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Ducks and Diversity: Expanding Pre-College Engineering Participation through Themed STEM Fairs

Dr. Douglas Yung, Syracuse University

Dr. Douglas Yung is an Associate Teaching Professor and Program Director in the bioengineering undergraduate program at Syracuse University, where he has made a significant impact through his teaching, research, and community outreach efforts. With a research focus on interfacing microbes with engineering tools at the micro- and nano-scale, Dr. Yung is exploring methods to rapidly assess the viability of superbugs and harness energy from extremophiles using advanced electrochemical, optical, and MEMS devices. A champion of diversity and equity in engineering education, Dr. Yung has designed innovative curricula that integrate project-based learning, hands-on activities, and peer collaboration. He is a strong advocate for incorporating disability perspectives in biomedical engineering, aiming to train a generation of engineers who are equipped to tackle accessibility challenges in healthcare technology. Dr. Yung's commitment to STEM outreach is evidenced by his extensive work with underrepresented K-12 students in Central New York. Through various programs, including those at La Casita Cultural Center and local schools, he has fostered a love for science and engineering in young minds, providing over 300 hours of instruction. His dedication to equitable education extends to developing initiatives that engage students from all backgrounds, and his efforts have earned him the Chancellor's Excellence in Citation Award at Syracuse University. In addition to his academic duties, Dr. Yung is an active leader in promoting humanitarian engineering, emphasizing the importance of socially inclusive and sustainable engineering solutions in his teaching. He has collaborated on various projects aimed at addressing the needs of marginalized communities and has led numerous outreach activities to expose high school students to biomedical engineering. Dr. Yung's contributions to education and outreach have been widely recognized, including receiving the College Educator of the Year Award (2022) and STEM Outreach Award (2024) by the Technology Alliance of Central New York.

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Abstract

This study explores the impact of themed, hands-on STEM fairs in expanding engineering participation among underrepresented K-12 students by fostering engagement and self-efficacy. Situated within the broader field of STEM engagement research, this work contributes insights into how culturally resonant, informal learning environments enhance STEM interest and confidence. Specifically, it examines the "United We End Racism" STEM Fair, where interactive, duck-themed stations, such as “Splash Shield: Duckling Drop Engineering” and “Quake-Proof Quacks: Duck House Design,” serve as mechanisms for engagement. These activities introduce engineering principles, including surface tension, biomimicry, material science, and structural engineering, in an accessible and relatable manner, aligning with diversity and inclusion efforts in STEM education.

A mixed-methods approach was employed to assess the fair’s impact. The study involved a diverse cohort of K-12 students from underrepresented backgrounds. Data collection methods included pre- and post-event surveys to measure shifts in STEM confidence and interest, observational analyses of student engagement, collaboration, and problem-solving behaviors, and embedded knowledge checks to evaluate comprehension of engineering concepts. The findings highlight high engagement rates, with 85% of participants actively interacting with multiple stations. Qualitative feedback underscores the effectiveness of integrating social justice themes, such as disaster resilience, in making STEM education culturally relevant and inclusive. Educators and parents reported that the thematic activities enhanced students’ ability to connect STEM principles to real-world challenges, reinforcing the value of hands-on, contextualized learning experiences.

Additionally, this study explores the scalability and cost-effectiveness of themed STEM outreach, providing insights into best practices for implementation in low-resource settings. By demonstrating how culturally relevant, gamified engineering challenges foster both engagement and STEM self-efficacy, this research offers a framework for designing inclusive STEM education initiatives that inspire long-term interest and participation among underrepresented students.

Introduction

Despite significant advancements in education, STEM fields continue to exhibit a persistent underrepresentation of marginalized groups, particularly among K-12 students. Black, Hispanic, and Native American individuals collectively make up only 11% of the STEM workforce in the United States, despite representing over 30% of the overall population [1]. This disparity underscores systemic inequities, including limited access to quality STEM education, under-resourced schools, and a lack of visible role models in technical fields. These challenges are further compounded by broader societal factors, such as implicit biases and socioeconomic barriers, that disproportionately affect underrepresented communities [2].

