Applied Machince Learning Bootcamps:

Engineering Self-Efficacy

NACME

NATIONAL ACTION COUNCIL FOR MINORITIES IN ENGINEERING

The National Action Council for Minorities in Engineering (NACME)

The National Action Council for Minorities in Engineering (NACME) was established in 1974 by a group of concerned business leaders to develop and catalyze a suite of strategies to increase the participation of individuals from populations that have been historically underrepresented in engineering, specifically Black/African American individuals, Hispanic or Latino/a individuals, and Native American individuals (sometimes grouped together as "underrepresented minorities" or "URMs").[1] In recent years, NACME has also expanded to include a focus on broadening participation in computing. Despite some strides, the challenge of diversifying the engineering profession remains—and has not kept up with the nation's demographic reality.

The Applied Machine Learning Bootcamp

In our rapidly advancing digital age, computational engineering stands at the forefront of progress. It's an exciting multidisciplinary field that captures our imagination with its transformative potential to reshape engineering and influence industries worldwide. Yet, a persistent gap exists for equitable access to computer science, machine learning, and AI education across diverse groups, including those defined by race, gender, socioeconomic status, and geography.

The Google Applied Machine Learning (AMLI) Bootcamp - a collaborative venture between the National Action Council for Minorities in Engineering (NACME) and Google Education. This summer initiative is a robust response to this inequity by providing underrepresented minority (URM) undergraduate students with opportunities to bridge this educational divide.

Since its launch in 2021, just two summers ago, the AMLI Bootcamp has begun to rewrite the narrative as it ignites the passion of 124 students interested in computational engineering. This journey unfolded at three public research-intensive universities - the University of Kentucky, the University of Arkansas, and Morgan State University. Regardless of the delivery method - online-only, hybrid, or in-person - every student has reaped the benefits of immersive, hands-on learning and robust professional development.

Immersive and hands-on learning boosts students' mastery experiences. In this brief, we share data on students' engineering self-efficacy. Mastery experiences comprise one aspect of self-efficacy. Self-efficacy refers to an individual's belief in his or her capacity to execute behaviors necessary to produce specific performance attainments. It also reflects confidence in an individual's ability to control their motivation, behavior, and social environment.

1 Underrespresented minority groups include Hispanic/Latinx, Black or African American, and American Indians or Alaska Natives. Diversity and STEM: Women, Minorities, and Persons with Disabilities. National Center for Science and Engineering Statistics (NCSES) 2023.

Engineering Self-Efficacy

In addition to evaluating the student's learning journey and outcomes via pre- and post-assessments (e.g., career interests, confidence in machine learning, etc.). NACME reviewed the impact of the boot camp on their engineering self-efficacy. Engineering self-efficacy quantifies students' beliefs in their capability to execute tasks and solve problems specific to the engineering discipline. Yet, it is not merely an indicator of a student's confidence but a multifaceted measure linked to motivation, effort, persistence, and success in engineering undertakings.

The engineering self-efficacy survey explored four areas: General Self-Efficacy, Engineering Skills Self-Efficacy, Design Self-Efficacy, and Tinkering Self-Efficacy.

In the 2021 and 2022 boot camps, 55.9% and 55.6% of the students reported as engineering majors, respectively. Not surprisingly, students indicated moderately high levels of confidence related to engineering self-efficacy at the start of the boot camp, with even higher confidence after the boot camp.

See Table 1 for a comparison of results (pre and post-values)[2] for each year across the four areas of engineering self-efficacy.

It is encouraging to see students in the AMLI boot camp enter the program confidently and leave with even more confidence in their engineering abilities and skills. Engineering self-efficacy provides a holistic perspective on students' confidence and belief in their engineering capabilities when viewed through these four areas. With a holistic perspective, NACME and their corporate and educational partners can develop targeted interventions to bolster students' self-belief (as needed) and promote the success and growth of underrepresented students in engineering programs.

