NC STATE UNIVERSITY

NSF-ITEST: Evaluating the Impact of a STEM-focused Advanced Manufacturing Program on Rural Middle School Students' STEM Content Knowledge Development

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[1]College of Engineering, [2]Friday Institute for Educational Innovation

ABOUT THE PROJECT

Project DeSIRE (Developing STEM Identity in Rural Audiences through Community-based Engineering Design):

- A four-year **research-practice partnership** (RPP)
- Students and teachers within the project experience:
  - A 3-part, grade level specific Engineering Design elective course with a focus on **Advanced Manufacturing** processes and technologies
  - Mentoring by NCSU undergraduate engineering students
  - In-depth out of class STEM Enrichment Experiences (such as a Saturday Academy and Summer Scholars program)

Project Partners:

- North Carolina State University College of Engineering
- Friday Institute for Educational Innovation at NCSU
- NC Mathematics and Science Education Network Pre-College Program (MSEN)
- A rural North Carolina School District
- Local advanced manufacturing industry

Scan the QR Code for more information on this project.

NSF Award #1949454

PURPOSE OF THE STUDY AND RESEARCH QUESTION

***Purpose of the Study*:** To explore the impact of a STEM-focused advanced manufacturing program on the STEM content knowledge of rural middle school students (grades 6-8).

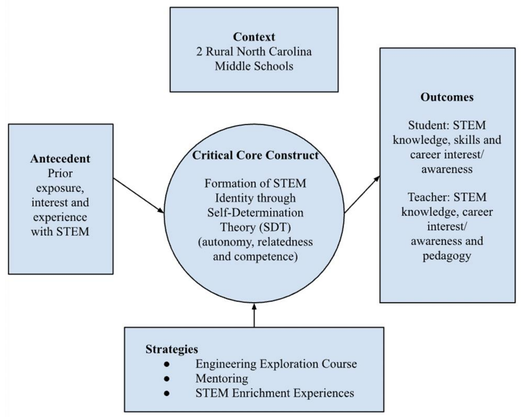
Research Question: To what degree does the engineering design-focused program impact students' science content knowledge?

THEORETICAL BACKGROUND

This project explores student **STEM knowledge & career interest/awareness** and is grounded in Self-Determination Theory (SDT) which has three core constructs:

- Autonomy
- Relatedness
- Competence

Figure 1. DeSIRE Project Theory of Action



PARTICIPANTS AND METHODS

Study Participants

- Middle school students attending two rural NC schools that both serve a predominately minority population
- Data presented represent students enrolled in 2020-21 as sixth graders and completed the course sequence as eighth graders in 2022-23.

Data Source

- **NC End-of-Grade (EOG) science tests** for grades five and eight.
- 5th grade EOG: baseline of students' knowledge of science prior to taking the 3-part engineering design course
- 8th grade EOG: final measure of science knowledge after taking the course

Methods

- Bayesian ordinal regression was performed using EOG scores to determine the impact of the program on students' science content knowledge, particularly understanding whether the number of years in the DeSIRE program had an effect on 8th grade EOG scores.

DeSIRE Course Learning Outcomes and Topics by Grade Level

	Year 1	Year 2	Year 3
	6th Grade	7th Grade	8th Grade
Topic	• Manufacturing vs. Advanced Manufacturing • Introduction to Advanced Manufacturing in the Food, Pharmaceutical and Energy Systems Industries • What is research? • Engineering Design Process • Introduction to Coding • Oral/Written Communication	• Advanced Manufacturing Technologies in the Food, Pharmaceutical and Energy Systems Industries • Engineering Design in Manufacturing Environments • Introduction to Microsoft Excel • Introduction to Basic Statistics • Data Collection • Data Analysis and Interpretation • Preparing a Scientific Poster	• Advanced Coding • Advanced Statistics • Advanced Microsoft Excel • How does data analysis and interpretation drive business decisions? • Career Opportunities in Advanced Manufacturing • Career Opportunities in STEM • Preparing an Oral Presentation

Learning Outcomes

At the conclusion of the course sequence, students will be able to:

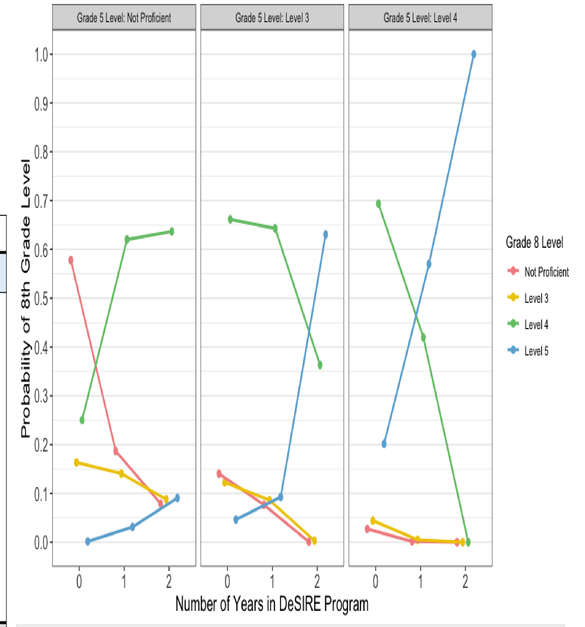
1. Define the term advanced manufacturing and provide examples of advanced manufacturing technologies.
2. Explain the difference between traditional manufacturing and advanced manufacturing.
3. Define the term research.
4. Describe examples of research being conducted in advanced manufacturing and in STEM fields generally, and the potential impact of that research on society.
5. List examples of career opportunities available in the advanced manufacturing industry and in the various STEM fields.
6. List and describe the steps of the engineering design process.
7. Implement the steps of the engineering design process in the design of various artifacts, including manufacturing systems.
8. Demonstrate knowledge of basic coding required in the programming of Lego Mindstorms, Raspberry Pi computing and Arduino microcontrollers.
9. Demonstrate growing proficiency in oral and written communication of technical information.

FINDINGS

- Overall, the DeSIRE program improved students' chances of reaching higher proficiency levels by the 8th grade regardless of their 5th grade EOG score.
- Students who participate in more years of DeSIRE increased their probability of scoring higher on the 8th grade EOG.
- Students who scored "Not Proficient" in 5th grade were 3 times more likely to earn a Level 4 with just one year of DeSIRE participation.
- Gender and ethnicity did not have a significant impact on EOG scores.
- The specific school had no significant effect on 8th grade EOG scores despite the course being taught by two different teachers in two different learning environments.

Probability of Score Level on 8th Grade EOG given 5th Grade Level and Dosage

95% Credible Interval about Expected Probability



CONCLUSION

- DeSIRE had a positive impact on participants' science content knowledge.
- The DeSIRE project's success highlights how effective, targeted educational initiatives have the propensity to impact students in rural communities.

NC STATE UNIVERSITY

Dr. Leah Bug & Dr. Amy Isvik

Engineering Together: Expanding PK–20 Engineering Outreach Across Communities

the **engineering** place

Summer Camps

Our summer day and residential camps serve rising 1st–12th graders with hands-on engineering and computer science activities delivered by NC State faculty, graduate students, and K–12 teachers. Participants join us from across the state, nation, and world. We also support partner camps statewide and collaborate with researchers and academic departments to offer **discipline-focused residential programs** for rising 11th and 12th graders.

Teacher Professional Learning

We support educators in bringing engineering into their classrooms through state and national conference workshops, Research Experiences for Teachers, team leadership at summer camp, on-campus workshops, and custom designed session for schools and districts. We host the annual ***Building Engineers in the K-5 Classroom*** Conference.

Engineering on the Road

Our Engineering on the Road programs brings engineering to life for K-12 students across North Carolina. We work with a variety of community partners: schools, Girls Scouts, 4-H, after school programs, and more.

Solar House

Solar House programs introduce students to renewable energy and sustainable engineering concepts. Visitors tour the home's passive and active solar systems and apply these ideas into a hands-on engineering challenge.

On-Campus Outreach

We welcome school and community groups to explore engineering, experience campus life, and tackle hands-on challenges through events like Engineering Bits & Bytes Days and the Boys & Girls Club Teen Summit.

Broader Impacts and Grant Support

The Engineering Place provides support to researchers looking to include K-12 students and teachers as part of their broader impact grant proposals.

The Engineering Place Impact:

In 2024 - 2025, we reached:
5,028 K-12 Students
374 Teachers

Countless future engineers inspired

86 programs

10+ Broader Impact Grant Support

44 Summer Camps

462 opportunities to engage with NC State students

20+ School Groups

7 Family STEM Nights

50+ counties

23 states

8 countries

Connect With Us!

coe-theengineeringplace@ncsu.edu
go.ncsu.edu/tep

Interdisciplinary Certificate
Skills for a Circular Bioeconomy Systems Workforce

John Classen[1] (presenter), Praveen Kolar[1], Alison Deviney[2], Mary Leigh Wolfe[3]

1 Biological and Agricultural Engineering Dept, NC State University, Raleigh, NC

2 Science and Technologies for Phosphorus Sustainability Center (STEPS), Raleigh, NC

3 Professor Emerita, Department of Biological Systems Engineering, Virginia Tech, Blacksburg, VA

Background

The **Circular Bioeconomy Systems Institute (CBSI)** hosted eight workshops in 2024 to identify major societal challenges, and the **knowledge and skills needed** for system-level innovation to transition to a circular bioeconomy system. Capabilities needed were summarized into three Strategic Themes

Strategic Themes	Capabilities Needed
Transformational Initiatives	▪ ability to work toward complex system solutions using design methods that retain system complexity ▪ disciplinary expertise to create innovations in harmony across multiple perspectives
Network Development	▪ access to and integration of representative perspectives and expertise in complex value chain ▪ ability to communicate and partner across disciplines, professions, and knowledge domains
Cultural Norms & Common Practices	▪ means to communicate state of sustainable CBS practices ▪ abilities to measure and report key aspects of circularity

Workshop Outcome: Recognition that the transition to a circular bioeconomy ***requires a workforce equipped with interdisciplinary knowledge and skills***.