Addressing this disparity requires innovative strategies that extend beyond traditional classroom settings. Informal learning environments, such as STEM fairs, offer a promising avenue to engage underprivileged students by providing hands-on, interactive learning experiences. Research demonstrates that micro-learning, short, focused educational activities, can significantly enhance comprehension and retention, particularly for students with irregular access to formal education [3], [4]. Additionally, incidental learning, which occurs naturally during enjoyable and engaging activities, has been shown to foster curiosity and build foundational knowledge among students who might otherwise disengage from STEM subjects [5]. These approaches, when combined with culturally relevant and community-driven initiatives, can play a pivotal role in bridging educational gaps.

The “United We End Racism” STEM Fair exemplifies how community-centered events can integrate engineering education with themes of social justice to create impactful learning experiences. Through duck-themed activities, the fair connects abstract engineering principles to tangible, real-world applications, making STEM both accessible and meaningful. For instance, “Soapy Science: How Surface Tension Propels Ducks” introduces the concept of surface tension in a playful and relatable way, while “Quake-Proof Quacks: Duck House Design” demonstrates structural engineering concepts within the context of disaster resilience. These activities not only promote critical thinking and problem-solving skills but also inspire students to see themselves as potential contributors to addressing global challenges [6], [7].

Moreover, thematic STEM fairs serve as transformative platforms for introducing students to engineering as a tool for social change. By contextualizing STEM concepts within culturally resonant and socially significant themes, such as environmental stewardship and disaster resilience, these activities provide students with a sense of purpose and agency. This alignment with real-world issues has been shown to enhance long-term engagement in STEM careers, particularly for underrepresented groups who may not see themselves reflected in traditional STEM narratives [8], [9].

This study investigates the dual outcomes of engagement and self-efficacy within the context of the “United We End Racism” STEM Fair. Specifically, it addresses the following research questions:

1. How do themed STEM activities, such as Ducks and Diversity, foster engagement and self-efficacy among underrepresented K-12 students?
2. What impacts do these experiences have on students’ interest in STEM careers and their self-confidence in applying engineering concepts?

To explore these questions, the study employs a mixed-methods approach. Pre- and post-event surveys measure shifts in students’ STEM interest and self-efficacy, while observational metrics, such as task engagement, peer collaboration, and facilitator interactions, provide qualitative insights. Knowledge checks and thematic analysis of feedback from participants, parents, and educators further enrich the evaluation of the fair’s impact. Preliminary findings highlight how culturally and socially relevant STEM activities can inspire and educate underrepresented students, fostering both technical skill development and sustained interest in engineering fields.

By contributing to the broader discourse on diversity and inclusion in STEM education, this paper underscores the value of integrating social justice themes into STEM outreach. The results provide actionable insights into the strategies and frameworks needed to design scalable, impactful, and inclusive STEM initiatives that can inspire the next generation of diverse engineers.

Methodology

Design of Themed STEM Activities

The “United We End Racism” STEM Fair featured a diverse range of interactive stations, each designed to integrate core engineering principles with accessible, hands-on challenges. These stations included:

- **Soapy Science:** Focused on surface tension and buoyancy through experiments that demonstrated how water interacts with soap and other substances.
- **Splash Shield:** Explored material science and structural integrity by challenging students to design and test waterproof barriers for ducklings.
- **Quake-Proof Quacks:** Introduced structural engineering concepts for disaster resilience through the design of earthquake-resistant duck houses.
- **Quack & Code:** Provided an introduction to basic coding and robotics, where students programmed simple robotic ducks.
- **Beak Engineering:** Highlighted biomimicry and functional design by encouraging students to create beaks optimized for specific tasks.
- **Magnetic Marvels:** Examined the principles of magnetism using interactive experiments involving magnetic forces and materials.
- **Quack-tacular Optics:** Explored optical science and perception through activities that demonstrated light refraction and reflection.
- **Quack the Code:** Focused on brain function and neuroengineering with tasks that simulated neural pathways and responses.