Understanding Engineering Self-Efficacy

>>> General self-efficacy is a student's belief in their capability to organize and execute the necessary actions to manage various situations. **Relevance in Engineering:** In engineering, general self-efficacy relates to students' belief that they can handle different engineering challenges, work in teams, or adapt to unfamiliar scenarios.

>>> Engineering Skills Self-Efficacy is the student's confidence in applying engineering principles and methods. **Relevance in Engineering:** Skills self-efficacy relates to core technical skills such as understanding mathematical and scientific principles and using them in real-world contexts.

>>> Design Self-Efficacy is the confidence in a student's ability to design solutions to engineering problems. **Relevance in Engineering:** Design is a fundamental aspect of engineering. Students' ability to conceptualize, plan, and implement designs that solve real-world problems.

>>> Tinkering Self-Efficacy is the student's belief in their ability to explore, experiment, and innovate with tools, materials, and techniques without always having a set objective. **Relevance in Engineering:** Tinkering can be seen as the more playful, exploratory side of engineering, often leading to serendipitous discoveries and innovations. It emphasizes hands-on experimentation over theoretical knowledge.

2 Data extracted from AMLI Reports by NACME; 2022. Results are the mean value (M=) across for all participating universities using a 5-point scale with a response of 1 being the lowest value and a response of 5 representing the highest value.

Engineering[2] Self-Efficacy	Summer 2021		Summer 2022	
	Pre	Post	Pre	Post
General	4.18	4.26	4.19	4.49
Engineering Skills	4.02	4.23	4.14	4.41
Design	3.75	4.08	3.89	4.27
Tinkering	3.68	3.91	3.81	4.13

Table 1 *- Mean values for the four areas of engineering self-efficacy assessed.*

Longitudinal Assessment of Engineering Self-Efficacy (LAESE)

Additionally, NACME conducted a longitudinal assessment of engineering self-efficacy (LAESE) with the AMLI students. Ordinarily, LAESE is done over an extended period (i.e., their entire undergraduate career or even beyond into their professional careers). These results can offer a potential starting point to track changes and evolution in AMLI's students' self-belief and confidence as they gain more experience, knowledge, and exposure in their engineering journey.

Twenty-three items were extracted from the LAESE survey instrument and administered as a pre- and post-assessment. Similar to the responses for engineering self-efficacy, students expressed high levels of efficacy.

Summer 2021	
Pre-Assesement Results	**Post-Assesement Results**

• Responses averaged above 4 on 78% of the items
• Top four responses were:
  ○ I will complete my degree at my current institution (M=4.80),
  ○ I can make friends with people from different backgrounds and/or values (M=4.69),
  ○ I will do well in my major courses this year (M=4.59) and
  ○ A degree in engineering will allow me to obtain a well-paying job (M=4.59).
	• Responses averaged above 4 on 91% of the items
	• Top four responses were:
	  ○ I can make friends with people from different backgrounds and/or values (M=4.59),
	  ○ I will complete my degree at my current institution (M=4.58),
	  ○ I can adjust to new work or learning environments (M=4.55) and
	  ○ Someone like me can succeed in an engineering career (M=4.48).

Summer 2022	
Pre-Assesement Results	**Post-Assesement Results**

• Responses averaged above 3.5, with responses above 4 on 74% of the items.
• Top four responses were:
  ◦ I can make friends with people from different backgrounds and/or values (M=4.65),
  ◦ I will complete my degree at my current institution (M=4.61),
  ◦ I will do well in my major courses this year (M=4.58) and
  ◦ A degree in engineering will allow me to obtain a well-paying job (M=4.52).
	• To streamline the survey process and mitigate student survey fatigue,' pre-assessment results and prior learnings were integrated into the program facilitators' knowledge base.
	• The results provided invaluable insights into student perceptions about completing their degrees, doing well in their majors, and leveraging their engineering degrees to obtain well-paying jobs.

