for success in obtaining an advanced degree. We assessed the extent of their skill development after they engaged in research and conversations with their mentors and lab mates, journal clubs and discussions with faculty, ambassadors, and their peers, and professional development seminars. We also assessed participant satisfaction with the mentorship from the faculty and graduate ambassadors and the program overall. Because of our small sample size of 19 and normal distribution and homogeneous variation of the data we used a parametric t-test to conduct our analysis. The data from questions 1 and 2 on Table 2 indicated participation in the program influenced student interest in applying to graduate school p < 0.05 and students felt more prepared to conduct independent research after participating p<0.05. The data from questions 3 and 4 on Table 2 indicated that by the end of the program participants felt better prepared to find and read research articles p<0.01. The data from question 5 on Table 2 indicated that students felt better prepared to participate at a conference p < 0.05. The first cohort of this REU did not feel as though they were prepared to contribute to the field of BMMB. On the contrary, 71% the faculty mentors from the first cohort indicated their mentee produced data that could be included in a future publication¹. Therefore, we sought to understand whether the 2nd cohort perceived they could contribute to the field of BMMB. The data from question 6 on Table 2 indicated participants from the second cohort felt prepared to contribute to the field of BMMB p<0.05 despite the absence of this perception by cohort 1¹. This was the only one of our proposal objectives for which there was a lack of concurrence between the two cohorts. Data for this question was analyzed for cohort one and published in the 2021 ASEE Illinois-Indiana regional conference proceedings.

	BUC	KEYE RE ASSES	U OUTCC FMENT	OMES			
	Р	re	Po	ost	Mean	Sig	
	Mean	S.D.	Mean	S.D.	Diff.	Diff. ²	Ν
Question 1	3.38	1.12	4.12	0.56	0.74	p<0.05	19
Question 2	3.19	1.35	4.45	0.53	1.26	p<0.05	19
Question 3	3.37	1.11	4.11	0.52	0.74	p<0.01	19
Question 4	3.58	1.34	4.3	0.93	0.72	p<0.01	19
Question 5	2.41	1.14	3.88	0.62	1.47	p<0.05	19
Question 6	3.22	1.21	4.64	0.51	1.42	p<0.05	10*

Table 2. The data analyzed from the pre- and post- surveys, from Table 1, administered to participants. Sig Diff = significant difference. *Only data for the 10 students from cohort two were analyzed.

In addition to skill development, participants also had positive views of the program with 95% of them indicating the REU SITE met or exceeded expectations, and they would recommend the program to others (Figures 1 and 2). Similarly, 95% of participants were satisfied with the mentorship they received from their graduate ambassador and 100% indicated they were satisfied with faculty mentorship (Figures 3 and 4). We have also had success with recruiting students



Figure 1. Shows participants perception of our REU SITE program.



Figure 2. Shows whether participants are likely to recommend our REU SITE program to other students.

from underrepresented backgrounds in STEM. Eighty-five percent of participants were URM's and 70% were females. So far, 92% of those participants who are now in graduate school or have applied are URM and 75% are female.



Figure 3. Shows participant satisfaction with graduate ambassador mentorship.

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Figure 4. Shows participant satisfaction with faculty mentorship.

Conclusion

In summary, we have been able to influence our participants decision to pursue a graduate degree. The combination of research immersion and structured and unstructured professional development has helped our eligible students garner admission to graduate programs. We have continued to make progress on increasing the representation of underrepresented minorities and women in BMMB. Since participants felt better prepared to conduct activities necessary for success in graduate school, we believe they are better positioned for success. It is our hope that they will complete their graduate degrees at a higher rate than currently observed. Moreover, we have been successful in meeting or exceeding the expectations the participants have had regarding the faculty mentors and graduate ambassadors. Strong mentorship is a fundamental necessity for fostering research success and development. We believe we have the foundation for a model REU SITE program and look forward to sharing our best practices with others.

Future work

We recognize the number of students in each cohort is small and aim to strengthen the statistical validity as more cohorts complete the program. We will continue to track student decisions related to pursuing a graduate degree. We will also continue to track their progress and completion of their graduate degrees. As our program continues, we will constantly improve based on feedback from our participants. Though we have provided graduate ambassador training in the past, we aim to provide formalized mentor training to our ambassadors going forward.

This research is supported by the National Science Foundation grant number 1852298.

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Paper Session 5: Labs and Experiential Learning

Location: Engineering Building 1033

Session Chair: Ralph Tayeh

12:45 – 1:00pm	The Development of Low-Cost
	Programmable Logic Controller Labs for a
	Control Systems Course
	Benjamin D. McPheron, Devin J. Goodrich
	Michael Q. Mullinix (Anderson University)
1:00 – 1:15pm	A Hands-on Activity on Human-Powered
	Lights For a Lab Experiment and In-Class
	Demonstration
	Purno Ghosh, Frances Harackiewicz, Omer
	Elsanusi (Southern Illinois University
	Carbondale)
1:15 – 1:30pm	Work in Progress: Work in Progress: A
	Simple Plug-in Implementation of Extreme
	Audio Stretching
	Ethan Laptew, Yufeng Lu (Bradley
	University)

The Development of Low-Cost Programmable Logic Controller Labs for a Control Systems Course

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Abstract

Many engineering disciplines require an undergraduate course in control systems, but few introduce students to programmable logic controllers (PLCs), which are commonly used to implement real-time process control in industry. Curricular exposure to PLC systems is desirable for many internship and full-time career opportunities for students studying Mechanical, Electrical or Mechatronics Engineering. Unfortunately, outfitting a laboratory with PLC systems for a few lab experiences is resource intensive and thus infeasible for many smaller engineering programs. In the area of industrial control, a single training station may cost upwards of \$8000 or more. This motivates the development of low-cost laboratory experiences for teaching industrial control topics.

This paper details the development of lab apparatuses and lab documentation for several low-cost PLC labs for an undergraduate control systems course. To assess the efficacy of these labs, pre- and post- quizzes were used. In addition, students were surveyed to self-assess their understanding of and comfort with industrial control concepts. Initial results suggest that these labs effectively introduced students to PLCs, ladder logic, and pneumatic systems.

Introduction

Laboratory experiences are an essential part of engineering education, allowing students to gain concrete understanding of engineering concepts through experimentation on physical systems, augmented by simulation, test, and measurement hardware and software [1,2]. However, it can be challenging to fit many laboratory-specific courses into an engineering curriculum at a liberal-arts focused institution; leading faculty to adopt a mixture of in-class, virtual, take-home, or homework-style lab experiences [3]. One area where these experiences can be particularly useful is in control systems education, as students may struggle to bridge the gap between the mathematics and control algorithms and the implementation of real-world control applications [4]. In many industrial settings, Programmable Logic Controllers are used to implement real-time process control and automation, and make excellent educational tools for control systems labs [5,6,7]. Unfortunately, many PLC demonstrator platforms are expensive, costing upwards of \$8000, excluding the purchase of a PLC, which may be cost-prohibitive for many small liberal arts focused institutions [8]. These factors motivate the development of low-cost laboratory experiences for engineering education.

There has been extensive research on the development of low-cost alternatives to options provided by educational supply companies [9,10,11,12]. The development of low-cost laboratory experiences can be accomplished in several ways: by modifying toys [9], modifying inexpensive

systems for alternative uses [10], or by building new systems from scratch [11]. Taking the third path, the goal of this work is to present two new lab experiences for teaching PLC concepts to engineering students with bespoke demonstrator hardware. Specifically, a pneumatic system finite state machine was constructed using wood, PVC piping, valves and cylinders to translate a golf ball through a system in a continuous loop.

These lab experiences were designed with particular learning outcomes in mind. By the completion of the lab experiences, students should:

- 1. Gain familiarity with and experience with Programmable Logic Controllers
- 2. Program a PLC using ladder logic for real-time control
- 3. Become familiar with pneumatic systems

Direct and indirect assessment methods were used to assess the effectiveness of these lab experiences in student achievement of the learning outcomes.

This paper presents some detail on the design and development of the laboratory experiences, as well the assessment strategy and results from the pilot offering of these exercises.

Development of Laboratory Experiences

As stated in the Introduction, the primary goals of the laboratory experiences presented in this work were to familiarize students with a PLC platform, ladder logic programming, and interaction with physical systems controlled by a PLC. Two labs were designed, one that provided a ladder logic programming tutorial followed by programming exercises, and a second which had students develop a program from scratch to control a pneumatic finite state machine.

The CLICK Plus PLC from Automation Direct was chosen as the primary hardware platform for this study as it is widely available and relatively inexpensive. The PLC system, shown in Figure 1 cost approximately \$400 and possessed more than enough computational resources and input/output modules for the purpose of this work. A full Bill of Materials is available in the Appendix of this paper.

Most PLC systems come with their own proprietary ladder-logic programming software. Figure 2 shows a screenshot of the CLICK programming software used as a part of the tutorial lab. In the tutorial, students learned how to implement basic logic operations and gained exposure to PLC timers. Then, they were given three exercises to complete, shown in Figure 3, which required them to use the digital outputs on the PLC hardware.