These stations were carefully crafted to ensure inclusivity and engagement, making complex engineering principles accessible and relatable to K-12 students.

Importance of Coherence

Coherence in STEM outreach activities ensures that participants can seamlessly connect concepts as they progress through increasingly complex tasks. As highlighted in Table 1, each station is carefully designed to introduce foundational principles that build upon one another. For instance, participants explore material properties in Splash Shield and later apply this knowledge in Quake-Proof Quacks, where they design structures capable of withstanding simulated earthquakes. This scaffolded approach fosters a deeper understanding of engineering principles while ensuring that students gain confidence incrementally. The seamless flow between activities reduces cognitive overload, enabling participants to focus on learning rather than struggling to connect disparate concepts.

Station	Activity Station	Purpose and Learning Objective
Soapy Science	Participants race rubber ducks in water while experimenting with soap and other liquids.	Introduce surface tension and buoyancy concepts in a playful and engaging manner.
Splash Shield	Students design protective cases for ducklings and test them against water impacts.	Explore material properties, absorption, and design for durability in engineering contexts.
Quake-Proof Quacks	Participants build duck houses and test them on a simulated earthquake platform.	Teach structural stability, load distribution, and disaster resilience through hands-on problem-solving.
Quack & Code	Students program simple robotic ducks to perform specific tasks.	Introduce computational thinking, logic, and basic coding skills through an interactive robotics challenge.
Beak Engineering	Students design and test duck beaks optimized for specific tasks, such as gripping food.	Highlight the principles of biomimicry and functional design inspired by nature.
Magnetic Marvels	Participants manipulate ducks using magnets to achieve specific goals.	Explore magnetic forces, attraction, and repulsion, connecting physics principles to practical applications.
Quack-tacular Optics	Students engage with optical illusions and light puzzles using duck-themed props.	Introduce light refraction, reflection, and perception concepts to bridge physics and biology.
Quack the Code	Students model brain circuits using ducks to simulate neural pathways and signal flow.	Demonstrate neuroengineering principles and the interplay between biology and technology.

Table 1: Overview and Purpose of Themed STEM Stations

Table 3 expands on this narrative by emphasizing the fun elements and STEM principles embedded in each activity. By blending enjoyment with education, the fair ensures that abstract concepts like fluid dynamics and biomimicry become accessible and relatable. For instance, the playful design challenges in **Beak Engineering** not only engage participants but also instill an understanding of how biological systems inspire functional designs.

Gamification in STEM Fairs

Gamification serves as a powerful tool to sustain engagement and drive motivation throughout the STEM fair. Participants were incentivized with tiered rewards based on the number of stations they completed, as shown in Table 2. This structure encouraged students to explore a wide range of activities, reinforcing the interconnectedness of STEM principles across the stations. For instance, students who successfully completed challenges in Quack & Code often brought insights into computational thinking to Quack the Code, where they modeled neural circuits. This synergy between stations highlights how gamification not only motivates but also enhances the coherence of the overall learning experience.

Moreover, gamification fosters collaboration and goal-setting. As participants competed in challenges like programming robotic ducks or designing quake-resistant structures, they often worked in teams, optimizing solutions and sharing insights. This collaborative spirit enhances learning outcomes and mirrors the teamwork essential in real-world STEM careers.

Station	Connection to Other Activities	Broader STEM Facet Explored
Soapy Science	Builds foundational knowledge in fluid dynamics, which supports understanding in stations like Quake-Proof Quacks.	Physics and environmental engineering.
Splash Shield	Directly connects to Quake-Proof Quacks by extending material application to structural designs in earthquake scenarios.	Material science and mechanical engineering.
Quake-Proof Quacks	Emphasizes collaboration and structural design, complementing principles seen in Magnetic Marvels and Splash Shield.	Civil and disaster engineering.
Quack & Code	Sets the stage for advanced problem-solving used in Quack the Code for neuroengineering and circuit simulation.	Computer science and robotics.
Beak Engineering	Reinforces the relevance of biomimicry, linking natural designs to man-made solutions, which complements Magnetic Marvels.	Biology-inspired design and mechanical engineering.
Magnetic Marvels	Provides a segue into understanding energy and forces, aligning with optical experiments in Quack-tacular Optics.	Physics and electromagnetic applications.
Quack-tacular Optics	Connects the idea of sensory inputs to Quack the Code, where brain signals mimic optical pathways in the nervous system.	Physics and biomedical engineering.
Quack the Code	Culminates knowledge by integrating mechanical, biological, and computational concepts.	Neuroengineering and systems integration.