Table 2 *- LAESE summary results.*

Assessing Both Engineering Self-Efficacy and its Longitudinal Assessment

Across the three campuses, the self-efficacy results were promising. In the overall responses and across individual universities, there was an uptick in multiple dimensions of engineering self-efficacy, while there were little to no significant changes recorded for the Longitudinal Assessment of Engineering Self-Efficacy (LAESE) items. Such differing results substantiate the importance of assessing engineering self-efficacy and LAESE. Assessing both psychosocial measures provides NACME with valuable insights when it comes to existing and future programming by providing:

- **Comprehensive View:** While understanding the components of engineering self-efficacy offers a snapshot of a student's confidence at a particular moment, its longitudinal assessment offers a dynamic view, capturing the ebbs and flows over time. Together, they offer a holistic picture of a student's journey.

- **Early Intervention:** By continuously assessing engineering self-efficacy, help identify and assist students at risk or facing significant challenges well in advance.

- **Program Improvement:** Continuous assessment helps to refine and improve programs like AMLI. For example, if a batch of students consistently shows low design self-efficacy, program changes might be needed to address that particular area of the program.

- **Career Development:** A longitudinal assessment can guide students' career choices. For example, suppose students' self-efficacy is consistently high in tinkering but low in structured design; the student might be more inclined to roles in research and development rather than traditional design roles.

- **Research Insights:** From a research perspective, understanding both the components and their longitudinal changes can offer insights into pedagogical strategies, the impact of modern technological tools, or the role of external factors like industry involvement in education.

In essence, while engineering self-efficacy provides the "what" (the components of confidence at a given time), the longitudinal assessment offers the "how" (how these components evolve, grow, or diminish over time). Assessing both psychosocial measures ensures that NACME has depth and breadth in understanding student confidence, allowing for a more tailored, responsive, and effective approach to our program strategy.

Key Takeaways >>>

★ **Significant Uptick in Student Confidence >>>** During both years of the AMLI boot camp, students not only started with a moderately high level of engineering self-efficacy but also exhibited a notable increase by the end of the program.

★ **Holistic Approach to Assessing Engineering Confidence >>>** Four distinct yet interconnected areas of engineering self-efficacy were explored - General Self-Efficacy, Engineering Skills Self-Efficacy, Design Self-Efficacy, and Tinkering Self-Efficacy. Each offers a picture of a student's engineering abilities and confidence levels.

★ **Longitudinal Insights for Future Growth >>>** NACME's Longitudinal Assessment of Engineering Self-Efficacy (LAESE) positions them for a dynamic view of students' confidence levels over an extended period. Such insight allows for tracking evolving self-belief and offers valuable insights for early interventions and career development.

★ **Value in Assessing Both Short-Term and Long-term Efficacy >>>** The AMLI experience highlights the value of evaluating the "what" and "how" of self-efficacy for a look at the immediate and long-term aspects of engineering self-efficacy and LAESE. By understanding both, NACME can develop targeted interventions to bolster self-belief and promote the success of underrepresented students in engineering programs.

Let's Bridge the Equity Gap

The AMLI Bootcamp is a testament to the transformative power of collaboration, education, and unwavering dedication.

As evidence-based research advocates, NACME invites you to lend your expertise and passion for creating a world where every aspiring mind, regardless of background, can flourish and contribute to the transformative landscape of engineering and technology.

By joining our collaborative efforts, you will play a pivotal role in designing and implementing programs that address the disparities in access, ensuring that every aspiring student, regardless of their background, has an equal opportunity to thrive in these rapidly evolving fields.

As you embark on this journey with us, your dedication will inspire countless young minds, ignite a passion for learning, innovation, and growth, and become a driving force in bridging the gap of inequity in computer science, engineering, and AI education for underrepresented minority undergraduate students.

Let's forge a path toward a more equitable and promising future in technology and beyond.

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