Proposed Certificate Program

Certificate Topic	Gaps and Barriers Addressed
Sustainability Science: Builds systems literacy ▪ Supports outreach and mindset shifts	• Low public awareness • Poor understanding of CBS complexity • Cultural resistance
Systems Thinking & Modeling: Enables system-level analysis ▪ Promotes integration across fields	• No predictive tools • Disconnected disciplines • Lack of shared metrics and methods
Business Basics: Teaches cost-benefit skills ▪ Supports sustainable business planning	• High costs / Low perceived ROI • Supply & value chains • Industry hesitation
Policy: Builds advocacy skills ▪ Aligns policy with research and industry	• Weak incentives • Disconnected decision-makers • Policy gaps
Bio-Based Technologies: Offers technical skills ▪ Supports innovation and scale-up	• Limited tech readiness • Unclear biomass supply • Few demos

Here we present a conceptual graduate certificate to prepare students for interdisciplinary work that integrates with a variety of graduate programs:

- **Complements a student's graduate education** in their respective fields based on their knowledge goals
- **Consists of 12 credit hours of coursework** across five topics, selected from existing or newly designed courses **Figure, right)**
- **Addresses education gaps and barriers** identified in a post-workshop SWOT analysis (**Table, left**)

Bioeconomy Systems Workforce Certificate Topics

01 Sustainability Science

Life Cycle Analysis · Techno-Economic Assessment · Environmental Impact Analysis

05 Bio-Based Technologies
Synthetic Biology
Bioprocessing
Biomaterials
Bioresource Utilization

02 Systems Thinking & Modeling
Systems Thinking
Systems Dynamics
Holistic Perspectives

04 Policy
Governance, Regulations & Policy
Stakeholders and Engagement

03 Business Basics
Ecological Economics
Business Operations
Supply Chains

Questions / Next Steps…

- How can we develop a nationwide or industry-wide, association-based credential to prepare the future workforce to manage uncertainty while addressing multiple complex challenges?
- How can universities collaborate on content to make such a credential available and accessible to students across disciplines?
- How can we develop assessment rubrics for certificate competencies?

More information and Opportunities

Circular Bioeconomy Systems Institute

Presentation ID: 2501321

Interdisciplinary Certificate Skills for Navigating Uncertain Environments

John Classen[1] (presenter), Alison Deviney[2], Praveen Kolar[1]

1 Biological and Agricultural Engineering Dept, NC State University, Raleigh, NC

2 Science and Technologies for Phosphorus Sustainability Center (STEPS), Raleigh, NC

The Challenge

- Engineers design and implement change
- Change and development is accompanied by **uncertainty** (e.g. markets, time horizons, regulations, environmental conditions, ?)
- **Navigating uncertainty** in the broader context of society is different than uncertainty in measurements and data—and not something students are often trained for
- Skills to operate in a changing environment with more **unknown unknowns** is highly valued by employers

Certificate Proposal

A **12-credit hour certificate program** to fill this gap in engineering education.

Goal: to develop graduate engineers who can navigate an uncertain environment. The objectives of this certificate are for students to:

- **Use systems thinking tools and techniques** to identify and model the major drivers of change in their selected fields
- **Communicate effectively** across disciplines and audiences by building shared language and understanding
- Work effectively in **high performing teams**

Proposed topics:

- Governance, Policy, and Regulations
- Stakeholders and Engagement
- Systems Thinking and Dynamics
- Change Theory and Change Management
- Case Studies of Managing Change
- Artificial Intelligence Tools and Ethics
- Team Science and Integration and Implementation Sciences

Training for Navigating Uncertain Environments

What is needed:

- Understand circularity concepts and interdependencies
- Common language within & across disciplines & perspectives
- Shared working knowledge across disciplines
- Managing trade offs, risk, and ambiguity
- Recognizing interconnectedness among systems
- Model system changes over time
- Understand tipping points

Generalizable across education and experience levels

Overarching Competencies:

Systems Thinking

Communication

Teamwork

Customizable across different graduate programs

Acquired skills upon completion:

- Ability to mange information, feedback loops, and interdependence
- Effectively engage with different audiences
- Advise policy- and decision-making
- Working in/with complex, ambiguous, and/or dynamic systems
- Anticipate impactful changes or unintended consequences
- Develop and use modeling tools

Next Steps…

- Customize proposed certificate to different programs while addressing the overarching competencies listed above.
- Consult with local industry advisory boards and thought leaders for employer needs.
- Develop assessment rubrics for certificate competencies.

Presentation ID: 2501322

CORA: Enhancing Learning for Nuclear Reactor Operator Trainees with Large Language Models

Jason Clifford[1,2], Jake Mikouchi-Lopez[1], Mason Mines[1], Jason Hou[1], Alexander Heifetz[2], and Xu Wu[1]

[1]Department of Nuclear Engineering, North Carolina State University

[2]Nuclear Science and Engineering Division, Argonne National Laboratory

Operator Training Materials

PULSTAR Materials
- Fundamental NE content
- Facility-specific operation procedures, tech specs, and safety protocols

NRC GFE Question Bank
- 1,400+ pages of MCQ
- Extensively validated
- Covers NE fundamentals and reactor operation

Schematics & Visuals
- System diagrams
- P&IDs
- Operational data trends

Data Processing Pipeline

- Document parsing
- Natural language processing
- Validation checks with human experts
- Visual Indexing

Knowledge Graph

- Structured network linking concepts, procedures, and equipment
- Graph-RAG for contextual knowledge
- Traceable source nodes for LLM responses
- Visual interface for intuitive exploration

Case Study Implementation

- NE 235 Nuclear Reactor Operations
  - 15-25 students
- NCSU Reactor Operator Training Program
  - 3-6 annual trainees

User Progress Profiles

- Tracks scores and knowledge gaps
- Informs content personalization
- Correlates CORA engagement with learning outcomes

Human Evaluation

- Maintain traditional assessment methods
- Certified instructors perform regular knowledge checks
- Expert validation of operator readiness
- Human-in-the-loop safety oversight

Student

- Unique profile for each user
- Personalized content delivery
- System adapts to learning style over time
- CORA assists, not replaces, the study of traditional materials

CORA

Cognitive Operator Readiness Assistant

AI-Enhanced Training for Nuclear Reactor Operators

Adaptive Learning Cycle

LLM Agent

- Domain-specific tuning on reactor operations
- Retrieval-augmented generation (RAG) with knowledge graph
- Grounded responses limit hallucination
- Modular architecture

User Interface

Three modes address diverse learning needs

Guided Learning
- Step-by-step concept breakdowns

Dynamic Q&A
- Freeform exploration of topics to identify knowledge gaps

Personalized Assessment
- Adaptive quiz generation to prepare for instructor checks

U.S. DEPARTMENT OF ENERGY

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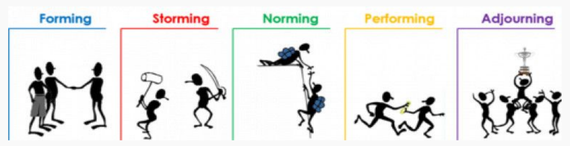
Argonne NATIONAL LABORATORY

NC STATE UNIVERSITY

Impact of Team Formation Technique in ECE Capstone Course

Rachana Gupta, ECE NC State and Greg Dunko, RiOT NC

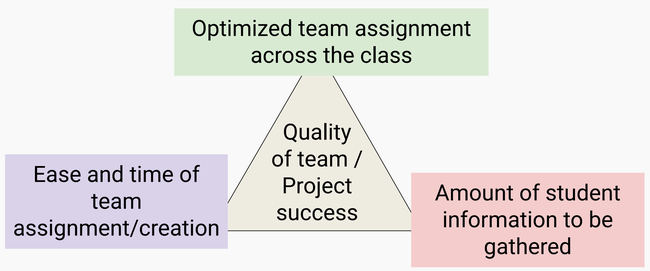


Introduction and Background

This 6-year study presents a successful, scalable method for forming teams in large engineering capstone courses. By factoring in variety of student attributes and preferences, the technique optimizes assignments, significantly improving project performance and teamwork learning outcomes.

Teamwork is a vital capstone outcome, where complementing skills and personalities (e.g., trust, synergy) drive better design. Data collected from 2015-2017 revealed challenges such as unbalanced project popularity, conflicting student priorities (teammates vs. project topic), and distinct engineering personas (Coder, Builder, Designer). In response, a new assignment method was implemented (2018-2020) to address these issues. This method aims to optimize success across *all* projects globally rather than creating isolated "dream teams," while also teaching team effectiveness and ensuring the process remains scalable for large classes of up to 200 students.