Table 2: Connections and Breadth of STEM Principles

Station	Fun Element	STEM Principle	Intent
Soapy Science	Rubber duck races where students add soap to modify water properties.	Surface tension, buoyancy, and fluid dynamics.	Designed to capture students' attention with competitive races while demonstrating the effect of surfactants on water behavior.
Splash Shield	Designing waterproof shields for ducklings and testing against simulated rain.	Material properties, absorption, and structural integrity.	Encourages creative problem-solving as students test and iterate their designs, promoting an engineering mindset of testing for improvement.
Quake-Proof Quacks	Building and testing duck houses on a vibrating platform simulating earthquakes.	Structural stability, load distribution,	Demonstrates real-world engineering challenges, teaching

		and disaster resilience.	the importance of safety and design in disaster-prone areas.
Quack & Code	Programming robotic ducks to navigate mazes or complete tasks.	Basic coding, logical sequencing, and computational thinking.	Introduces coding principles in a tangible, visual format, allowing students to see immediate results of their efforts.
Beak Engineering	Designing and testing duck beaks for tasks like gripping, scooping, or picking objects.	Biomimicry and functional design inspired by nature.	Highlights the transfer of biological concepts into engineering designs, emphasizing how nature can inspire innovative solutions.
Magnetic Marvels	Guiding ducks using magnets to move through a course or perform a task.	Magnetic forces, attraction, and repulsion.	Simplifies abstract physics concepts into tactile, engaging activities that reveal the practical applications of magnetism in engineering.
Quack-tacular Optics	Exploring optical illusions and light puzzles with duck props.	Light refraction, reflection, and perception.	Combines fun optical tricks with hands-on learning about light behavior, enhancing understanding of physics in everyday life.
Quac the Code	Building circuits using ducks to model brain pathways and signal transmission.	Neuroengineering and electrical signaling.	Links biological systems to electrical engineering, demonstrating how circuits mimic neural pathways in a way that's approachable for learners.

Table 3: Activities with Fun Elements and Core STEM Principles

Together, these tables create a holistic picture of the STEM fair's thoughtful design, integrating coherence, gamification, and thematic elements. By aligning these principles, the fair successfully engages participants, fosters learning, and inspires underrepresented students to envision themselves as future STEM innovators.

Equity & Inclusion Considerations

The themed STEM activities were intentionally designed to foster equity and inclusion by lowering barriers to participation for underrepresented students. Each activity was crafted to be accessible to students with varying levels of prior STEM exposure, ensuring that all participants, regardless of their background, could engage meaningfully.

To achieve this, the following design principles were implemented:

- **Culturally Relevant Themes**: The duck-themed activities were carefully developed to connect STEM concepts to real-world issues that resonate with diverse student experiences. For example, activities such as *Quake-Proof Quacks* introduced disaster resilience, an issue that disproportionately affects marginalized communities, helping students see how engineering can directly impact their own lives. Additionally, by incorporating narratives and examples relevant to students' cultural and environmental contexts, the activities aimed to make STEM concepts more relatable and engaging.

- **Hands-On, Low-Cost Materials**: Many STEM education programs rely on specialized and expensive equipment, which can deter participation among students from under-resourced schools. To counter this, the fair utilized everyday materials such as paper, rubber bands, tape, and household liquids for experiments. This approach ensured that students could replicate and extend their learning outside the event without financial barriers, reinforcing the idea that innovative problem-solving does not require expensive technology.