Figure 1: CLICK Plus PLC used in these lab experiences



Figure 2: Example of CLICK PLC Programming Software

North-South see (1 second) flashing red East-West see (1 second) flashing yellow North-South see (1 second) flashing yellow East-West see (1 second) flashing red Standard cycle through lights every 12 seconds (Red - 6 seconds, green - 4 seconds, yellow - 2 seconds)



For the second lab experience, students used relay outputs on the PLC to control pneumatic solenoid valves. The valves were connected to a continuous loop finite state machine which passes a golf ball through a repeating circuit. The finite state machine is shown in Figure 4. In this lab students added wiring to the PLC system and used ladder logic programming knowledge to translate the golf ball using process control techniques.

In addition to lab handouts, students were provided with lecture material on ladder logic programming, PLC timers and counters, and pneumatic systems prior to Lab 1. Since these resources were provided before the lab experiences, it was possible to measure the change in student achievement of the Lab Learning Outcomes that resulted specifically from completion of the lab exercises.



Figure 4: Pneumatic Finite State machine

Assessment Strategies

As a method of direct assessment for the lab experiences, students were given a pre-quiz before the first PLC laboratory and then the same quiz with randomized question order and randomized answer order after each PLC lab as a post-quiz. Students were not allowed to see what they had gotten incorrect on any of their previous attempts. An example of this quiz is shown in the appendix of this paper.

To indirectly assess the effectiveness of the lab exercises in helping students achieve the learning outcomes, students were asked to rate their self-efficacy in an anonymous 7 prompt Likert scale survey. The survey was on a scale of 1 (strongly disagree) to 5 (strongly agree). Specific prompts are listed in the survey results section.

Results and Discussion

Pre- and Post-Quiz Results

Online pre- and post-quizzes were utilized to measure student achievement of lab learning outcomes. Figure 5 shows the average results by quiz number, with Quiz 1 being the pre-quiz before the PLC laboratory experiences, Quiz 2 being the post-quiz after the first PLC lab exercise, and Quiz 3 being the post-quiz after completing the second PLC lab. Table 1 shows the numerical averages as well as the high and the low for each quiz. It can be seen from these results that not only did the average quiz score increase as a result of completing the laboratory experiences, but also the minimum and maximum scores increased in a similar manner. Since students were not able to see what they had done incorrectly on earlier quizzes and the questions were randomized, it is clear that students saw improvement in their achievement of the laboratory learning outcomes. The largest change was after the second lab which included pneumatics and asked students to interact with real-world systems. This suggests that pairing both an introduction to PLCs and pneumatics with a physical demonstration is significantly impactful in improving student learning.



Figure 5: Quiz results for the direct assessment quizzes with averages and high and low scores shown

Quiz	Average	High Score	Low Score
1	40%	60%	20%
2	57%	80%	40%
3	80%	100%	60%

 Table 1: Quiz results for the direct assessment quizzes

Survey Results

In addition to direct assessment, students were asked to rate their self-efficacy on lab learning outcomes through a 7 question anonymous Likert scale survey with 5 indicating strongly agree and 1 indicating strongly disagree with the following prompts (with specific learning outcome specified for the reader):

- 1. I can implement real-time control on physical systems (LO2)
- 2. I possess a basic understanding of control for industrial processes (LO1)
- 3. I understand fundamentals of pneumatic systems (LO3)
- 4. I understand basics of ladder-logic programming (LO2)
- 5. I can control pneumatic actuation (LO3)
- 6. I feel more comfortable talking about PLCs after completing the control labs (LO1)
- I feel that these experiences have exposed me to concepts I may see in the real world (LO1)

Table 2 shows the average response values for these questions. Of the 10 students involved in this study, all 10 completed the survey. For Lab Learning Outcome 1, students rated their familiarity with PLCs an overall average of 4.1/5 across three related questions, indicating agreement with achievement of this learning outcome. On Lab Learning Outcome 2, students rated their ability to program PLCs as an average of 3.95/5 across two related questions, corresponding with general agreement with achievement of this learning outcome. Finally, for Lab Learning Outcome 3, student responses averaged 3.65/5 across two related questions which also skews towards agreement.

Since there were only 10 students involved in this study, averages may not be the most meaningful metric for looking at the survey responses. As an alternative, Figure 6 shows a stacked bar chart which breaks down the percentage of respondents in each of the 5 categories. This is even further simplified in Table 3, which puts responses into three bins: Disagree or Strongly Disagree, Neither Agree nor Disagree, and Agree or Strongly Agree. This is useful to see that for all 7 questions, the percentage of respondents which agreed with the prompts is much higher than the percentage who disagreed. In fact, for 4 of the 7 questions, no respondents indicated disagreement. These results demonstrate that students felt like they met the Lab Learning Outcomes, which is particularly encouraging for the extension of this study.

Table 2: Aver	age response values on a	a 5 point scale
Question	Average	Standard Deviation
1	3.8	0.92
2	3.5	0.71
3	3.5	1.1
4	4.1	1.0
5	3.8	0.79
6	4.3	0.95
7	4.5	0.53



Figure 6: Stacked bar chart visualizing the responses to the Likert scale survey

Question	Disagree or Strongly Disagree	Neither Agree Nor Disagree	Agree or Strongly Agree
1	10%	20%	70%
2	0%	60%	40%
3	20%	30%	50%
4	0%	40%	60%
5	0%	30%	70%
6	10%	0%	90%
7	0%	0%	100%

Table 3: Survey responses categorized by agreement or disagreement with the prompt

Conclusions

The results of assessment are very encouraging for the efficacy of inexpensive lab exercises for teaching Programmable Logic Controller content to engineering students. While expensive test-beds are shiny and exciting, the measurable improvement in student understanding with much less-expensive and less-refined test beds is exciting.

Future work on this project will include refining the existing pneumatic finite state machines and adding additional laboratory experiences using a similar technique. One important additional topic, not covered in the lab exercises covered in this work, is receiving external input signals with the PLC, which was not accomplished due to time constraints on the project. This will be the top priority for the next test-bed system. Continued data collection will also benefit this work to determine if the results shown here are repeatable and accurate.

Acknowledgements

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Appendix

Table 4: Bill of Materials

Part	Supplier	Cost
CLICK Power Supply C0-01AC	Automation Direct	\$54
CLICK PLC C2-02CPU	Automation Direct	\$151
CLICK Discrete Combo Module C2-14DR	Automation Direct	\$70
CLICK Discrete Output Module C0-08TD2	Automation Direct	\$49
CLICK Discrete Combo Module C0-16CDD2	Automation Direct	\$80
3/4in bore, 1/4in rod, 1in stroke NITRA A12010SP Pneumatic Cylinder	Automation Direct	\$20
2in bore, 5/8in rod, 2in stroke double acting NITRA A32020DD-M Pneumatic Cylinder	Automation Direct	\$93
Nitra Solenoid Valve AVS-3211-24D	Automation Direct	\$28.50
Nitra Solenoid Valve AVS-533C2-24D	Automation Direct	\$106
Pneumatic Tubing	Automation Direct	\$22.50
PVC Piping	Lowe's	\$25
Wood Pieces	Lowe's	\$25
DC Power Supply (24V)	Lab Equipment	
Air Compressor	Lab Equipment	
Total		\$724

Example Quiz (Correct Answers in Bold)

- 1. What does PLC stand for?
 - a. Proportional Logic Controller
 - b. Proportional Ladder Controller

c. Portable Logic Computer

d. Programmable Logic Controller

- 2. To implement a logical AND in ladder logic put contacts:
 - a. On different rungs
 - b. In feedback
 - c. In series
 - d. In parallel
- 3. To implement a logical OR in ladder logic put contacts:
 - a. On different rungs
 - b. In feedback
 - c. In series
 - d. In parallel
- 4. How can you tell how many valve positions a pneumatic valve has?
 - a. Arrows on the valve
 - b. Number of position and flow boxes
 - c. Number of ports
 - d. Circuit connection symbols
- 5. On a PLC, input contacts are represented using
 - a. X
 - b. R
 - c. Y
 - d. IN
- 6. Pneumatic actuation is not good for:

a. Controlling position

- b. Velocity control
- c. Controlling force
- d. Making good contact
- 7. A PLC can activate a solenoid valve using a(n)
 - a. Switch
 - b. Digital Output
 - c. Analog Output
 - d. Relay Output
- 8. Which of the following is not a function of the CLICK Programming Software?
 - a. Counters
 - b. Tickers
 - c. Timers
 - d. DataView
- 9. On a PLC, output coils are represented using
 - a. X
 - b. R
 - c. Y
 - d. OUT
- 10. A contact with a line through it is
 - a. Normally Closed (NC)

- b. Normally Open (NO)
- c. Inactive
- d. Active

A Hands-on Activity on Human-Powered Lights for In-Class Demonstration

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Abstract- To generate electricity by pedaling a bicycle is an old idea but designing and constructing the system to be used as an experiment in the classroom is novel. This work informs students about the efficiency of energy transformations and various light bulbs using a hands-on demonstration and engineering calculations. Three light bulbs of different categories (incandescent, compact fluorescent, and LED) were connected to a motor that is driven by a human pedaling a bike fixed to a frame. The efficiency of the system and each of the light bulbs is calculated using measured voltages and currents. Each bulb's heat dissipation and luminance are captured and measured using a thermal camera and lux-meter respectively. A short survey was given to the participating undergraduate students in an electromagnetics course. According to the survey results, all students found this hands-on experiment very useful in their learning process. This experiment would be a good fit for the students in their sophomore and junior years.