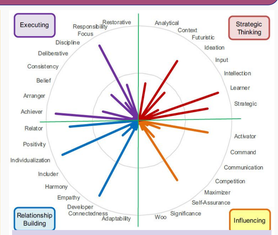
Purpose and Goals



- Optimize design teams across the class to maximize broad success
- Ease of team assignment in large classes (120 and more)
- Teaching Team Formation Effectiveness to Students

Instructor Based Team Assignment (2015-2017)

Engineering Technical Skills



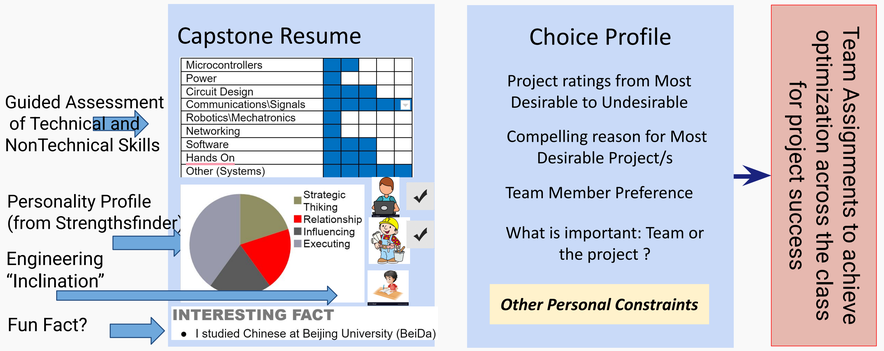
Personality Profiles and Non-technical skills

Author Observations from 2015-2017:

- **Imbalance:** 30% of projects are selected by 50% students as their top choices.
- **Preferences:** Students preferences vary between prioritizing specific teammates vs. specific projects.
- **Reasoning:** Students select projects without sound reasoning for a project based on background, experience, passion, etc.)
- **Personas:** Inability to accurately self assess skills and and understand personalities Three distinct types emerged: Coder, Builder, and Designer.
- **Member choice**: 50% of teams picked by themselves struggle through team storming and performing stages.

New Flowchart of Team Formation (2018 - 2020)

Student submits "Capstone Resume" and "Choice Profile"



- Explaining Team member preferences vs project preference
- Prioritized project choices with compelling reason
- Unique "Capstone resume" including technical skills, Engineering Inclinations and Personality profile
- Guidance on how to evaluate technical skills
- Place for students to add personal constraints (remote work, jobs, family constraints, timing constraints, etc.)

Performance Measurement and Results

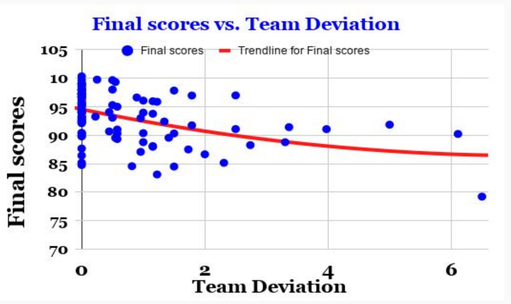
Team Deviation score : How badly does a team deviate from ideal teamwork.

- A lower score represents better teamwork through all team stages.
- Calculated via team surveys, team assessment score by instructors, team members, mentors and sponsors throughout the project span.

Final Project Quality Score: How successful was the project outcome

- Represented by the average scores for quality of design, project demos, design documents by each team.

Deviation	*Quality*	*What it means*
0-1	Excellent	No issues or able to resolve issues without help, and matching project report and assessments.
1-2	Good	Fewer issues resolving quickly, Progress assessment matches to > 90%
2-4	Poor	Several issues, need external help, progress assessment match <70%
>4	Bad	Very bad issues, no team motivation, no common ground



- 98.72% students (Extremely or very satisfied with project assignment)
- Projects success: 93.6% vs 89.4% (2 sub-letter grade change on highest project quality)
- Team and individuals assessments: 90 % teams (very good to excellent team assessments) (93.1% average project quality score)
- *90% of strong teams have balanced personalities and complimentary skills.*
- *50% of teams with no such balance but picked by themselves struggle through team storming and performing stages.*

Conclusion and Future Work

Our Team Formation approach

- enables class wide balanced team formation across full set of capstone projects
- enables assignment of balanced teams across large class sizes
- the process (and information shared) accelerates progression through the stages of team formation
- results in more successful project outcomes
- makes team assignment substantially easy and fast for instructors

Future work:

- Assessment and validation of stated skills and personalities vs performance on project
- Scaling the process to classes bigger than 200 with multiple instructors and multi-disciplinary projects
- Consideration of other personality assessment tools such as DISC or Myers Brigg

References:
1. Clifton Strength: https://www.gallup.com/cliftonstrengths/en/253862/cliftonstrengths-for-schools.aspx
2. Tuckman's stages of group development: https://en.wikipedia.org/wiki/Tuckman%27s_stages_of_group_development
3. What Google Learned From Its Quest to Build the Perfect Team, https://www.nytimes.com/2016/02/28/magazine/what-google-learned-from-its-quest-to-build-the-perfect-team.html?smid=pl-share

This paper was published in 2021 ASEE-SE conference and later was selected as the Best Paper in SE section in ASEE 2021.

NC STATE UNIVERSITY
Electrical and Computer Engineering

Social Annotation for Crowdsourcing

Abida Haque <ahaque3@ncsu.edu>
NC State, Computer Science

Abstract

I use Perusall, a social annotation tool, to inform continuous updates to an open education resource (OER) textbook. The textbooks are under Creative Commons licenses. For a higher enrollment class (400 to 800 students), I find that students ask questions or make comments that can then be implemented in the next iteration of the textbook. I have used this tool in classes with smaller enrollment (6 to 80 students), and find that the improvement cycle is not as strong due to the limited number of comments.

Social annotation takes students from being passive readers into contributors for the class. I take the comments at the end of each session of class and rewrite the textbook for the next set of students.

Students have improved textbooks before by working with instructors. There are textbooks which are not just OER but open-source. Additionally, Perusall is used in many classes for student engagement or as alternatives to reading quizzes for accountability. However, to my knowledge, the idea of "crowd-sourcing" textbooks to allow students to improve future iterations of a class is novel.

Introduction

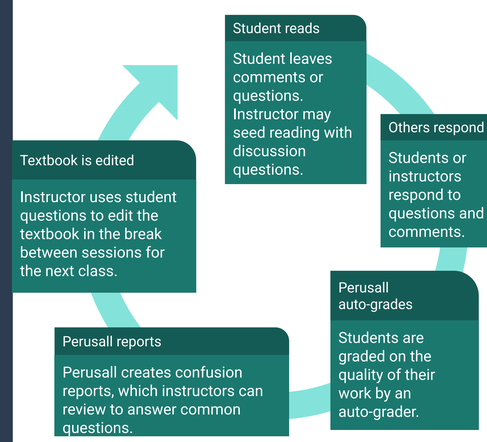
In a traditional setting, students read a text in isolation. Later, they may use the reading to deepen their understanding of lectures or use the textbook to help them complete assignments. With social annotation, students share their thoughts directly within the text. The annotation tool allows students to collaborate and answer each other's questions directly within the text. Additionally, the fact that the text is highlighted provides context into why the student is asking that question, as the readers can review all the material in the highlighted portion and across the page.

While social annotation tools like Perusall[1] or Hypothes.is[2] are used in different classes, typically to drive engagement, I implemented a continuous improvement cycle in which the instructor reviews the student questions and the confusion report that Perusall creates to rewrite the textbook.

There are OER textbooks, and some open-source textbooks such as Pat Morin's *Open Data Structures*[3] and Don Sheehy's *First Course on Data Structures in Python*[4]. Both books are hosted on GitHub. However, to my knowledge, no authors have crowd-sourced new editions, such as through pull requests on GitHub.

For higher enrollment classes, Perusall's auto-grading feature help us grade student work without reading thousands of comments per assignment and judging them. Auto-grading helps to remove me from the process of judging the work, and rather focusing on their context to help with understanding.

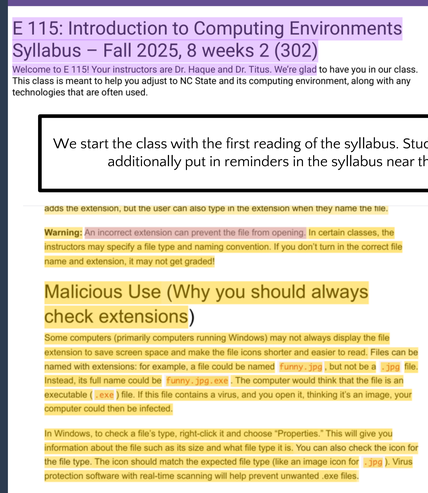
Methods



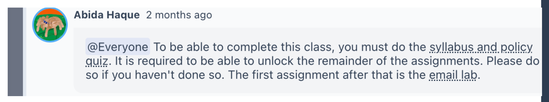
I have used Perusall and this technique across several classes:

- CSC 297, Distributed Algorithms behind Blockchains, a 1-credit hour pass/fail class with one meeting a week. There are between 6 and 12 students in this class. We used the book *Blockchain Foundations* by Dionysis Zindros[7]. I also supplemented the reading with self-made videos and posted on YouTube.
- CSC 333, Automata, Grammars, and Computability, a 3-credit hour letter-graded class with two meetings a week. There are between 60 and 80 students in this class. We use the book *Foundations of Computation* by Carol Critchlow and David Eck[8]. I supplemented with self-made videos.
- E 115, Introduction to Computing Environments, a 1-credit hour pass/fail class with no meetings (hybrid). We have between 400 and 800 students per session, which meets twice in a semester (8 weeks long class). We use the E 115 textbook[9], which is authored by myself and prior instructors of the course.

Results


E 115: Introduction to Computing Environments Syllabus – Fall 2025, 8 weeks 2 (302)

Welcome to E 115! Your instructors are Dr. Haque and Dr. Titus. We're glad to have you in our class. This class is meant to help you adjust to NC State and its computing environment, along with any technologies that are often used.