- **Collaborative Learning**: Research suggests that collaborative learning environments improve STEM retention rates among underrepresented students. The activities were structured to encourage teamwork, allowing students to engage in cooperative problem-solving while developing communication skills. For instance, the *Quack & Code* station required students to work in pairs or small groups to program robotic ducks, fostering peer-to-peer learning and making engineering concepts more approachable through discussion and shared problem-solving.

- **Flexible Engagement Options**: Recognizing that students arrive with varying levels of confidence in STEM subjects, the event provided multiple levels of engagement. Some activities required structured problem-solving, while others allowed for more open-ended exploration, enabling students to choose their comfort level. This flexibility was particularly beneficial for students who might be hesitant to engage in a highly structured academic setting but were still curious about STEM concepts. Additionally, facilitators were trained to provide adaptive guidance, ensuring that every student, regardless of prior exposure, could participate meaningfully.

Data Collection

Participant Demographics

The study involved K-12 students, parents, and educators who attended the United We End Racism STEM Fair. A significant proportion of student participants (80%) identified as members of underrepresented racial/ethnic groups in STEM, including Black, Hispanic, and Native American communities. Additionally, 70% of attendees came from schools classified as under-resourced based on state funding data. Educators and parents were also surveyed to assess perceptions of STEM engagement and inclusion. This demographic context is crucial in evaluating the effectiveness of themed STEM activities in fostering self-efficacy and interest among marginalized students. As shown in Figure 1, participants actively engaged in STEM stations, collaborating with facilitators to explore structural engineering, fluid dynamics, and biomimicry through duck-themed activities.

Figure 1. Students and facilitators engaging in hands-on STEM activities at the fair. The left image shows participants interacting with an engineering design challenge in making a shock-resistant house for duck eggs, while the right image captures students experimenting with water dynamics and surface tension using floating duck models. These interactive activities were designed to make engineering concepts more accessible and engaging for diverse learners.

Survey Design & Assessment

To evaluate the impact of the themed STEM activities, pre- and post-event surveys were administered to participants, capturing both quantitative and qualitative data on engagement, learning outcomes, and shifts in STEM interest. These surveys were designed to measure participants' self-efficacy in engineering, their perception of STEM's relevance to real-world problems, and the extent to which the activities influenced their future aspirations.

The survey consisted of Likert-scale questions to track changes in attitudes toward STEM and open-ended questions to provide deeper insights into participants' experiences. By analyzing pre- and post-event responses, we assessed how the themed activities contributed to students' confidence, problem-solving abilities, and perception of engineering as a field accessible to diverse populations. The survey questions assessed:

- **STEM Interest**:
  - "Before attending this event, how interested were you in pursuing a STEM-related career?" (Scale: 1 = Not Interested, 5 = Very Interested)
  - "After participating in the event, how has your interest in STEM fields changed?" (Scale: 1 = Decreased, 3 = Stayed the Same, 5 = Increased)
  - "Which aspects of the event most influenced your interest in STEM (e.g., hands-on activities, interaction with facilitators, problem-solving challenges)?" (Open-ended)

- **Self-Efficacy in Engineering**:
  - "Before this event, how confident were you in your ability to solve an engineering problem?" (Scale: 1 = Not Confident, 5 = Very Confident)
  - "After completing the activities, how confident do you feel in designing and testing a solution to an engineering challenge?" (Scale: 1 = Not Confident, 5 = Very Confident)

    - "Can you describe a specific challenge you faced during the activities and how you overcame it?" (Open-ended)

- **Perceived Relevance of Engineering**:
    - "Which activity helped you see how engineering can solve real-world problems?" (Open-ended)
    - "How do you think engineers contribute to solving challenges like disaster resilience or environmental sustainability?" (Open-ended)
    - "Did this event change your perception of who can be an engineer? Why or why not?" (Open-ended)

Engagement was tracked through detailed observational metrics. Facilitators recorded data on the time participants spent at each activity, the frequency and depth of collaboration with peers, and the number of interactions initiated with facilitators. For example, participants working in small groups at the "Quake-Proof Quacks" station demonstrated an average of three collaborative problem-solving attempts per team, reflecting high levels of peer interaction.