Introduction

Electricity generation by pedaling a bike is not a new concept but making the system for educational purposes especially used as a robust hands-on learning tool for students is something new. There are some published works where authors constructed a similar system with a focus on generating electricity in regions with no power due to either a temporary natural disaster or remoteness from electrification. Others focused on harnessing waste energy from people exercising on machines in a gym to instantly run some tiny electronic device or to store for use [1]-[4]. Also, a pedal-powered generator was constructed in [5]-[8], where the efficiency of the overall system was analyzed and the system was proposed for use either alone or along with photovoltaic modules for rural areas in Bangladesh and India. The human-powered bike was utilized with associated electronic devices to first store the electrical energy in a supercapacitor and then use it for a low-power lighting application [9]. In this work, generating electric power by pedaling a bicycle is constructed in a way so that it can be a part of a lab session where students learn about the energy transformation process, and can measure the light intensities, heat dissipations, and overall efficiencies of the system and different types of light bulbs. This demonstration can be set as a lab experiment for students in science and engineering majors namely Electrical Engineering, Mechanical Engineering, and Physics.

Theory

Students learn that because of the conservation of energy, chemical energy (burning calories in the body) transforms into mechanical energy (cycling the pedals) while pedaling a bicycle. Then mechanical energy transforms into electrical energy within an electric motor and its efficiency is assumed as 100%. This electrical energy is used to operate three light bulbs. The supplied energy

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ends up as either useful light or wasted as dissipated heat. Some of the terms including mechanical energy, power, electric power, energy efficiency, and luminous efficiency are described below.

Mechanical energy and power imposed on the rotating shaft are the product of the torque and the angular displacement and angular speed respectively as follows:

$$E_M = \tau \Theta$$
$$P_M = \tau \omega$$

Where E_M and P_M are mechanical energy and power respectively. τ is the torque, θ is the angular displacement and ω is the angular speed.

Instead of calculating torque (τ), mechanical power can be obtained from the rotational kinetic energy (K.E) of the wheel of the bike and is given below:

$$K.E = \frac{1}{2}I\omega^2$$

Where *I* is the moment of inertia.

Inertia is calculated as $I = mr^2$, where m and r are the mass and radius of the rim of the bike respectively.

And angular speed is calculated as $\omega = 2\pi N$, where N is the revolutions per minute.

It is to be noted that the mass of the spokes is included in the rim's mass.

Now, mechanical power is

$$P_M = \frac{K.E}{t}$$

Where t is the time of each measuring cycle.

And the electrical power is

$$P_E = VI$$

Where V and I are the measured voltage and current produced by the motor.

Finally, the efficiency of the system can be measured as

$$\eta = \frac{P_E}{P_M} X100\%$$

(100% would mean both powers are the same i.e., all mechanical energy transforms to electric energy)

Luminous efficiency can be defined as the amount of light (lumen) produced by a light bulb after consuming each watt of electricity [10].

Brief Description of the individual component and measuring device used in this project

The complete set-up and pictures of the individual parts are shown in figures 1-2.

- *Motor (1):* A 24Volt-250Watts MY 1016 Scooter dc motor with rated speed 2600-2850 rpm was used.
- *V-belt Pulley (2):* A pulley with an outer diameter of 2 inches was used to connect with the shaft of the motor.



Figure 1: Complete set-up for human-powered lights.

- *Adjustable Link V-Belt (3):* An adjustable belt of width 3/8 inch was used that connects the rear rim of the bike and pulley.
- *Bike Stand (4):* This adjustable bike trainer stand provides five-level adjustable heights and a solid wide frame for extra stability.
- *Wireless speedometer (5,6):* It comprises three parts namely, a small LCD (Liquid Crystal Display) unit called a bike computer that was attached to the handle of the bike, a transmitter/ sensor that was attached to the rear fork, and a magnet that was fixed in spokes of the rear rim.
- *Light bulbs (7):* Three different types of light bulbs (incandescent, compact fluorescent, LED (Light Emitting Diode))
- *Switches (8):* A total of 8 switches (2 are on the other side and not shown in the picture) control the voltage current of the whole system and the individual light bulbs.

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- *Multimeter (9):* A digital multimeter is used to measure the voltages and currents.
- *Digital Illuminance light meter:* This high-quality portable light meter was used to measure the illuminance of different types of light bulbs.
- *Thermal Imaging Camera:* The iOS-compatible thermal camera was used to capture the thermal images of different types of light bulbs.





Figure 2: Various parts and measuring devices used for construction and measurements.

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camera

Procedures of the measurement of electrical and mechanical power

A schematic circuit is drawn for clarifying the electrical connection and is shown in figure 3. The DC motor was connected to the three light bulbs in parallel so that each one can operate separately or simultaneously. The second part of the whole circuit was branched for measuring the current through and the voltage across each of the light bulbs. To measure the total circuit voltage, a multimeter is needed to connect parallel to the dc motor. The total circuit current on the other hand must come out from the motor that will pass through the multimeter and flow continuously through the rest of the circuit. That is what made it necessary to have branches like in figure 3. There are a total of 8 switches that control the measurements. Switch-1 controls the current flow through the whole circuit without the multimeter. Switch-2 was used to turn on when it is needed to measure the total circuit current provided by the dc motor. Switches 3, 4, and 5 were connected with the light bulbs 1, 2, and 3 respectively for controlling individual light bulbs as on and off. Similarly, switches 6, 7, and 8 played the role of measuring currents through the individual light bulb using a multimeter. For measuring the voltage across each light bulb, switches 2, 6, 7, and 8 were kept off, and the remaining were turned on. So, it was easy to find out the voltage required to turn any of the light bulbs on and in the same way to get the current flowing through each of the light bulbs. Both voltage and current measurements help to calculate the electrical power.



Figure 3: Electrical wiring layouts for measuring voltages and currents.

To determine the kinetic energy (K.E), it is needed to count the number of rotations of the wheel. By knowing the radius of the rim for the particular bike, its circumference can be calculated, and for one revolution it will cover a distance equal to the circumference. From the speedometer data, the total number of revolutions can be calculated. The time of pedaling (t) considered here is 5 seconds and the measured K.E. over time gives the mechanical power. In the presented case, the mass and radius of the rim are 2 Kg and 32 cm respectively. For a complete set of measurements, it is required for at least three people to conduct the following five tasks:

- 1. Pedaling and recording the time with a stopwatch
- 2. Measure the rotation speed with a speedometer and thereby the number of revolutions
- 3. Measure the voltage and current with a multimeter
- 4. Measure the heat dissipation with a thermal camera
- 5. Measure the illuminance of each light bulb with a lux meter

Experimental results and discussion

Measurements were taken while operating the mechanism, and calculations were made to determine the efficiency of each different type of lightbulb and the system.

Light bulb type	Voltage [V]	Current [A]	Time [sec]	No. of rotation [RPM]	Light Intensity [Lumens]
Incandescent	19	0.03		220	10
Compact fluorescent	19	0.08	5	250	100
LED	19	0.25		200	180
All	19	0.30		270	-

Table 1: The set of measurements for obtaining voltage, current, rotation of the wheel, and light intensity.

Light Bulb Type	K. E (Joule)	P _E (Watts)	P _M (Watts)	ω (rad/s)	I (Kg-m ²)	η(%)
Incandescent	54.35	0.57	10.87	23.03		5.24
Compact Fluorescent	70.25	1.52	14.05	26.18	0.205	10.82
LED	44.91	4.75	8.98	20.93		52.89
All	81.86	5.70	16.37	28.26		34.82

Table 2: Efficiency calculation of different light bulbs and the system.

The light intensity of the individual light bulb was measured using a lux meter and it is seen from Table 1 that for any constant period of pedaling, the LED is more luminous than either the incandescent or the compact-fluorescent (CFL) light bulbs. For each type of light bulb, the calculation was done to find the kinetic energy (*K*.*E*), electrical power (*P_E*), mechanical power (*P_M*), angular velocity (ω), and finally efficiency (η). The calculated values are shown in Table 2. Efficiency data from Table 2 suggests that LED is the most efficient (using only 8.98 watts of mechanical power) and on the other hand the incandescent bulb is the least efficient.