Abida Haque 2 months ago

@Everyone To be able to complete this class, you must do the syllabus and policy quiz. It is required to be able to unlock the remainder of the assignments. Please do so if you haven't done so. The first assignment after that is the email lab.

We start the class with the first reading of the syllabus. Students do have questions about the course curriculum, due dates, or other class policies. I additionally put in reminders in the syllabus near the beginning. My first image showcases a comment that I made on syllabus text.

adds the extension, but the user can also type in the extension when they name the file.

Warning: An incorrect extension can prevent the file from opening. In certain classes, the instructors may specify a file type and naming convention. If you don't turn in the correct file name and extension, it may not get graded!

Malicious Use (Why you should always check extensions)

Some computers (primarily computers running Windows) may not always display the file extension to save screen space and make the file icons shorter and easier to read. Files can be named with extensions: for example, a file could be named `funny.jpg`, but not be a `.jpg` file. Instead, its full name could be `funny.jpg.exe`. The computer would think that the file is an executable (`.exe`) file. If this file contains a virus, and you open it, thinking it's an image, your computer could then be infected.

In Windows, to check a file's type, right-click it and choose "Properties." This will give you information about the file such as its size and what file type it is. You can also check the icon for the file type. The icon should match the expected file type (like an image icon for `.jpg`). Virus protection software with real-time scanning will help prevent unwanted .exe files.

2 months ago

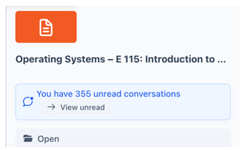
I understand that there are different file extension names that are often associated with the type of file, but I am confused about why this changes how the file is presented. I read further on and see the different ways these extensions are ran in a computer but am curious as to why.

2 months ago

File extensions are primarily used by the file system to indicate what program should be used to open, preview, or run the file. Many programs do not check the file extension to interpret the file, but instead look for byte patterns in special locations to indicate what type of file it is. An image program may look for the "PNG" bytes before attempting to interpret the file in the *Portable Network Graphics* format, even if the extension is ".jpeg" or ".webp". An interesting consequence is that **polyglot files** can be constructed to follow the syntaxes of multiple formats for either novel compatibility or concealed malware.

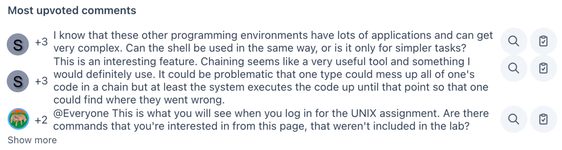
Although I have used the technique across several classes, E 115 has the highest enrollment, with hundreds of students, so the yield of student comments is the highest. I update the E 115 textbook[9] at the end of each semester by reviewing the confusion report.

After that, each page of the textbook is posted, broken into assignments with due dates. My second image shows a student asking a question, and the second student uses `@' to refer to the first poster and answer their question.


Operating Systems – E 115: Introduction to ...

You have 355 unread conversations
View unread

Open


Most upvoted comments

+3 I know that these other programming environments have lots of applications and can get very complex. Can the shell be used in the same way, or is it only for simpler tasks?

+3 This is an interesting feature. Chaining seems like a very useful tool and something I would definitely use. It could be problematic that one type could mess up all of one's code in a chain but at least the system executes the code up until that point so that one could find where they went wrong.

+2 @Everyone This is what you will see when you log in for the UNIX assignment. Are there commands that you're interested in from this page, that weren't included in the lab?

Show more

Because of the size of the class, there are hundreds of comments. Typically, some students will have their comments upvoted. As the instructor, also find that my comments are upvoted as they provide some insight into the class.

Related Work

Social annotation tools are used in science and engineering classes. McKenney and Glover[5] explored student behavior across the semester, concluding that students may be the first or last to post, depending on whether they have questions or want to answer questions. Analyzing student behavior helps with our work, as we find, for instance, that the later assignments in a semester get less social interaction as students post fewer comments.

Shindler et al.[6] use Perusall in another innovative way, which is for code review. Here, students review each others' work, helping to find errors in their programming assignments (typically, bugs or readability). This work reflects a real-world use case, as in industry, software engineers do review each other's code before releasing it. Shindler et al. note that students "desired improved functionality from Perusall". For my classes, I found that students also had criticisms about how Perusall does its grading, or felt that the reading was long and unhelpful.

References

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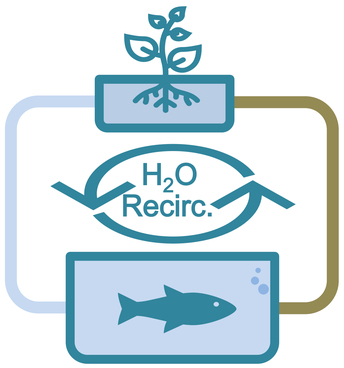
NC STATE UNIVERSITY

USING GAMIFICATION AND AQUAPONICS TO ENHANCE FIRST-YEAR ENGINEERING ENGAGEMENT AND SUSTAINABILITY AWARENESS

INTRODUCTION

- **The Challenge:** The need to engage students in K-14 science to solve global challenges like food insecurity and saltwater intrusion
- **The Approach:** Using "gamification" to increase content engagement and retention in unfamiliar STEM topics
- **Research Question:** Does gamifying aquaponics content with team-based challenges improve student engagement compared to traditional aquaponics lectures



Aquaponics Schematic

RESULTS

Group B Participant Quote: "It's actually pretty cool and [I] was told there's so [much] overlap with my major and I'd like to learn more about [Bio/Ag Engineering]."

Gamified = Higher Engagement With Unfamiliar Topics

3.2 out of 5

(14 votes)

Activity Approval Rating Overall

The gamified group reported greater engagement, with 9 out of 14 participants rating the overall experience highly, with most of the top ratings from Group B

CONCLUSIONS

Key Takeaways: Gamification, especially when combined with hands-on experiences (ex: taste tests or lab tours), increased interest in unfamiliar topics like aquaponics and Bio/Ag Engineering (BAE). Effectiveness depends on user motivation and attitudes toward gamified content (Hamari et al., 2014)
Limitations: Small sample size (n=14) and short duration

METHODOLOGY

Pedagogical Plan: Engineering First-Year (EFY) students (n=14) recruited from E101 (introductory) classes; Split evenly between two groups (A & B)

[Group A: 15-min Traditional Lecture]

[Group B: 15-min Gamified Lecture]

[Group A: Lettuce Taste Test]

[Both groups: BAE/Aquaponics Lab Tour]

Data Collection: Taste test input; Pre- and post-surveys via Google Forms
Activity: 15-minute session using same content on environmental sustainability centered around aquaponics followed by an aquaculture lab tour and an optional taste test of aquaponically grown "salty" lettuce for Group A only
Gamification Model: Fish-themed teams, tasked to design a survival scenario, using curated web-based information, as quickly as possible

ACKNOWLEDGMENTS & CITATIONS

Special thanks to Dr. Steven Hall and Dr. Chris Pasqual for their assistance with the taste test and tour; Thanks to my co-lecturer and project partner, Ms. Perry Berlin (BAE, 2025)
Citations are available at go.ncsu.edu/gamifposter

AUTHOR

Linda L Hargrove, Teaching Academic Advisor, North Carolina State University; Engineering Academic Affairs (Raleigh, North Carolina)

Semiconductor Electronics Manufacturing Program – EPack-LAB

STUDENT OUTCOMES FOR RURAL COMMUNITY COLLEGES:
Technicians Who Operate, Maintain & Install Equipment & Processes

JOIN OUR PROGRAM DEVELOPMENT

4-Yr Colleges:
Developing Electronics Manufacturing Technology Educators (EMTEs)

Electronic Manufacturing Technology Curriculum:

***Solo XR**: immersive engineering education, leveraging AUGMENTED REALITY & VIRTUAL REALITY to bridge the gap between physical and digital worlds.*

Up-Skilling

DUAL USE: Low Volume, Secure, Custom Assembly & Manufacturing Facility

EDUCATORS

2-Yr Rural Community Colleges

STUDENTS

GRADUATES

EPack-LAB PILOT "BOX" at *NC State Univ*

Electronics Manufacturing Technology Educator
- *Engineering science learning modules*
- *Training modules for the physical lab*
- *AR/VR training on Vendor Equipment*

THE BOX

1.Assemble semiconductor chips into packages

Class 100K Cleanroom

Deployable Permanent Installation

2.Assemble packages onto circuit boards

3.Assemble circuit boards into systems

*EPack-LAB: Electronics Packaging Laboratory in a **BOX***

PREES Laboratory NC STATE UNIVERSITY
PACKAGING RESEARCH IN ELECTRONIC ENERGY SYSTEMS

dchopkins@ncsu.edu

FREEDM SYSTEMS CENTER

NC STATE UNIVERSITY

Innovations in Engineering Education

Experience inside and outside the classroom

George List
Civil, Construction, and
Environmental Engineering

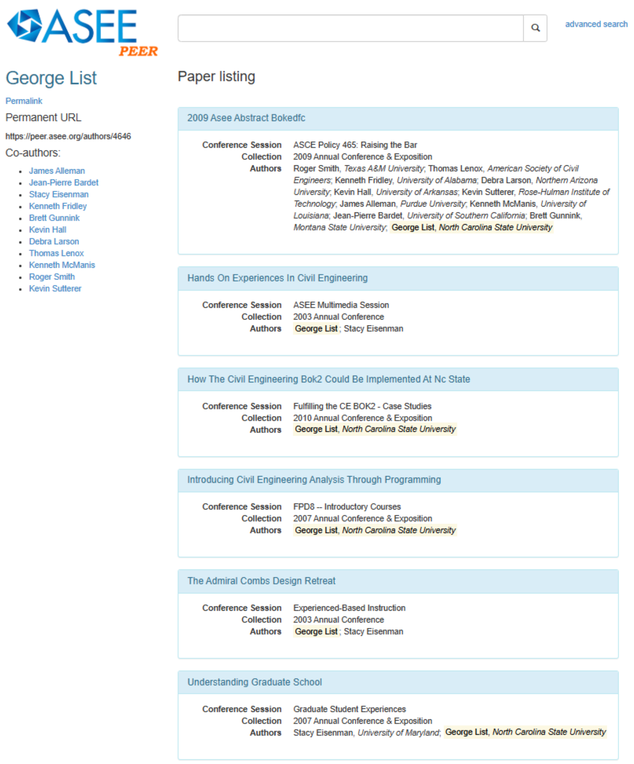
Problem: no contet, subdiscipline choice uncertainty, no exposure, limited guidance
Solution: immerse the students in subdiscipline problems in the real world