Knowledge checks were embedded into the activities to assess comprehension of engineering principles. These brief tests, tied directly to specific learning objectives, evaluated participants' understanding of concepts such as biomimicry, material properties, and coding logic. At the "Splash Shield" station, for example, 68% of participants successfully identified the material with the highest water resistance, demonstrating practical application of material science concepts.

Analysis Framework

Quantitative analysis focused on identifying statistical changes in survey responses and knowledge check scores. Metrics such as average confidence ratings and correct response rates provided a clear measure of shifts in STEM interest and comprehension. For example, the average confidence score increased by 30% post-event, while correct answers in knowledge checks rose by 25% across all stations.

Qualitative analysis involved a thematic review of open-ended survey responses and facilitator notes, providing richer insights into the impact of the themed activities. Students frequently highlighted the relatability and cultural relevance of the duck-themed challenges. One participant noted, “The duck theme made learning fun and less intimidating—it felt like solving real problems but in a playful way.” Educators echoed this sentiment, with one teacher commenting, “Connecting engineering to social justice themes, like disaster resilience, made the activities meaningful for students who may not usually see themselves in STEM fields.” This feedback reinforced the value of designing culturally resonant activities that align with students' lived experiences.

Data Collection

A comprehensive mixed-methods approach was utilized to evaluate the effectiveness of the activities at the STEM fair. Pre- and post-event surveys were distributed to participants to capture changes in STEM interest and self-efficacy. These surveys included Likert-scale items to quantify shifts and open-ended questions to gather qualitative insights into participants' experiences. For instance, students rated their confidence in tackling engineering challenges on a 5-point scale before and after the event, while also providing narrative responses about the most impactful aspects of their participation.

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Qualitative analysis involved a thematic review of open-ended survey responses and facilitator notes. Patterns in participants' narratives revealed recurring themes, such as the appeal of relatable and playful activities, the perceived importance of collaboration, and the excitement of applying engineering concepts to solve real-world problems. Feedback from parents and educators further enriched this analysis, highlighting the cultural relevance and educational value of the program.

Results

The feedback insights presented in this study were drawn from multiple sources, ensuring a well-rounded understanding of how themed STEM activities influenced student self-efficacy and interest in engineering. Data sources included:

- Student Surveys – Pre- and post-event responses, Likert-scale ratings measuring confidence and interest**,** and open-ended reflections on their learning experiences.
- Parent and Educator Interviews – Conducted through optional post-event discussions, where attendees provided qualitative feedback on student engagement and perceived learning outcomes.

- Facilitator Observations – Collected throughout the event, capturing real-time engagement patterns, student collaboration, and shifts in problem-solving behaviors.

Participant Engagement and Self-Efficacy Growth

Survey data revealed a significant increase in self-efficacy among participants following their engagement in the themed STEM activities. Prior to the event, only 42% of students reported feeling confident in solving engineering challenges, whereas post-event responses indicated that 78% of participants felt either confident or very confident in their ability to apply engineering concepts in real-world scenarios. This notable improvement suggests that hands-on, problem-based learning approaches are effective in fostering engineering self-efficacy, particularly among students who may not have previously considered themselves capable in STEM.

Several students highlighted how the hands-on nature of the activities contributed to their learning and sense of capability. One student noted, "*Before today, I thought engineering was just about numbers and formulas. But when I built my quake-proof duck house, I realized it's about solving real problems in creative ways*." Another participant shared, "*I was nervous at first because I didn't think I was good at engineering, but after programming the robotic duck, I felt like I could actually do this*." Facilitator observations reinforced these findings. Many students exhibited increased willingness to take risks and engage in iterative problem-solving as the activities progressed. For example, at the Splash Shield station, facilitators noted that students who initially hesitated to test their waterproof designs later eagerly modified and retested their prototypes, demonstrating a shift toward engineering persistence and resilience.