When all of the light bulbs were in operation, heat dissipation was recorded using a thermal camera and is shown in figure 4. It is seen that the CFL bulb produced measurable heat over the greatest area and the LED bulb over the smallest area. It may seem that the CFL bulb dissipates more heat than the incandescent in Figure 4 which is an image taken when all bulbs were lit at once. For the incandescent bulb, heat radiation mainly depends on the filament temperature. When all bulbs were in operation, the filament of the incandescent bulb did not get enough electrical energy to heat up and glow as it did alone. Measuring heat dissipation for individual light bulbs provides the

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expected result where the incandescent bulb is less efficient than the CFL bulb. The most efficient lightbulb is the one that loses the least energy as heat.



Figure 4: Pictures of heat dissipation from different lightbulbs.

Survey results

This laboratory was tested in an introduction to electromagnetic fields course required for electrical engineering students. These students would typically have had a course in electric circuits and be able to understand the schematic diagram of figure 3. Students of other engineering courses such as thermodynamics may find it useful as well. A survey was taken among undergraduate students in the introduction to electromagnetics course. The goal of the survey was to usefulness of the demo in the student's learning process. The total number of participants from three consecutive semesters was 38. Students were asked five questions after completing the associated measurements. The question type was binary (yes/no). The survey result indicates that 45% of the participating students did not see this type of energy conversion demonstration before. Only 22% of students had prior experience in measuring light intensity and heat dissipation, and 44% of students measured efficiency in any other systems under different courses. All students agree that this demonstration and hands-on experience by using various measuring tools is a very useful way of learning. They all suggested continuing this hands-on for every student in any of the semesters. Figure 5 shows the result of the survey.



Figure 5: Survey result on hands-on activities of energy transfer demonstration.

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Conclusion

A hands-on demonstration based on energy transformation from pedaling a bike to lighting three types of light bulbs was successfully constructed. The efficiency of the system was measured along with the efficiency, illuminance, and heat dissipation of the individual light bulbs. The usefulness of the project was justified by the results from the surveyed undergraduate students. According to the survey result, more than 55% of the students did not have any prior experience in seeing and measuring light intensity, heat dissipation, and efficiency. It is highly expected that this hands-on demonstration will help many students to learn about energy production for different purposes. In the future, some modifications in the electrical circuit part will be made for making the measurement procedure more straightforward.

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Disclaimer

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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Work in Progress: A Simple Plug-in Implementation of Extreme Audio Stretching

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Abstract

Music is ubiquitous and one of the most popular multimedia formats in our lives. Significant research efforts have been made in music signal processing. It becomes challenging for music educators to understand and apply these developed techniques. This study aims to develop a simple audio plugin for extreme audio stretching for music production. An audio effect algorithm, PaulStretch, is implemented and evaluated. It could be used as an educational tool to explore music signal processing applications.

Keywords:	Music Production	Extreme Audio Stretching	PaulStretch
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I. Introduction

In sound design and music production, time stretching and audio warping has been playing an essential role in producing high-quality music tracks. There are three main methods for stretching audio. The simplest one is to change an audio clip's playback speed, which affects the tempo and pitch. Another method is time scale modification (TSM). This is used to speed up or slow down audio without affecting the frequency content. J. Driedger and M. Muller reviewed fundamental TSM methods in [1]. In general, the procedure of TSM includes three processing pipelines: signal decomposition, frame relocation adaption, and signal reconstruction. Both parametric and non-parametric methods are applied to analyze and decompose signals [2-6]. A repetitive window breaks audio into monophonic and polyphonic, where sinusoids are repeated to match the desired length. Monophonic favors time resolution, while Polyphonic favors frequency resolution. The problem with this technique is that you get long stagnant tones that jolt suddenly to new frequencies. Even visually, audio programs struggle to display stretched audio. This method is fine for stretching audio a little to moderate amount. Finally, the third method, audio slicing, cuts the signal up into small frames with blank or empty spaces in between. This has an unpleasant result as jittery, broken, and unpleasant tones are obtained. Significant efforts are also in synchronizing and smoothing signals [7 - 10].

All of these are just a small portion of research efforts in music signal processing. There is an application gap between music signal processing and music education. It becomes

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challenging for music educators to understand and apply these techniques. As such, many audio plugins have been developed so that users can play and try out different techniques interactively. PaulStretch is an audio effect algorithm, that is useful for pads, textures, choirs, and orchestras. It is a simple plugin wonderful for beginners to comprehend. The screenshot of PaulXStretch open-source plugin by Sonosaures [11] is shown in Figure 1 below. It is very complicated both mechanically and visually. RealStretch is another example. It is meant for live performance, much like a guitar pedal, and works by pushing the play head back every few seconds [12].



Figure 1. Control Panel of PaulXStretch Plugin [11]

The goal of this study is to create a simple audio plugin (.VST/.Component) that can stretch audio to extreme lengths, without changing pitch. Specifically, an audio effect algorithm, the PaulStretch algorithm, is implemented. it aims to develop a simple plug-in implementation of extreme audio stretching, PaulStetech.Q, for music production, not live performance. Simplicity and multi-platform support are the major features to be sought after.

II. The PaulStretch Algorithm

PaulStretch is an audio effect algorithm created by Paul Nasca for extreme stretching in 2006. PaulStretch has two main parameters. The first is Stretch Factor - How much the audio will be stretched. This has no limit and may process until the computer runs out of memory or battery. The second is Time Resolution - This breaks up the sample into windows, which affects the frequency and the time resolution of the resulting sounds. Smaller windows have better time resolution while larger windows have better frequency resolution.

The mathematical process of PaulStretch is described as follows: Based on user input parameters such as stretch factor and time resolution, an original audio file (.wav or .mp3) is progressively stretched through windowing data into overlapped segments. Then the Fast Fourier Transform (FFT) is applied to each windowed frame. The original phase information is discarded, then randomized phase information is inserted to create enjoyable textures, instead of stagnant tones. The inverse FFT of each window is computed and added back together, overlapping but spaced out how the user specified.



Figure 2. Paulstretch algorithm [13]

III. Progress and Results

Since MATLAB is one of the standard programming languages used in engineering programs, it is chosen as the first platform to implement the plugin. MATLAB app designer can be used to create professional apps through an easy graphical user interface and an integrated editor. The developed MATLAB app is shown in Figure 3.

MATLAB app designer eases up the programming-heavy area of app development for those who do not have professional software development experience. However, the user interface within MATLAB app designer is very restrictive. Pre-defined codes for buttons and class declarations are not fully accessible to be edited. Passing information between buttons and back-end operations becomes extremely challenging. In addition, a professional license for MATLAB compiler is needed. Without this license, one can only share the project file, not export it as a standalone application. The drawback of coding capabilities in the app developer, along with the compiler is not fully available. It decreases the availability of the plugin to students and consumers. Therefore, a popular cross-platform game engine by Unity Technologies is evaluated.

	P	aulStr	etch	
Test Nipj	ple	Upload Audi	o File	
	Stretch Fact	or:		0
	Time Resolu	tion (seconds):		0
	Play Original A	udio Pl	ay Edited A	udio
	Play Original A	udio Pl Export	ay Edited A	Send2Text

Figure 3. PaulStretch MATLAB GUI

Unity has been used to create a wide variety of software including video games, medical apps, virtual reality experiences, mobile apps, and more. The developed Unity app is shown in Figure 4.

Pa	ulStretch
	Import Audio
Stretch Factor:	Ense est.
Time Resolution (see	conds):
Play Original Audio	Play Edited Audio
	Export

Figure 4. PaulStretch Unity GUI

The challenges with Unity derives from its limited support of manipulating user input audio files. Editing audio files is not straightforward for programmers. Developers may spend more time working with user-defined packages and filer converters. One of the most important design features is to test the algorithm for music production with simplicity and easiness. As a result, JUCE, an open-source cross-function application framework is adopted as the platform for the plugin implementation. It allows users to create audio plugins with a VST framework. From the framework, it generates a C++ project in Xcode. Figure 5 shows a proposed graphic user interface (GUI) of PaulStretch developed using Aseprite. The developed PaulStretch plugin (PaulStretch.Q) supports multiple platforms. As a demonstration, Logic Pro, an audio workstation and MIDI sequencer software application from Apple Inc. is used to test the plugin. Figure 6 shows the PaulStretch JUCE GUI in Logic Pro X.



Figure 5. PaulStretch Aseprite GUI



Figure 6. PaulStretch JUCE GUI in Logic Pro X (12.2023)

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As a summary, Table 1 compares the language, application, and file types of different platforms for the audio plugin implementation.

	MATLAB	Unity	JUCE / C++
Language	MatLab Script	C#	C++
Application	Engineering Simulations	Video Games and Software	Audio Plugins
Files	Project File	Stand Alone App	VST/Component

Table 1. Comparative Table of development platforms.