In the Classroom

- Practitioner partners
- Zoom visits by former students
- Paper-based exercises
- Use of programming and computer tools for analysis
- Kahoot quizzes
- Use freshmen to evaluate project work by seniors
- Round robin design exercises among teams at multiple universities
- Coordinated class offerings at two universities
- Use of SimCity and similar tools to illustrate infrastructure management

Outside the Classroom

- Immersion experiences
- Weeklong camps
- Hands-on experiences



Session 2793

Hands on Experiences in Civil Engineering

Stacy Eisenman and George List
Department of Civil and Environmental Engineering
Rensselaer Polytechnic Institute

Abstract

New "hands-on experiences" are being incorporated into the undergraduate civil engineering program at Rensselaer. The aim is to have students see real civil systems; better relate their classroom knowledge to the real world; tie their knowledge together, within and across the disciplines; and learn how to learn through experimental investigation and analysis. Various options are being explored ranging from three two-credit classes to a set of experience modules distributed across all four years. The areas being addressed are structural, geotechnical, transportation, and environmental engineering. The experiences will range from basic experiments to multi-disciplinary charettes. Some of the more advanced ones will emphasize simulation, where virtual systems are compared with their real-world counterparts. Others will tie together concepts from several disciplines. Some will be visits to construction sites, traffic management centers, and special lab facilities at other universities. This paper describes the experiences being devised, their potential packaging, and the findings from a pilot implementation. Overall, the experiences will help the students tie their classroom knowledge to the real world.

Fostering Critical and Creative Thinking in Undergraduate Engineering Students Using Formative Assessments

Nancy J. Moore

NC State Engineering Education Symposium, January 9, 2026

INTRODUCTION

Thermodynamic fundamentals are taught to Mechanical and Aerospace Engineering (MAE) students at NC State University in their sophomore years. During the fall of 2022, new formative assessments were created to provide students with opportunities for critical and creative thinking to improve the quality of student learning.

METHOD

Three assignments were added to the course and administered throughout the semester to 168 students:

1. **Debate units of measurement and get to know classmates.**
2. **Create a solution to a given problem and then reflectively assess the solution's feasibility relative to the laws of thermodynamics.**
3. **Create a concept map that could be used to find a problem's solution.**

DEBATE USING JAMBOARD

English Units vs. Metric Units

Each of you have been assigned to a group and have been assigned to one side of the debate. Using Jamboard, each of you will post a sticky note with an argument for your side. Then you will post a sticky note in response to a note posted by someone on the other side.

Students' Posts:

"My only argument for English units is that they are more intuitive to people based on scale. SI units tend to be less."

"English units are better because they have better intervals. There is a big difference between 20˚C and 21˚C, but a smaller difference between 69˚F and 70˚F, so it's easier to get more precise and comfortable with english units."

"Metric units are the best because they standardize all measurements to base 10. This is much easier to work with than the numerically unrelated English system."

"This is a great resource to remind me of the nicer things in life, unlike the English units."

CREATIVE SOLUTION USING MOODLE

Carter-Finley stadium will be the site of an outdoor NHL game this February. The university wants to make sure that every spectator is comfortable at the game. You have been asked to design a system that will regulate the temperature for each spectator at the stadium. In one or two paragraphs, explain the system that you would propose. You do not have to necessarily obey the laws of thermodynamics.

Students' Answers:

"My system would be an individual HVAC unit built into each seat of the stadium…"

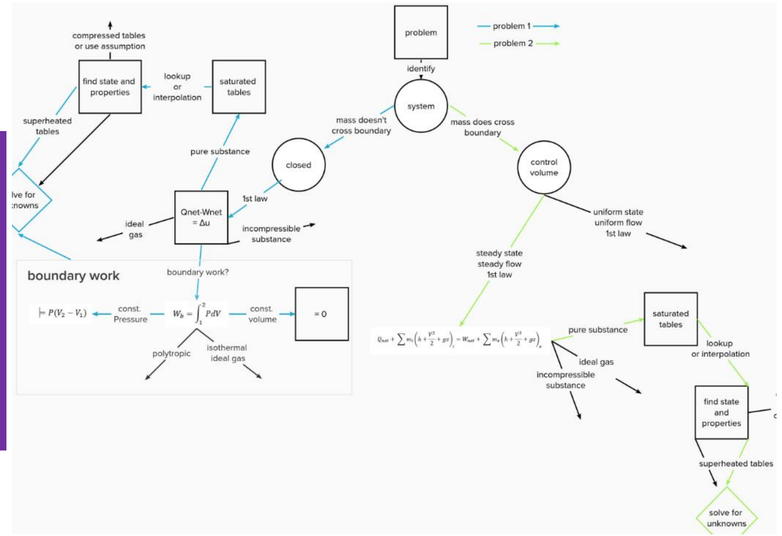
"The first step in my plan is to install seat warmers in the seats at Carter Finley. This can be done with technology similar to those in modern cars…"

"The heat pump will warm the stadium seats to 75 degrees Fahrenheit (about 24 degrees Celsius) by taking in how loud the crowd is and converting that to energy to power the heat pump…"

CONCEPT MAP USING MURAL

Student sample:

Develop your concept map using connectors and colors. Your concepts should be arranged in the way that makes sense for you and explains your steps for solving the two problems below. Your concept map should contain what you need to solve both problems.



Each of these assessments used a different online technology that could accommodate on campus students and those taking the course through distance education.

FEEDBACK FROM STUDENTS

Percent who strongly or somewhat agreed:

- 30.7% agreed that the debate helped them think about systems of units in a different way (n = 62).
- 33.8% agreed that the debate helped them get to know their classmates (n = 62).
- 27.8% agreed that making a concept map helped them think about the problem solution in a different way (n = 54).
- 57.4% agreed that making a concept map helped them better understand the first law (n = 54).

NC STATE UNIVERSITY

John Pawlowski – Senior Student, Teaching Assistant, B.S. Biomedical Engineering

Silvia Ceballos, PhD – Teaching Assistant Professor, Department of Biomedical Engineering

Transforming Linear Systems Education: Integrating KEEN, Bloom's Taxonomy, and the Question Formulation Technique to Foster Creative Thinking

Preparing Future Engineers: Cognitive Flexibility and Metacognition in Linear Systems Education – An Initial Implementation

IRB Protocol #28326

Lampe Joint Department of Biomedical Engineering

UNC CHAPEL HILL | NC STATE UNIVERSITY

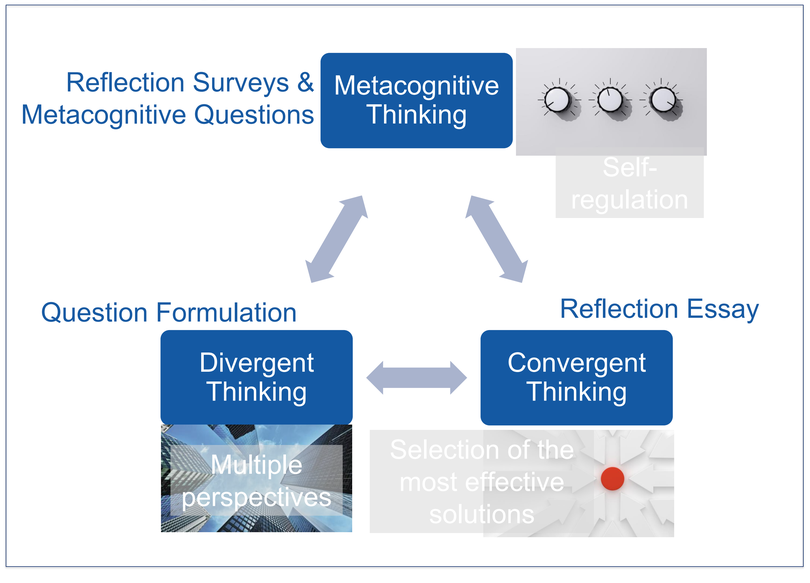
MOTIVATION: Why Metacognition Matters in Today's Employment Landscape

- Unemployment among college graduates has increased by 30% since 2022[1], disproportionately affecting entry-level positions.
- Fresh graduates who lack a strong capacity for asking and answering relevant and well-postulated questions remain vulnerable.
- It is imperative that we prepare students not only with technical knowledge, but also with the cognitive tools to navigate uncertainty.
- By fostering metacognitive awareness (through processes such as *monitoring*, *regulating*, and *adapting* their thinking) students will be better positioned to respond creatively and confidently to the challenges of the future.