Parent feedback also emphasized this growth in confidence. One parent commented, "*My daughter has always said she isn't good at science, but after this event, she kept telling me how much fun she had designing things. She even asked if we could try similar projects at home.*" This qualitative feedback suggests that increasing self-efficacy in engineering through interactive experiences can positively shape students' perceptions of their own STEM abilities beyond the event itself.

The integration of coherence and gamification proved essential in achieving high levels of engagement and learning outcomes. The scaffolded design of activities, as detailed in Table 1, ensured that students could connect concepts across stations, deepening their understanding of STEM principles. Meanwhile, gamification provided extrinsic motivation that complemented intrinsic curiosity, as evidenced by the 30% increase in self-reported confidence among participants. Together, these elements created an environment where students not only enjoyed the activities but also recognized the broader applications of STEM in solving real-world challenges.

Impact on STEM Interest and Perceived Relevance

Pre-event surveys showed that 56% of participants were already somewhat interested in STEM careers. After engaging in the activities, that number rose to 85%, with students frequently citing the interactive and collaborative nature of the event as a motivating factor. One student wrote, "*I didn't think I would like engineering, but now I want to learn more about how to build things* *that help people*." Another reflected, "*This was the first time I got to actually make something on my own instead of just reading about science. It made me realize I like working with my hands.*"

The survey also measured how students connected engineering to real-world applications. When asked which activity best demonstrated how engineering can solve problems:

- 63% of participants referenced the Quake-Proof Quacks challenge, noting its connection to real-world disaster resilience and how engineers design structures to withstand earthquakes.
- 28% of participants cited Beak Engineering, explaining how it helped them see how nature-inspired solutions influence engineering designs.
- Other students mentioned Quack & Code, highlighting the connection between coding and robotics in creating solutions for automated systems.

In addition to students, educators and parents shared positive feedback regarding how the activities made engineering more relatable. One teacher noted, *"Many of my students don't see themselves as 'engineering types,' but this event showed them that problem-solving is at the heart of engineering, and they are already good at it."* A parent remarked, *"Seeing my child so engaged and explaining engineering concepts to me at the end of the day was incredible. I wish there were more events like this."*

This feedback aligns with existing research on culturally relevant STEM education, suggesting that thematic, hands-on engagement is a crucial strategy in making engineering more accessible, particularly for students from underrepresented backgrounds who may not see traditional STEM pathways as relevant to their experiences.

Feedback Insights

Feedback from students and parents underscored the thematic impact of the duck-themed activities. One parent remarked, "*My child was excited to explain how their quake-proof duck house was similar to the buildings engineers design for earthquakes in real life*." Such comments reflect the effectiveness of linking technical education with relatable real-world applications. Similarly, 90% of educators surveyed believed the integration of social justice themes enhanced students' understanding of engineering's societal relevance. For example, a teacher observed that "*students became more engaged when they realized how engineering could help communities affected by natural disasters*."

Discussion

The findings from this study align with existing research on STEM diversity and inclusion, reinforcing the importance of culturally relevant, hands-on learning experiences in increasing participation among underrepresented groups. Prior studies have highlighted that informal STEM education plays a crucial role in fostering early interest and self-efficacy, particularly for students who may lack access to formal STEM enrichment opportunities [3, 4]. The Ducks and Diversity STEM Fair builds upon this body of work by demonstrating that themed, inquiry-driven activities can serve as a transformative tool in breaking down barriers to STEM engagement.

A key contribution of this study is its examination of how thematic engineering challenges promote self-efficacy and interest in STEM careers among underrepresented students. The increase in self-reported confidence levels (from 42% to 78%) and the rise in STEM career interest (from 56% to 85%) suggest that the activities created a meaningful shift in students' perceptions of their ability to succeed in engineering. These results mirror findings from Ong et al. (2011) and Archer et al. (2010), which emphasize the role of identity formation in STEM when students see themselves engaged in problem-solving activities that resonate with their lived experiences, they are more likely to envision themselves as future engineers.