IV. Conclusion

In this project, a simple plug-in implementation of extreme audio stretching, PaulStretch.Q, is proposed. The PaulStretch algorithm is implemented on JUCE, an open-source cross-function platform in C++. It could be an educational tool for music production or sound design. Engineering students may use it to explore their interest in audio signal processing applications as well.

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Paper Session 6: Pedagogy and assessment

Location: Engineering Building 1150

Session Chair: Keqin Gu

12:45 – 1:00pm	Using Concept Maps in an Undergraduate	
	Heat Transfer Course	
	Najmus Saqib (University of Indianapolis)	
1:00 – 1:15pm	Specifications Grading in Undergraduate	
	Fluid Mechanics	
	Julie Mendez (Indiana University-Purdue	
	University Columbus)	
1:15 – 1:30pm	Using Design Review in the Classroom	
-	Thomas J. Dobrowski (Purdue Northwest)	

Using Concept Maps in an Undergraduate Heat Transfer Course

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Abstract

Concept maps are widely used in foundational non-engineering science courses to help students express their own understanding of course material. By creating a concept map, students are able to visualize the relationships between different course topics. In recent years, the use of concept maps in fundamental engineering courses has gained growing attention. They have been reported to be very effective in providing students with an interactive learning experience by leveraging constructivist pedagogy. This work reports the effectiveness of integrating concept maps as a learning tool in an undergraduate Heat Transfer course for students majoring in Mechanical Engineering. Over the course of the semester, students were asked to create two concept maps: one for thermal conduction and one for convection. The students worked on the concept maps at regular intervals in class, and they grew as new material was covered. After students developed their own concept maps, instructor-created concept maps were also shared with the class immediately before exams, to serve as an exam study tool. A survey was conducted at the end of the semester to gauge student perceptions of using the concept maps. Qualitative and quantitative results from the survey are presented. Concept maps were found to be a useful, constructive learning tool for visually connecting and organizing course topics for both students and instructors. The results are limited to a single, primarily undergraduate institution with small class sizes. Future work will seek to expand the data set by including multiple institutions.

Introduction

A concept map (also known as a mind map or a knowledge map) is a graphical way to represent and organize relationships between course topics and ideas and draw connections between concepts [1-2]. Mapping is achieved by drawing connecting lines between concepts in a visual representation. It was introduced as an educational tool more than thirty years ago. Concept maps have been successfully used in a variety of STEM courses [3]. As engineering educators have strived to incorporate more active learning pedagogies in the classroom, concept maps have emerged as a valuable learning tool [4]. They fall under the umbrella of constructivist pedagogy whereby students create their own meaning of course concepts [5]. In Mechanical Engineering curricula, effective use of concept maps has been demonstrated in Mechanics, Thermodynamics, and Design courses [2,5]. These studies have reported that concept maps can help increase conceptual understanding.

This paper describes an active approach to using concept maps in an undergraduate Heat Transfer course. Over the course of the semester, students were asked to create two concept maps: one for thermal conduction and one for convection. The students worked on the concept maps at regular intervals in class, and the maps grew as new material was covered. After students developed their own concept maps, instructor-created concept maps were also shared with the class immediately before exams, to serve as an exam study tool. Preliminary results from the study include qualitative and quantitative feedback captured from a student survey at the end of the course. The results are limited to a single, primarily undergraduate institution with small class sizes. Because there exists some disagreement in the literature on assessing student-created concept maps, they were excluded from the results of the study. Specifically, Johnstone and Otis noted that concept maps should be treated as "very personal learning tools" due to the many necessary inferences that must be made in understanding a map and the corresponding opportunities for mistakes [6]. Instructor-created concept maps are presented herein.

Methods/Classroom Approach

Students in an undergraduate Heat Transfer course were introduced to concept mapping as a learning tool in Spring 2022. The course requires both Thermodynamics and Differential Equations as prerequisites. Seven students were enrolled in the course, which is designed for the third year of the Mechanical Engineering program at the University of Indianapolis.

Student mastery of course content was evaluated via homework, quizzes, in-class activities, and three exams. The exams were cumulative, but each exam focused on key concepts from recent lectures. New concepts for each exam are listed in Table 1. Permitted reference materials on the exams included only an individual equation sheet created by the student.

Concept maps were introduced to students during the first week of the 15-week course, with a short discussion to share with students the learning benefits of concept mapping. During the third week of classes, students were sorted into two groups asked to create a concept map within each group based on recently covered topics. After this, students were given time during class once a week to expand their concept maps. In the week preceding the first exam, which focused on Conduction Heat Transfer, an instructor-created concept map was shared with the class. Students were reminded that there was no "correct" version of a concept map and that theirs may look

different. In the week following the first exam, students were asked to begin developing a concept map for Convection Heat Transfer. In the week preceding the second exam, which focused primarily on Convection Heat Transfer, another instructor-created concept map was shared with the class. Student-created concept maps were collected at the end of the course, but they were not graded. Note that a concept map was not developed for Radiation Heat Transfer as the course schedule permitted only a brief (approximately two weeks) introduction to the topic. An instructor-generated concept map is presented in Figure 1.



Table 1: Topics Covered on Exams

Figure 1: An example of an instructor-generated concept map.

Qualitative and Quantitative Student Feedback

In order to gather data on concept mapping in the Heat Transfer course, a survey with shortanswer and Likert scale questions, to be administered at the end of the course, was developed. The anonymous student survey was distributed through Qualtrics. The questions were adapted from previous work by the author [7]. The survey results are summarized below.

Likert Scale Survey Questions

Select your level of agreement with the following statements:

(1 - Strongly Disagree, 2 - Disagree, 3 - Neutral, 4 - Agree, 5 - Strongly Agree, DNR - Do Not Remember)

- *A) I* had previously used concept maps before taking this course.
- *B)* The concept mapping activity was a group effort.
- C) The use of concept maps improved my learning experience in the course.
- D) The concept maps were a useful resource for exam study.
- *E)* I plan to use concept maps in the future.

Table 2: Average Results of Likert Scale Survey Questions.

Somostor	Sample Size	Likert Scale Question Average				
Semester	Sample Size	Α	В	С	D	Ε
Spring 2022	7	1.57	4.00	4.57	4.86	4.14

Short Answer Survey Questions

What aspects of the concept map did you find either useful or not useful for your learning in this course?

- "The concept maps we made helped me visualize how the new topics we learned each week connected to each other."
- "They were very useful for exams, but I would like to see them used for classroom problem solving and homework."
- "I did not find it very useful for actually solving problems."

Please provide any additional comments about the use of concept maps in this course.

- "I would like to see an overall concept map for the entire course."
- "Concept maps are a great idea. We should use them in other classes."

The results of the student survey are positive and encouraging for the continued use of concept maps in future iterations of the course. Most students had not used concept maps before, but they strongly agreed that improved their course learning experience. They also agreed that the maps served as a useful study tool for exams and intend to use them again in the future. A few students noted that the concept maps did not directly apply to problem solving strategies. Perhaps a more detailed concept map could help with this. One student noted that an overall map for the entire list of course topics may also be beneficial.

From the instructor's perspective, concept maps can be beneficial for someone undertaking a new course preparation or reviewing topics. They can also inform a reorganization of a course or alternate methods to introduce topics.

Limitations of this study include, data from only a single offering of the course with only seven students, and lack of any demographic data. There are plans to continue this study to include larger groups of students. Another interesting addition to this study will be to analyze student performance with and without the use of concept maps.

Conclusions

This paper describes the use of concept maps in an undergraduate Heat Transfer course. Summarizing the results from student surveys, concept maps were found to be a useful, constructive learning tool for visually connecting and organizing course topics for both students and instructors. More data should be collected to increase the sample size and account for variations in course offerings for conclusive evidence to be gathered on the impact of concept maps in undergraduate Heat Transfer courses. Planned future studies will provide additional information about this promising pedagogical tool.

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Specifications Grading in Undergraduate Fluid Mechanics

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Introduction

Alternative grading practices are being used increasingly in science, technology, engineering, and mathematics (STEM) courses in place of traditional points-based grading systems [1]–[17]. One such method is specifications grading, in which student work is scored pass/fail according to whether the assignment submission met the provided requirements. The final course grade is determined by students completing pre-determined "bundles" of assignments [18].

The last several years have seen an increase in the use of specifications grading in higher education courses in STEM, including examples in chemistry [19], biology [20], physics [21], mathematics [22], first-year engineering [23], [24], engineering computer applications [25], engineering mechanics [26], thermodynamics [27], fluid mechanics [28], biomedical engineering statistics [24], a chemical engineering laboratory [29], a biomedical engineering elective course [30], and capstone design [24].

This paper will describe the implementation of specifications grading in two offerings of an undergraduate fluid mechanics course, one with lecture and laboratory components and a lecture-only course the following year. Student course performance data presented here will be limited to the assessments in the lecture portion of the course.