[1] A. Raman, "I'm a LinkedIn Executive. I See the Bottom Rung of the Career Ladder Breaking," The New York Times, 19 May 2025.

GOAL: Move beyond passive knowledge acquisition to cultivate a dynamic, creative mindset that equips students to navigate complexity and uncertainty.

THEORY & DESIGN:



Central Message:
Curiosity sparks **confidence.**
Reflection builds **adaptability.**
These skills prepare students to thrive in today's fast-changing job market.

METHODOLOGY: In-class / out-of-class activities

Instructor grades | Individual work | Group work

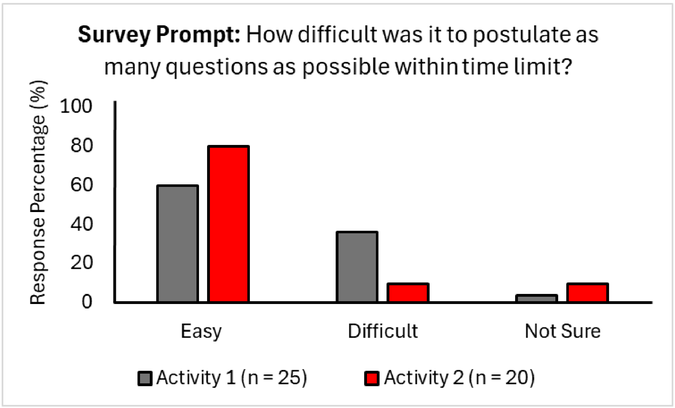
S: Survey, R: Reflection

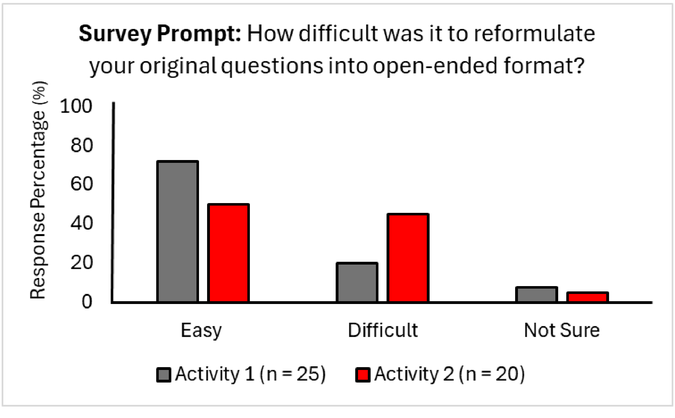
1. Produce Questions → 2. Improve Questions → 3. Prioritize Questions (S) → 4. Explore Questions → 5. Evaluate Understanding (R) → 6. Reflection on the Process (S) → 7. Instructor Evaluation

- Two in-class activities (1. Gallery Walk and 2. LEGO® Serious Play) were implemented to encourage students to generate as many questions as possible within a set timeframe. Then, a shared question bank was created and refined collaboratively.
- Students then answered metacognitive prompts about their questions, fostering reflection on biases and assumptions.
- Finally, each student wrote a two-page essay based around one question, exploring contrarian viewpoints and uncertainty.

RESULTS: Student Responses

class size: 32 students





OVERARCHING FINDINGS

(1) Students valued the opportunity to pursue curiosity and deepen their understanding of their chosen topic of interest without confined parameters in typical homework assignments.

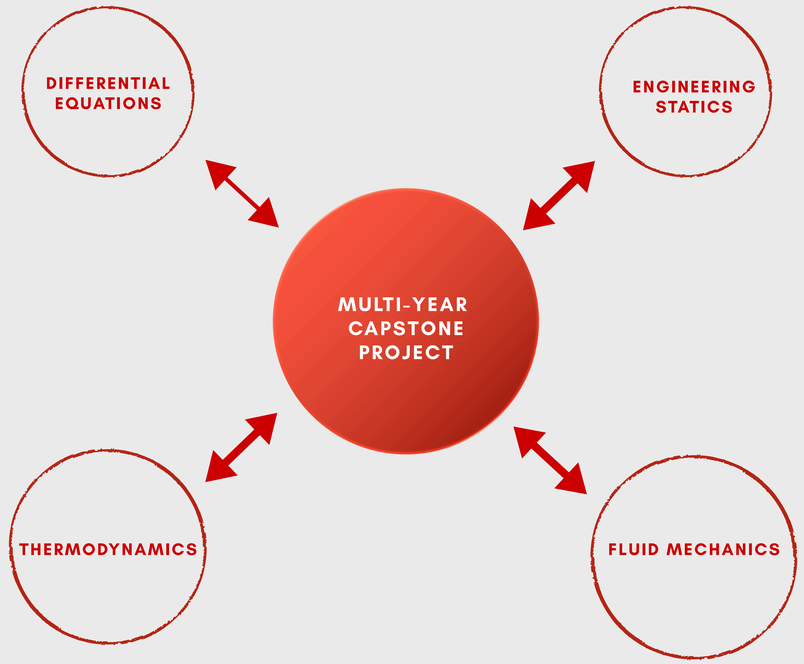
(2) Many students noted that even when answers were incomplete, the process of question generation, refinement, and metacognitive reflection led to new insights and unexpected connections.

(3) The learned process became an everyday tool for the students to provide a sense of confidence and newfound ability to navigate uncertainty/ambiguity and contrary points-of-view.

NC STATE UNIVERSITY

Integrated & Practical Engineering Programs

Do Engineering from Day One



PROBLEMS

THEORY-PRACTICE DISCONNECT
Most coursework lack practical application

FRAGMENTED LEARNING
Courses exist in isolation, with no clear connection to each other or to a practical engineering project

EXPERIENCE GAP
Graduates lack enough real-world engineering skills coming out of college

OUR SOLUTION

INTEGRATED MULTI-YEAR CAPSTONE PROJECT

COURSE INTEGRATION
As many courses as possible should be adapted to connect to the multi-year capstone project. The College of Engineering could work with strategic industry partners or even resources like the nuclear reactor at NC State to allow students to work on actual problems that industry is trying solve.

EARLY ENGAGEMENT
Engineering students get to build from day one of their careers at NC State, whereas capstone projects currently only start in senior years.

EXPECTED OUTCOMES

IMPROVED STUDENT RETENTION
Engineering students who get to work on real world projects that have actual impact, will feel more connected to the program.

CONNECTED LEARNING
Theory meets direct application from day one, leading to great student engagement and performance.

JOB-READY GRADUATES
Portfolio-worthy practical experience, that improves the employability of graduates.

IMPLEMENTATION CONSIDERATIONS

PROJECT DESIGN
Develop multi-year capstone projects aligned with program learning goals.

COURSE ADAPTATION
Restructure courses to contribute components to integrated capstone.

AUTHOR

By: Cale Rogoyski, Graduate Student, Nuclear Engineering Department

SUPPORTING PRE-SERVICE TEACHERS IN **ENGAGING EARLY LEARNERS IN ENGINEERING DESIGN**

Elementary pre-service teachers at NC State's College of Education are required to take a course titled *Children Design, Invent, and Create*. In this course, they build content knowledge in engineering and the engineering design process, identify the benefits of incorporating engineering and making it into the elementary classroom, and demonstrate the ability to utilize this knowledge to design integrated lesson plans for K-5 learners.

AUTHOR

Briana Trager

AFFILIATION

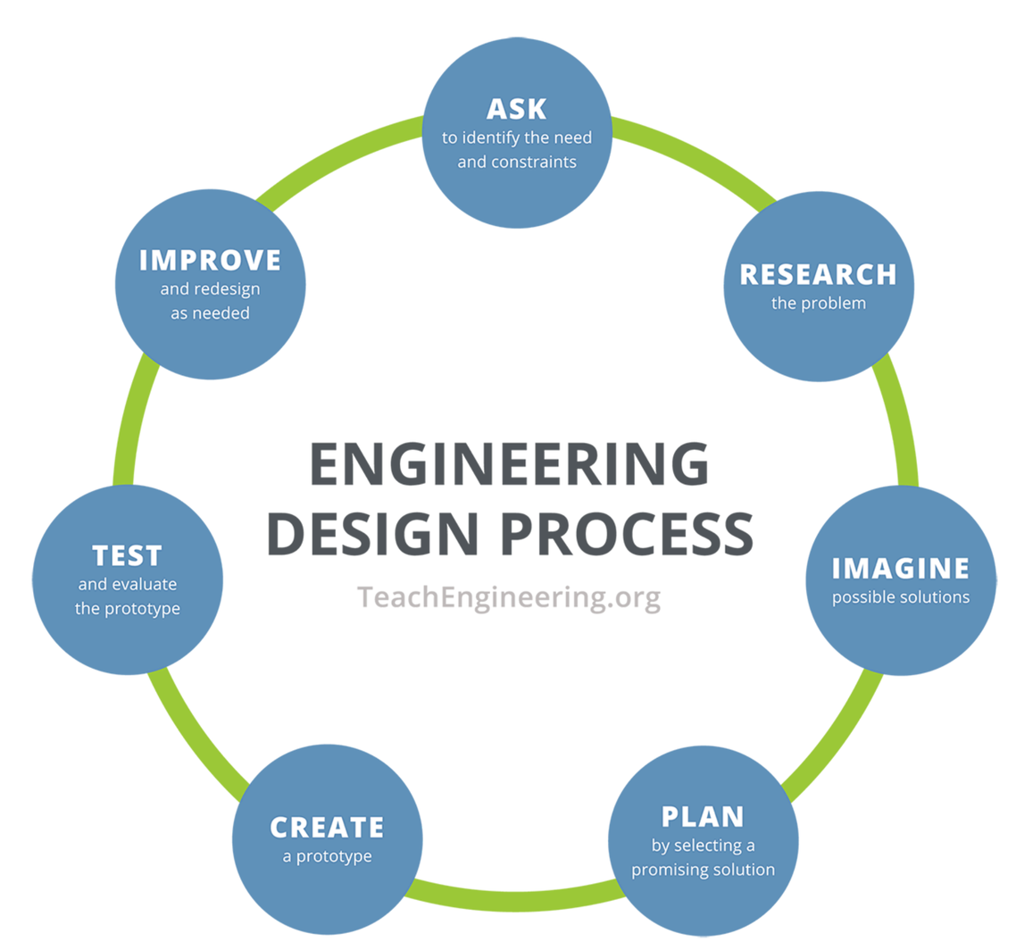
North Carolina State University
College of Education - Elementary Education