Additionally, this study provides specific evidence of how students from marginalized backgrounds engaged differently and benefited more from the activities. Facilitator observations indicated that students who were initially hesitant to participate became increasingly engaged over time, particularly in tasks that allowed for collaboration and iterative problem-solving. One student who had never coded before remarked, "*I always thought coding was too hard for me, but after making the robotic duck move, I want to learn more about how computers work.*" Another participant noted, "*At first, I just wanted to watch, but when I saw how the other kids were figuring out how to make stronger duck houses, I wanted to try it too.*" These qualitative insights suggest that low-stakes, play-based learning environments provide an entry point for students who might otherwise feel excluded from traditional STEM settings.

The duck-themed activities specifically contributed to STEM identity formation by contextualizing engineering concepts within relatable, real-world challenges. For example:

- Quake-Proof Quacks allowed students to experiment with structural resilience, making direct connections between disaster preparedness and engineering solutions.
- Beak Engineering introduced the concept of biomimicry, encouraging students to draw inspiration from nature to create functional designs.
- Quack & Code made programming accessible by embedding computational thinking in a fun, tangible challenge that demystified the coding process.

The integration of thematic and culturally relevant elements was pivotal in fostering both engagement and understanding. Students not only learned STEM principles but also connected these concepts to broader societal challenges. For instance, participant feedback emphasized the value of addressing real-world issues like disaster resilience through activities like Quake-Proof Quacks (see Table 1). The cultural resonance of the duck theme further contributed to the program's success, with one facilitator noting, "*Students from all backgrounds could relate to the theme, which made STEM feel more accessible and inclusive*." These qualitative insights illustrate how thoughtfully designed activities can inspire underrepresented students to see STEM as both achievable and impactful.

Despite these achievements, challenges remain in scaling the program to underserved areas. Resource constraints, including limited access to materials and trained facilitators, present barriers to broader implementation. Additionally, the reliance on self-reported survey data and observational metrics introduces potential biases. While 78% of students reported increased confidence in solving engineering challenges, some of this feedback may reflect social desirability rather than true learning gains. Facilitator observations, while valuable, also varied in consistency, underscoring the need for standardized assessment tools to ensure reliable data collection.

Conclusion

This study underscores the power of culturally relevant, hands-on STEM engagement in fostering self-efficacy, interest, and diverse participation in engineering education. The Ducks and Diversity STEM Fair not only provided an accessible and engaging learning environment but also demonstrated that themed, problem-based challenges can be instrumental in shifting perceptions of STEM among underrepresented students.

Findings indicate that students from marginalized backgrounds particularly benefited from the collaborative, low-stakes structure of the activities, with many participants expressing newfound confidence in their problem-solving abilities. The significant increase in self-efficacy and STEM career interest suggests that similar approaches could be scaled and adapted to other informal STEM learning environments, further supporting efforts to broaden participation in STEM fields.

In contrast to traditional outreach efforts that focus solely on content delivery, this study emphasizes the importance of designing activities that are both engaging and socially relevant. The success of this fair highlights a critical framework for future STEM outreach initiatives:

- Use thematic storytelling to make STEM concepts more relatable and meaningful. –
- Leverage hands-on, iterative challenges to promote engineering persistence and resilience.
- Create structured opportunities for collaboration to encourage peer learning and identity formation in STEM.

Future research should explore the long-term impacts of participation in themed STEM events, examining whether early exposure to hands-on engineering challenges influences students' course selections, extracurricular involvement, or career aspirations over time. Additionally, expanding the duck-themed framework to other STEM disciplines, such as environmental sustainability, robotics, or biomedical engineering, could provide further insights into how contextualized learning supports diverse participation in STEM education.

By continuing to design inclusive, immersive, and culturally relevant STEM experiences, we can foster a new generation of engineers who see problem-solving as not only an academic pursuit but also a means to create meaningful change in their communities.

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