Pedagogical Approach

Course Description

In 2018, specifications grading was implemented in a 4-credit junior-level fluid mechanics lecture and laboratory course in a mechanical engineering curriculum. The course is typically taken in the first semester of the third year in the program. The prerequisites are courses in thermodynamics, dynamics, and differential equations. The course is a prerequisite for the heat and mass transfer course.

The lecture portion of the course was organized into 8 modules based on content: fundamental concepts, fluid statics, elementary fluid dynamics, control volume analysis, dimensional analysis, flow in pipes, external flows, and compressible flow. There were 7 laboratory experiments: pressure measurement, Venturi meter, flow loss, vertical flow through an orifice, horizontal flow through an orifice, flow meters, and fluid friction. The lecture portion of the course met twice per week for 75 minutes during a 15-week semester. The laboratory sections met approximately once every two weeks for 110 minutes.

When the course was next offered in 2019, due to a program curriculum change, the course became a 3-credit lecture, and the laboratory portion was moved to a separate course. The lecture

course met twice per week for 75 minutes during a 15-week semester and maintained the 8 content modules used the previous year.

Assessments and Grading

From the 8 course outcomes specified by the program (see Appendix A), the topics were refined into a list of 16 measurable topics, listed in Table 1. The topics presented here reflect those used in the 2019 course. Quiz 2C was revised from "Determine *hydrostatic* force acting on floating or submerged bodies" in 2018 to "Determine *the buoyant* force acting on floating or submerged bodies" in 2019 to more accurately describe the problems associated with this topic.

Quiz		Specifications:		
Number	Торіс	You will earn a score of "Pass" by		
1	Describe the scope of fluid mechanics.	correctly answering the question in your own words.		
2A	Determine pressures from measurements using various types of manometers.	correctly applying the manometer rule to the given scenario.		
2B	Calculate the hydrostatic force acting on a plane or curved submerged surface.	 completing the following: Sketch an appropriate free-body diagram for the given situation Correctly apply statics principles 		
2C	Determine the buoyant force acting on floating or submerged bodies.	 completing the following: Sketch an appropriate free-body diagram for the given situation Correctly apply Archimedes' principle 		
3	Apply Bernoulli equation to simple flow situations.	 completing the following: Correctly apply the Bernoulli equation Correctly apply the continuity equation, if necessary 		
4A	Apply the principles of conservation of mass and momentum to a control volume.	 completing the following: Correctly apply the continuity equation Correctly apply the linear momentum equation 		
4B	Use the energy equation to solve problems involving losses due to friction and energy input by pumps or extraction by turbine.	correctly applying the energy equation.		
4C	Determine flow characteristics of incompressible, steady, laminar, viscous flow between parallel plates and through circular tubes.	 completing the following: Choose the appropriate solution to the Navier-Stokes equations Correctly set up the appropriate equation to solve for the desired quantity 		
5	Use dimensional analysis to establish a set of similarity requirements for a model to be used to predict the behavior of another similar system.	 completing the following: Use the Buckingham pi theorem to determine pi terms and a relationship between them Use similarity to determine the requested quantity 		

Table 1. Standard associated with each quiz.

Quiz		Specifications:
Number	Торіс	You will earn a score of "Pass" by
6A	Solve a variety of pipe flow problems.	completing the following:Correctly apply the energy equation
		• Correctly account for major and minor losses, when applicable
		• Correctly apply the continuity equation, when applicable
6B	Determine flowrate through	completing the following:
	flowmeters.	• Select the correct equation relating flowrate and pressure
		Determine the appropriate discharge coefficient
7A	Calculate boundary layer	correctly setting up an equation to determine the
	parameters for flow past a flat plate.	requested quantity.
7B	Explain the physical process of boundary layer separation.	correctly answering the question.
7C	Calculate lift and drag forces.	applying the principles of lift or drag to solve the problem.
8A	Calculate Mach number for a specific compressible flow.	correctly calculating the Mach number for the specified flow.
8B	Solve problems involving	completing the following:
	isentropic flow with area	• If necessary, determine whether or not the flow is
	change.	choked.
		• Set up the correct equation to solve for the requested quantity.

Each topic was assessed by a quiz problem/question. Most were calculation-based problems; a few topics were assessed by short answer responses to a prompt. To earn a score of "Pass" on a quiz, a student had to solve the problem to the specifications, which were available in the learning management system in advance of the quiz. If a score of "No Pass" was earned, the student could request to attempt a new problem on the same topic. These additional attempts could be scheduled outside of class time during the instructor's office hours or during class. Quizzes took place approximately once per week toward the end of the class period.

In the 2018 course, a written report was required for each of the 7 laboratory experiments. To earn a score of "Pass" on a laboratory report, a student had to submit a written report that met all requirements specified in the assignment description provided in the learning management system. For an example, see Appendix B. If a score of "No Pass" was earned, the student had the option to submit a revised version when they were ready, up to the final week of the course. The separate laboratory course that was first offered in 2019 is not described here.

There were two categories of smaller assignments: 14 guided practice assignments and, in the 2018 course, 7 pre-lab assignments. Guided practice assignments were meant to prepare students in a flipped classroom for the group activities [31], [32]. The pre-lab activities were short reading assignments with a few questions to prepare students for the laboratory experiments. For the guided practice and pre-lab assignments, a student earned a score of "Pass" on each assignment

by attempting each problem/question and submitting the assignment prior to the lecture or laboratory period corresponding to the assignment. A score of "No Pass" was earned if there was no submission, if any question was left blank, or if any response did not reflect a good-faith effort to be correct, such as "I don't know". Guided practice and pre-lab assignments could not be revised or resubmitted because these assignments were meant to be completed prior to class to prepare for the in-class activities or lab experiments.

Table 2 describes how many quizzes and laboratory reports were required to earn a particular grade [33]. Since grades with "+" or "-", such as "B+", could be assigned, a plus was added to the base grade if a student earned "Pass" scores on at least 13 guided practice and on 7 pre-lab assignments in the 2018 course. A minus was added to the base grade if a student earned "Pass" scores on fewer than 7 guided practice or on fewer than 4 pre-lab assignments in the 2018 course. The 2019 course used the same requirements for number of quizzes and guided practice assignments passed to earn a particular grade.

10010 2. 000	ise grade requirements from 2010 syndous.
To earn	Accomplish the following:
this grade:	
А	Earn "Pass" scores on 15 quizzes AND earn "Pass" scores on 7 lab reports.
В	Earn "Pass" scores on 13 quizzes AND earn "Pass" scores on 6 lab reports.
С	Earn "Pass" scores on 11 quizzes AND earn "Pass" scores on 5 lab reports.
D	Earn "Pass" scores on 9 quizzes AND earn "Pass" scores on 4 lab reports.

Table 2. Course grade requirements from 2018 syllabus.

Results and Discussion

Copies of all student quizzes were kept during the course. For each of the 16 quizzes, the following data was collected for each student who completed the course (15 students in 2018 and 12 students in 2019): score on the initial attempt, number of attempts, and score on the final attempt.

The percentage of students who earned a "Pass" score on each quiz topic in the 2018 course is given in Figure 1. Two sets of data are shown, students who passed the topic on the first attempt and students who passed the topic by the end of the course. Four quiz topics were passed by all students on the first attempt: scope of fluid mechanics (Quiz 1), flat plate (Quiz 7A), boundary layer separation (Quiz 7B), and Mach number (Quiz 8A). Five additional quizzes were eventually passed by all students: manometers (Quiz 2A), buoyant force (Quiz 2C), Bernoulli equation (Quiz 3), differential analysis (Quiz 4C), and lift/drag (Quiz 7C).



Figure 1. Percentage of students earning score of "Pass" on each quiz topic in the 2018 course. Filled bars indicate students who passed on the first attempt. Dotted bars indicated additional students who passed on a later attempt.

The percentage of students who passed each quiz topic in the 2019 course is given in Figure 2. Three quiz topics were passed by all students on the first attempt: scope of fluid mechanics (Quiz 1), buoyant force (Quiz 2C), and Mach number (Quiz 8A). Three additional quizzes were eventually passed by all students: differential analysis (Quiz 4C), flat plate (Quiz 7A), and lift/drag (Quiz 7C).



Figure 2. Percentage of students earning score of "Pass" on each quiz topic in the 2019 course. Filled bars indicate students who passed on the first attempt. Dotted bars indicated additional students who passed on a later attempt.

For the 2018 course, the average number of attempts for each quiz topic and how many students had no attempt, one attempt, two attempts, or three or more attempts are given in Table 3. The topics with the highest average number of attempts were, in descending order, mass and momentum (Quiz 4A), hydrostatic force (Quiz 2B), and dimensional analysis (Quiz 5). These are also the topics with the lowest percentage of students passing on the first attempt. Dimensional analysis (Quiz 5) had the lowest pass rate by the end of the course. Mass and momentum (Quiz 4A) had the most students taking three or more attempts.