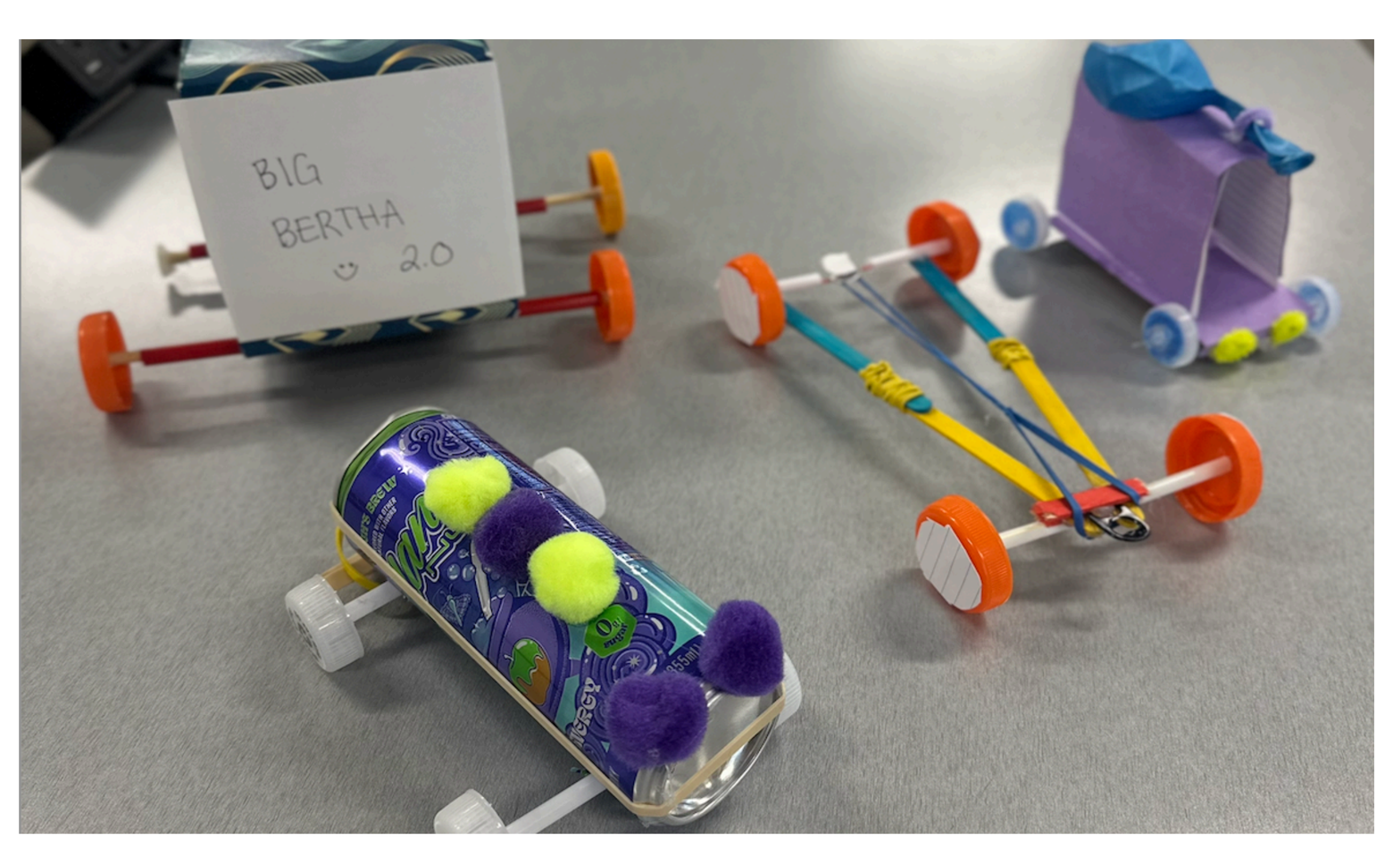
COURSE GOALS

- Build preservice teacher (PST) capacity to teach engineering in the elementary classroom.
- Bridge theory to practice
- Support elementary teachers in providing STEM and engineering access to K-5 students in local school.

BUILDING CAPACITY

Preservice teachers work to build their own understanding of engineering and engineering design through hands-on engagement In design challenges.





THEORY TO PRACTICE

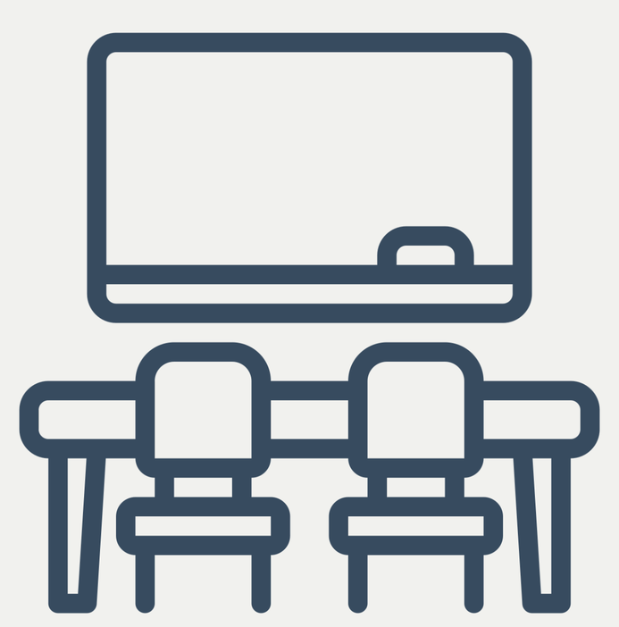
Throughout the semester, preservice teachers build connections between what they are learning about engineering and what that could look like in an elementary classroom by designing lessons and reflecting on pedagogical practices.

As a final project, students design an Integrated lesson plan which centers around an engineering design challenge and incorporates a **literacy** component and two other content areas in either **math, science**, or **social studies.**

INCREASING STEM ACCESS FOR EARLY LEARNERS

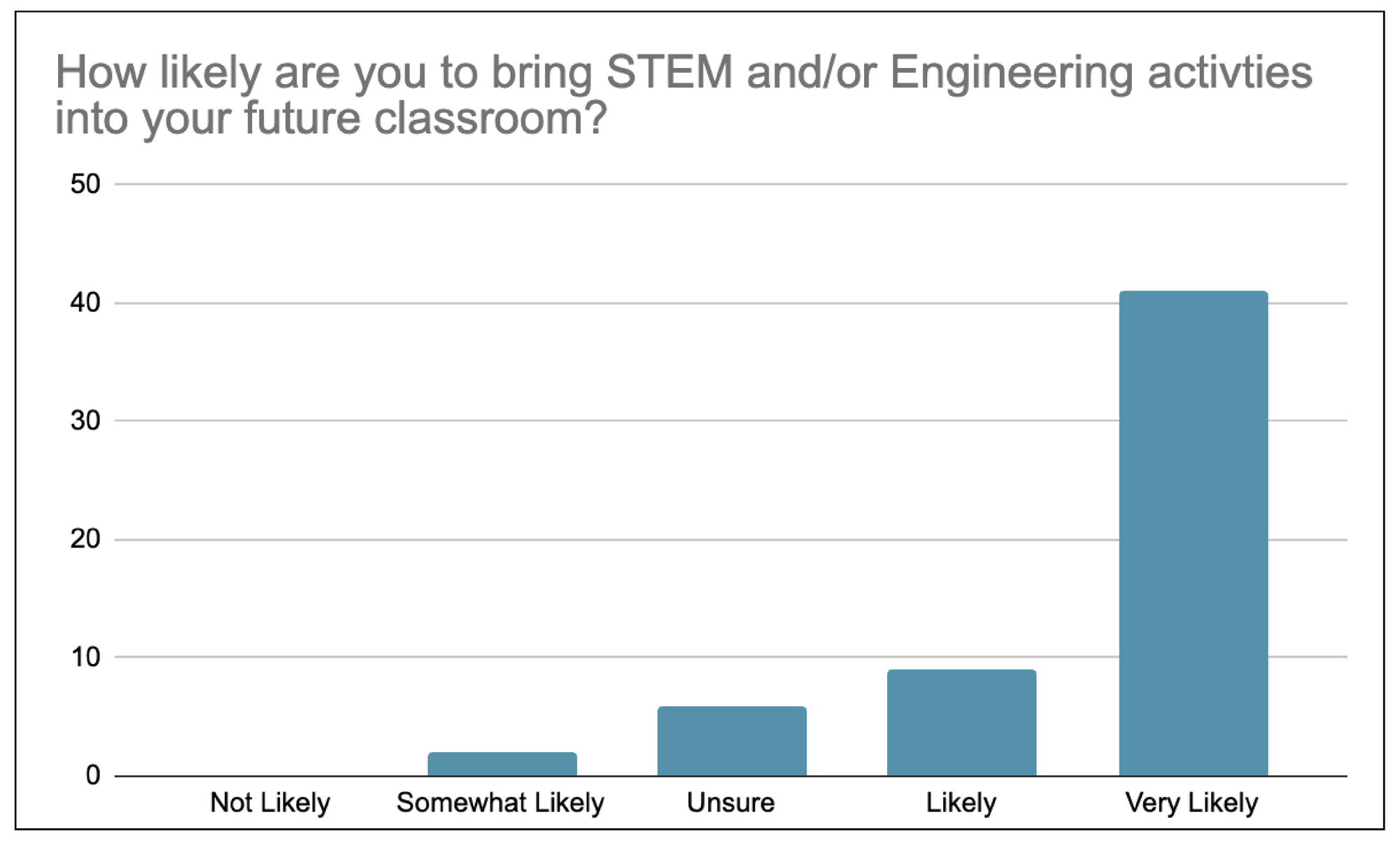
In 2025, students in this course brought engineering opportunities to:

10 elementary schools



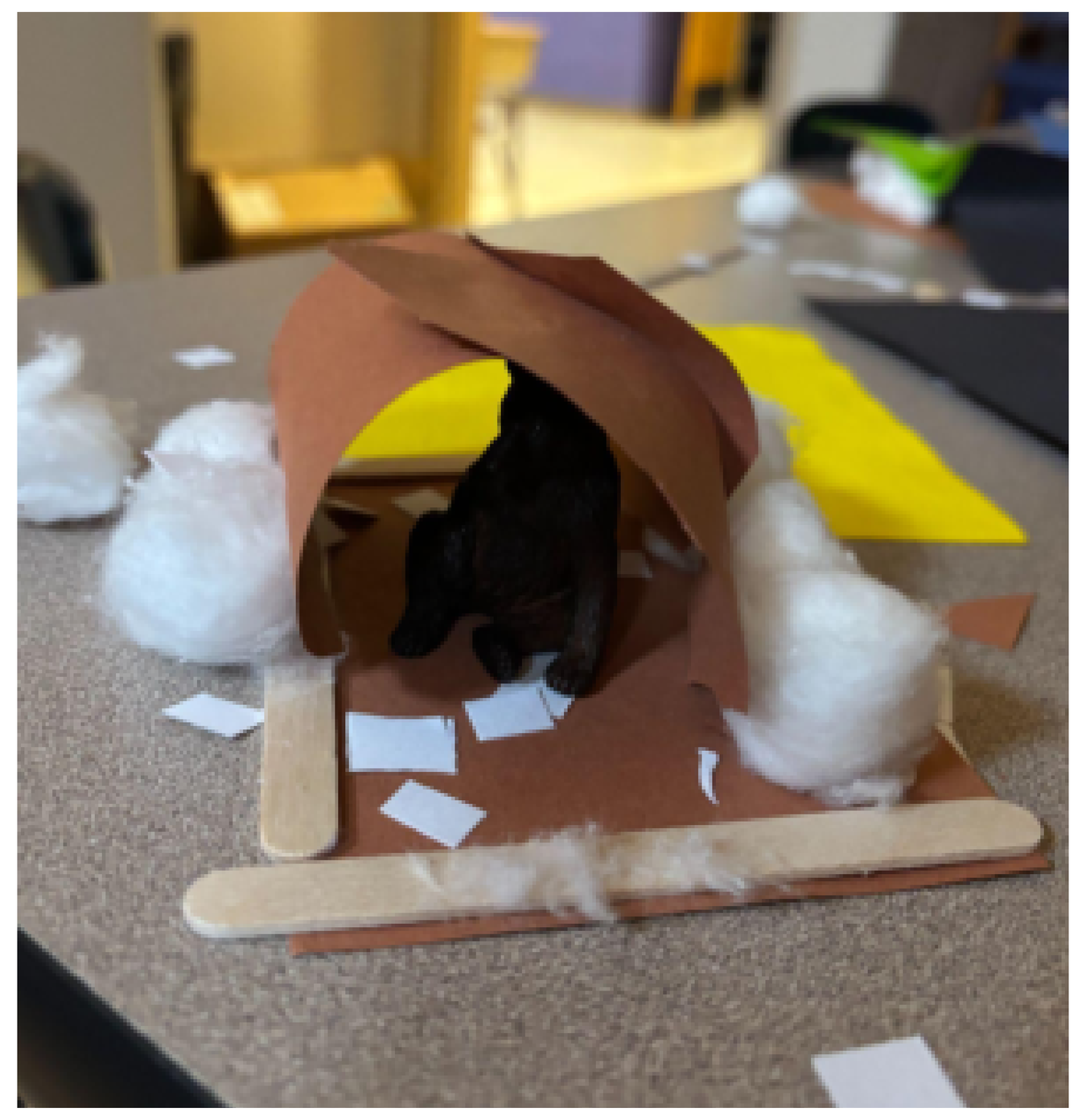
44 K-2 classrooms

Over 300 students



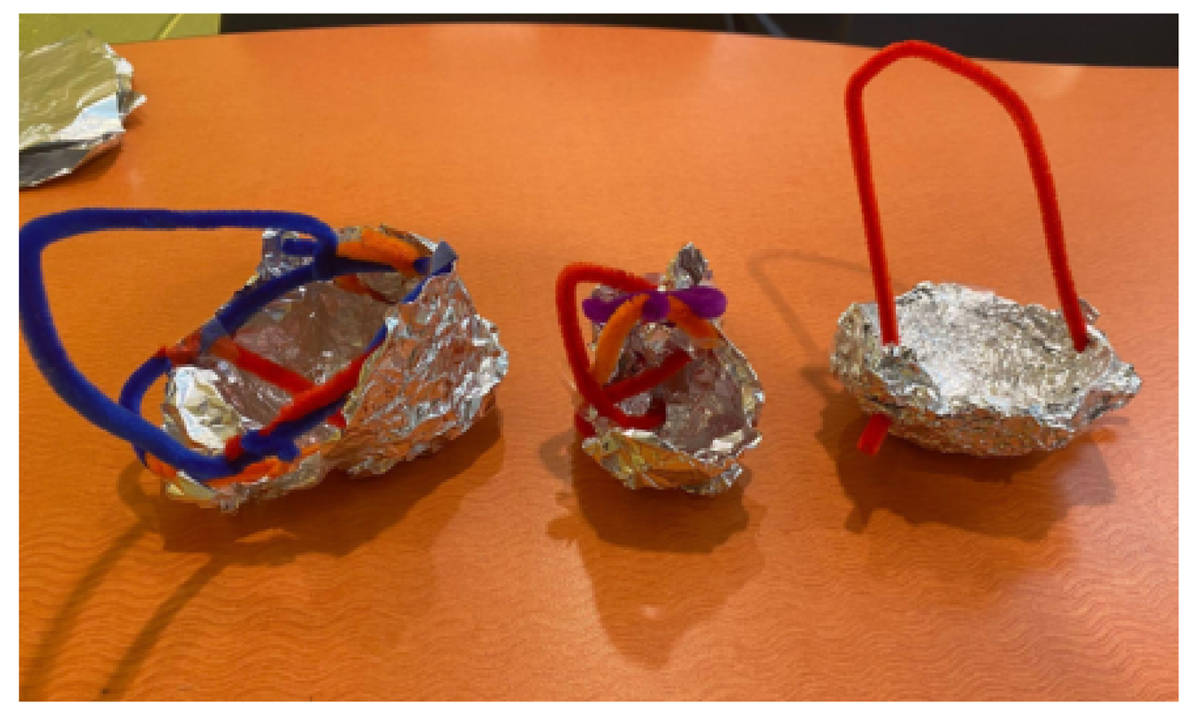
"I want to include engineering because I saw how excited the students were when we did engineering challenges and how engaged they were. I want all my students to be that excited in class and remember my class for learning something fun."

Kindergarteners design a spiderweb that can hold plastic spiders.



2nd graders build a shelter to protect animals from falling snow.

2nd graders build a bridge sturdy enough to hold weight (coins).



2nd graders design baskets to carry candy pumpkins from the "pumpkin patch".

FINDINGS

1. PSTs mindset shifted after learning what engineering is and engaging In engineering design.

Engineering is not something I would have thought could be incorporated into elementary school classes so I look forward to adding that into my future classroom.

2. PSTs see engineering as relevant to students beyond the technical skills.

I want to include engineering in my classroom because I really think it helps with life lessons and social skills. Engineering teaches us about teamwork and problem solving which are two important skills to have in the real world.

3. Challenges still persist in supporting implemention and overcoming challenges in the classroom.

I would love to [implement engineering]. I just think it may be a bit hard, realistically, since it isn't in the curriculum and would take a bit more time and effort to think about how to cater lessons to be engineering or STEM-centered.

CONCLUSION

With a rise in STEM career opportunities (U.S. Bureau of Labor Statistics, 2023), the integration of engineering into K-12 education has gained momentum and is even being promoted in classrooms as early as pre-K (Cardella et al., 2021; Ramanathan et al., 2024). With growing attention to engineering practices and skills that prepare students for a future STEM workforce, it is essential that we support teachers in developing strong instructional practices that foster high-quality engineering in the classroom, especially at the elementary level.

Engaging pre-service elementary teachers in authentic, hands-on engineering can positively impact their self-efficacy for bringing high-quality engineering experiences into their future classroom.

"Now knowing how important engineering is for Elementary level students, I am way more likely to incorporate STEM and Engineering into my lessons."