For the 2019 course, the average number of attempts for each quiz topic and how many students took different numbers of attempts are given in Table 4. The topics with the highest average number of attempts were, in descending order, hydrostatic force (Quiz 2B), and then manometers (Quiz 2A) and flowmeters (Quiz 6B). The topics with the lowest percentage of students passing on the first attempt were hydrostatic force (Quiz 2B) and flowmeters (Quiz 6B). Mass and momentum (Quiz 4A) had the lowest pass rate by the end of the course. Manometers (Quiz 2A) and hydrostatic force (Quiz 2B) had the most students taking three or more attempts.

	Average	Number of Students			
	Number of	No Attempt	One Attempt	Two Attempts	Three or More
	Attempts	_	_		Attempts
Quiz 1	1.0	0	15	0	0
Quiz 2A	1.3	0	12	2	1
Quiz 2B	1.7	0	8	5	2
Quiz 2C	1.1	0	14	1	0
Quiz 3	1.1	0	14	1	0
Quiz 4A	2.0	0	5	6	4
Quiz 4B	1.3	0	11	3	1
Quiz 4C	1.3	0	10	5	0
Quiz 5	1.4	1	7	7	0
Quiz 6A	1.3	0	11	3	1
Quiz 6B	1.0	0	15	0	0
Quiz 7A	1.0	0	15	0	0
Quiz 7B	1.0	0	15	0	0
Quiz 7C	1.1	0	14	1	0
Quiz 8A	1.0	0	15	0	0
Quiz 8B	1.1	0	14	1	0

Table 3. Number of attempts taken for each quiz topic in the 2018 course.

Table 4. Number of attempts taken for each quiz topic in the 2019 course.

	Average	Number of Students			
	Number of	No Attempt	One Attempt	Two Attempts	Three or More
	Attempts				Attempts
Quiz 1	1.0	0	12	0	0
Quiz 2A	1.6	0	10	0	2
Quiz 2B	1.7	1	4	5	2
Quiz 2C	1.0	0	12	0	0
Quiz 3	1.4	0	7	5	0
Quiz 4A	1.3	0	9	2	1
Quiz 4B	1.4	0	7	5	0
Quiz 4C	1.4	0	8	3	1
Quiz 5	1.5	0	7	4	1
Quiz 6A	1.3	0	8	4	0
Quiz 6B	1.6	0	5	7	0
Quiz 7A	1.2	0	10	2	0
Quiz 7B	1.0	0	12	0	0
Quiz 7C	1.3	0	9	3	0
Quiz 8A	1.0	0	12	0	0
Quiz 8B	1.2	0	10	2	0

The following topics were among the lowest pass rates and/or greatest average number of attempts in both offerings of the course: hydrostatic force (Quiz 2B) and mass and momentum (Quiz 4A). In future offerings of the course, these are topics the instructor could consider changing the way the material is delivered or providing additional opportunities for students to practice.

The 2018 and 2019 courses were taught by the same instructor using a flipped classroom approach with active learning techniques including Peer Instruction [34] and group problem-solving. In addition to the removal of the lab component, another difference in the course in 2019 was the introduction of concept maps to organize course topics. Students were encouraged to create concept maps as a study tool and viewed portions of an instructor-created concept map at certain points during the course. While students found the concept maps useful for some course activities, there was not a significant difference in quiz scores compared to the previous offering of the course without concept maps [35].

The 2018 course offering was the first time this instructor had taught this course. A considerable amount of time was spent in preparation before the course began. Multiple potential quiz problems were selected or written for each topic. Compared to how this instructor prepared other courses using a traditional grading scheme with exams, much of the course preparation time was shifted from during the semester to before the course began. The student course evaluations included positive comments about the course organization, which the instructor attributes to the time invested in preparing the course.

Once implemented, specifications grading saves the instructor time [18]. While instructor time spent on this course was not tracked, the grading of quizzes could be done relatively quickly by checking if all the specifications were met and providing some feedback on what was incorrect about the solution or recommending a portion of the course materials for the student to review.

It is recommended to have some limit on how often or how many times a student may reattempt a quiz or resubmit assignments. In this course, students were able to schedule an appointment with the instructor outside of class time once per week to reattempt up to two quizzes. These appointments were available on a first-come, first-served basis and had to be scheduled 24 hours in advance. Students were also able to reattempt quizzes during a later class period by requesting the quiz two days in advance. There was no limit to how many quizzes a student could request; however, there was a limited amount of time allotted in class for quizzes, typically 20-30 minutes once per week. The final opportunity for quiz reattempts was during the two-hour period at the end of the semester that would traditionally be used for a final exam. In the course evaluations, students commented on their enjoyment of the grading system and the ability to reattempt quizzes.

Conclusions

In a course using specifications grading with quiz reattempts, students were able to revisit course material and demonstrate improved proficiency in particular topics. From the instructor perspective, more time was spent preparing the course prior to the start of the semester, but less time was spent grading compared to courses with traditional exams. The quiz score results from

the two offerings of the course suggest two areas for the instructor to revise in future versions of the course: hydrostatic force and mass & momentum.

This paper described two subsequent offerings of the course in a traditional face-to-face classroom format. When the course was offered again using specifications grading in 2020, it was fully online due to the COVID-19 pandemic. Because of multiple differences between the two course formats, that work is not described here. The course returned to the traditional on-ground format in 2021 but was taught by a different instructor using a traditional grading scheme.

Future course preparation will involve revising portions of the course where quiz pass rates were low. Future work will involve surveying students on their perceptions of specifications grading.

Appendix A: Course Outcomes

Upon successful completion of the course, students should be able to:

- 1. Describe the scope of fluid mechanics.
- 2. Calculate the hydrostatic forces, pressures and moments on planar and curved submerged and floating surfaces.
- 3. Decide when it is appropriate to use ideal flow concepts and the Bernoulli equation.
- 4. Construct an appropriate control volume for a given engineering system and apply the principles of conservation of mass, momentum, and energy to this control volume in differential and integral forms.
- 5. Present data or governing equations in non-dimensional form and apply dimensional analysis.
- 6. Solve for internal flow in pipes and channels through simple solutions of the Navier-Stokes equations, the Moody chart and the head-loss equation.
- 7. Solve for external (laminar and turbulent boundary layer) flows, evaluate lift and drag, know when there is possibility of flow separation.
- 8. Describe the propagation of sound; apply the basic equations of 1D, steady compressible flow and isentropic flow with area change to solve for unknown properties using appropriate property relations.

Appendix B: Example Laboratory Report Specifications

To earn a score of "Pass", complete the following:

- Complete all sections of the cover page.
- Write an abstract that answers the five questions listed in the template.
- Correctly state the objectives of the experiment.
- Write an introduction that briefly relates the experiment to a real-world example.
- In the theory section,
 - Explain the theoretical principles behind the experiment.
 - Explain all equations used for the calculations.
 - Define all variables used in the equations.
 - Explain all assumptions used in the experiment and calculations.
- In the experimental methods section,
 - Describe in your own words how you completed the experiment.

- Provide a sketch, diagram, and/or photo to describe the experimental set-up. The main components of the experimental set-up should be labeled in each sketch/diagram/photo.
- Summarize the results.
- Include the graphs described in "Analysis" above. You may share graphs with your group members.
- Include a discussion of the results. Your discussion may include the following:
 - Was there a difference in gage error when you increased the pressure compared to when you decreased the pressure? Why?
 - Were there any differences in the readings from the different manometer types? Why?
 - Were there differences between the pressures measured using the gage and using the manometers? Why?
- Explain possible errors in the pressure gage readings and in the manometer readings. Describe any other experimental errors.
- State your conclusions from the experiment.
- Make recommendations based on the experiment. This could be ways to improve the experiment, or suggestions for what someone should do differently next time.
- Include a caption for each table or figure (graph, diagram, photo). A table caption is placed over the table. A figure caption is placed below the figure.
- In the body of the report, refer to any books, websites, etc. that were used in writing the report and list them in the reference list.
- Consistently format the items in the reference list, stating titles, authors, publisher, date of publication, and page number, as appropriate.
- In the sample calculations, show an example of how the results were calculated. Include units. Use an equation editor.
- Include units in the data tables.
- Provide an equipment list.
- Attach a scanned copy of the raw data sheet.

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Using Design Review in the Classroom

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Abstract

Several years ago, at a conference, the author heard a group of cadets from the United States Military Academy at West Point talking about using a "Design Review". They talked about checking all homework for each other and how it helped them in their studies. The author has always felt that as educators, we must prepare our students of life in the "real world". And whether in Construction (Cost Estimate) or Engineering (Design Calculations), there is almost always a checker. Upon contacting their Department Head, he then put me in contact with Colonel Aaron Hill then emailed the author a detailed syllabus as well as a sample of their "Design Review" form. After slightly modifying the form, the author then put it to use. This paper will look at the results of four years of instituting the Design Review and its effect on his students. He will go back upwards of thirty years to compare past grades with those of his students in the past five years and run statistical analysis to see how the Design Review affects the students.

The Beginning

The author has always believed that that first and foremost, as educators, it is our purpose to prepare our students for what they will be facing in industry. Therefore, he has always tried to keep the lessons practical and to discuss what actually happens in industry. So when, at a conference, he heard a group of Cadets from the United States Military Academy at West Point talking about a "Design Review", it piqued his interest. The cadets talked about how for homework assignments they were assigned either a "calculated by" or a "checked by" designation and were assigned a partner. The person assigned the "calculated by" designation would perform the calculation and after a few days, would have to turn their calculation over to the "checker", who in turn would then check the work and return it with comments. The person who then performed the calculation would have a couple of days to review the comments and would chose to take the comments and change their calculation (assuming the checker found "errors"), or keep what they originally had.

The week following the conference the author contacted the Department of Civil Engineering at West Point and was put in touch with Colonel Aaron Hill. Colonel Hill provided the author with a Syllabus as well as a copy of the Design Review Form and provided insight into the process. The following semester the author put the Design Review into his own syllabuses and implemented the process.

Because a majority of the classes the author teaches are math based classes, the Design Review works very well. Also, because the author has taught for thirty three years at Purdue Northwest, he has a wealth of information regarding his classes (well, for the past eighteen years anyways, as that is when he switched to excel grading as opposed to recording his grades in a book, which have all been misplaced). For the past five years (except for Fall 2020 and Spring 2021, which

lectures were conducted via Zoom and therefore the Design Review was not utilized) the Design Review was implemented.

The Procedure

During the class sign in, next to the students name is a letter in the alphabet and a column that states whether they will be performing the calculation or checking the calculation. When they sign in, they are to see which other student has the same letter as themselves an also to determine if they will be performing the calculation or checking it. While both students are required to perform the calculation, only the one in the "Calculated by" category will actually turn the assignment in. The student assigned to perform the calculation then has three days to do the calculation before they send it, along with the Design Review Form (see Appendix) over to the checker. The checker than has two days to review the calculation and return it with mark ups and comments on the form. This leaves two days for the student who performed the calculation to either agree with the checkers recommendations (assuming the checker found issues with the homework) or not. The student who then performed the calculation then turns in the assignment along with the Design Review Form completely filled out, including the comments from both parties. The checker turn in the completed form also, albeit without the final comments from the student performing the calculation.

The scoring of the assignment goes as follows. If the assignment is correct, and the checker either agreed with the calculation or suggested changes that the calculator agreed with, they both get full credit. If, however, the assignment is incorrect, then there are a three possible ways to score the assignment. First, if the checker agreed with the calculation, then they will get fewer points than the calculator. Second, if the checker made (correct) recommendations and the calculator ignored them, the checker gets the higher score on the assignment. Third, the checker made incorrect recommendations and the calculator went with their recommendations, again the checker will get fewer points. So why, might you ask, does the checker get to short end of the stick in two out of the three categories listed above if the calculator has the final say? Because the way the author sees it, no matter whether you are in construction (Senior Estimator) or engineering (Senior Design Engineer), it does not really matter who performed the calculation, it is who checks it (or stamps it, in the case of the engineer) that matters.

The following is a summary of three classes that the author has taught over the years and how the grades were affected by utilizing the Design Review.

CEMT 28100 – Structural Calculations

Course Description - Practice in the calculation of loads, reactions, shear, and moment for determinate structures. Analysis and design of steel structural members subjected to tension, compression, bending and combined stresses.

This course follows the course Statics and Strength of Materials and is the first structural steel design course to be taught. We will look at the exams and the homework scores going back to 2005.

CEMT 28100	Years		
	2005 - 2017	2018-2022	
Number of Students	287	67	
Exam 1	68.6	73.1	
Standard Deviation	8.2	10.2	
Exam 2	74.3	77.4	
Standard Deviation	9.8	10.1	
Exam 3	77.8	79.6	
Standard Deviation	8.8	9.3	
Exam Average	73.6	76.7	
Homework	82	88	

As can be seen, there was an increase in both the homework scores as well as the exam scores. The exam grades increase by 3.1% (an increase of 4.1%) while the homework increased by 6% (an increase by 7.3%).

CEMT 32500 – Structural Applications

Course Description - Techniques in analyzing statically determinant and indeterminate structures with a discussion of moment distribution. Standard design procedures for wood, steel, and concrete structures. Sizing of beams, columns and connections.

First, let me say that the course description is a little outdated. The course solely focuses on steel indeterminate structures. The course has ten lectures on indeterminate structures and ten lectures on miscellaneous topics (snow and wind loads, steel joists, steel decking, etc.). Following this, the students are put onto groups and then work on a semester project for the remainder of the school year. Because the semester project is so big, following the indeterminate structure lessons and exam, I give the students the option of starting on the semester project and simply reviewing the miscellaneous lectures on their own and asking any questions they might have as they go along (this is necessary because in order to finish the semester project, they will need to use the miscellaneous lectures). So, because of this, the grading of the course is accomplished by homework (10%) and the accompanying exam (40%) on indeterminate structures, and the semester project (50%). Therefore, the only two categories to compare are the homework and Exam 1.

CEMT 32500	Years	
	2005 - 2017	2018-2022
Number of Students	293	69
Exam 1	71.4	76.3
Standard Deviation	8.5	8.7
Homework	76.5	84.4

As can be seen, there was an increase of 4.9 percentage points (6.8% increase) for Exam 1 with a corresponding 7.9 percentage point increase (10.3% increase) for the homework.

CEMT 33100 - Properties and Behavior of Soils

Course Descriptions - Identification and properties of soils with emphasis on laboratory and field testing. Behavior of soils relating to design and construction of structures and highways.

Let me start by saying that the Exam I is, statistically, the hardest exam that the author gives (followed closely by Exam 1 of Strength of Materials). Over the twenty plus years that the author has taught this course, he has tried everything. More homework, less homework, three long problems on the exam, 7 short problems, running the lectures straight through, breaking the lectures up with a laboratory. Nothing has helped.

CEMT 33100	Years	
	2005 - 2017	2018-2022
Number of Students	263	62
Exam 1	56.7	62.3
Standard Deviation	9.8	11.2
Exam 2	82.9	83.3
Standard Deviation	12.2	11.5
Exam 3	73.2	79.6
Standard Deviation	9.0	9.6
Exam Average	70.9	75.1
Homework	78	86

As can be seen, the average exam score went up by 4.2 percentage points (5.9% increase), while homework scores went up 8 percentage points (an increase of 10.2%). One note is that Exam 2 is basically a make up exam to offset Exam 1. It is based upon soil classification, and therefore if the student can perform in the laboratory, they can perform in the exam. Because there is no homework for Exam 2, there is no Design Review (although the laboratories are performed as a group, the laboratory reports are written individually). If we were to look at just exams 1 and 3 which utilized the Design Review for homework), the table would be as follows:

	Years	
	2005 - 2017	2018-2022
Exam 1	56.7	62.3
Exam 3	73.2	79.6
Exam Average	65.0	71.0

As can be seen, the difference is greatly increased. The difference is now six percentage points apart (9% increase).

So, to summarize, the final table is as follows:

Years			
2005 - 2017	2018-2022		
CEMT 28100			
73.6	76.7		
82	88		
CEMT 32500			
71.4	76.3		
77	84		
CEMT 33100			
65.0	71.0		
78	86		
	Years 2005 - 2017 AT 28100 73.6 82 AT 32500 71.4 77 AT 33100 65.0 78		

* Subtracting out Exam 2

Conclusion

First of all, I would like to say that from my back of the envelope calculations, the percentage of students that received "A's" in the classes did not, statistically, change. Nor did those students who received "D's" or "F's". It would seem that over the years that the really good students would do well in any time period and no matter what the delivery method. And, unfortunately, the same can be said for those who do not perform the best will continue to perform poorly. The use of the Design Review did, however, seem to help the "bell curve average" student the most as I saw a healthy increase from "C's" to "B's".

This is not surprising when you think, that for the author's classes, roughly the top 10% receive "A's" and the bottom 10% receive either "D's" or "F's". So if neither the bottom nor top 10% had little movement in their final grades, then the middle 80% did, giving them approximately 20% higher increases than shown. However, one could argue that possibly other factors have come into play increasing the students scores, such as the instructor learning to be a better teacher. I discount this for one reason, this study consists of the last eighteen years of teaching, which means that the study did not start until my fifteenth year. At this point my lectures became pretty much standardized (I have typed out lecture notes that I distribute to my students) and have changed very little over the years.

Based upon the data, it would seem that the Design Review is working and improving the students' understanding of the material. The reason for this, I suspect, is that without the Design Review, the students either take a lackadaisical approach to their homework by waiting to do it at the last minute and just putting something down on paper, or simply copying homework from a classmate. Either way, the retention and understanding of it will be lacking. However, with the Design Review, if forces the students to put more emphasis on homework and in the authors opinion, better understanding of what is happening.

And on a more selfish note, the time to grade homework (which the author absolutely hates doing), is cut down dramatically. It is a win-win situation.

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