Expanding Access to Humanoid Robotics and AI Education: A Comparative Case Study of Two Youth Summer Camps for Underrepresented Students

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Abstract

This paper presents the lessons learned from an outreach initiative conducted by the Citadel in the form of a Summer Camp held in 2025. This camp represented the second in a planned series of nine Summer Camps over a five-year period, organized under a National Science Foundation (NSF)-funded project. The program aimed to increase public awareness among younger generations about Artificial Intelligence (AI)-enabled devices and humanoid robots, and their applications and impact in healthcare within South Carolina.

While originally the camp targeted underrepresented middle school girls as part of a broader effort to promote gender diversity in STEM fields, administrative changes in federal funding led the 2025 camp to expand eligibility to both girls and boys and age group shifted to 8 to 12. The program was facilitated by a multidisciplinary team of ten faculty members, staff, and volunteers from the Citadel, with logistical and administrative support from Four Rivers Outreach Community Development Corporation and Mt. Moriah Missionary Baptist Church, which also hosted the camp.

A total of 26 students participated in the four-day program. The curriculum introduced students to key STEM concepts, robot design, robot handling, algorithmic thinking, robot programming through Python and Choreograph software, and ethical considerations in robotics. Participants also received hands-on experience programming NAO-6 humanoid robots in small teams. The camp culminated in a “Robot Rally” performance, in which students showcased original skits demonstrating how humanoid robots can contribute to healthcare innovation. To evaluate the participants’ prior knowledge toward AI and robotics as well as the camp’s effectiveness in shaping students’ perceptions, participants completed pre- and post-assessment surveys. Results showed a 17% increase in participants’ confidence in programming and coding concepts and a 14% increase in confidence in working with AI, as well as an overall improvement in confidence in handling robots. In contrast, participants’ interest in pursuing STEM fields decreased by 10%.

This paper discusses effective pedagogical strategies, logistical challenges, and engagement patterns, comparing outcomes between the first camp (middle school cohort) and the second (younger, mixed-gender cohort), and offers recommendations for future implementations.

Introduction

Citadel is one of the participating institutions in the ADAPT (Artificial Intelligence-Driven Advances in Personalized and Transformative)-[State] team of [State] universities, funded by the National Science Foundation (NSF). The ADAPT-[State] consortium includes three Comprehensive Research Universities (CRUs), three Minority-Serving Institutions/Historically Black Colleges and Universities (HBCUs), four Predominantly Undergraduate Institutions (PUIs), and one technical college.

The overarching goals of the NSF-funded initiative include, but are not limited to, “*educating and training a diverse, competitive, AI-ready workforce; establishing STEM professional development* *pathways; and developing innovative strategies to broaden participation in STEM through the creation of intelligent and personalized healthcare infrastructure*.” Within this context, the project seeks to provide culturally relevant curricula that enable young students to program collaborative robots (co-robots), fostering early awareness of artificial intelligence (AI), its applications in healthcare, and the ethical dimensions of AI technologies. Student recruitment efforts specifically target underrepresented, rural, and first-generation populations to ensure broad and inclusive access to STEM education.

As part of this larger initiative, Citadel organized a series of summer camps designed to engage students in AI and robotics education. The current paper compares the outcomes of the first- and second-year camps implemented by Citadel, both conducted under the ADAPT-[State] project. While similar camps were held at other participating institutions, this paper focuses exclusively on the camps hosted by Citadel.

The experience of first-year camp, which is called 2024 camp in this paper, was previously documented by Singleton, E.T. et.al and presented at the ASEE 2025 National Conference and Exhibition. That study highlighted the camp’s emphasis on AI, healthcare robotics, and ethics. Participants interacted directly with AI-enabled humanoid robots designed for healthcare applications, exploring topics such as robotic diagnostics, assistive technologies, and the relationship between AI and empathy. The program was offered to underrepresented middle school girls and combined hands-on experimentation with mentorship to promote diversity and strengthen STEM identity formation among underrepresented youth [1].

Literature Review

Reviewing engineering education outreach publications shows that robotics-focused summer camps have been running for more than two decades. Over that time, humanoid robotics has progressed from serving as a basic introduction to STEM concepts to supporting far more advanced, AI-enhanced educational experiences. Early work by Dorsey and Howard [2] examined how socially assistive humanoid robots could engage underserved high school students in informal learning environments, prioritizing social interaction and accessibility over technical depth. More recently, humanoid robots have also appeared in classroom settings. For example, LeTendre and Gray (2024) investigated how sustained exposure to a social robot within a project-based elementary and middle school classroom shaped students’ evolving perceptions of robots [2].

Nugent et al. (2016) found that robotics-centered summer camps, similar to academic-year robotics clubs and competitions, support meaningful STEM learning gains. Their work highlights improvements in students’ understanding of engineering, engineering design, and programming, along with increases in self-confidence when performing robotics tasks [4].

As technology continues to evolve rapidly, AI has also become a prominent theme in recent summer camps. Slaton et al. (2024), for instance, documented a camp focused on AI-driven robotics and ethics for high school students, where participants built, programmed, and trained autonomous robots to navigate a test track while also engaging in discussions about the ethical dimensions of AI technologies [5].

Overall, factors such as participant age, program duration, residential versus day-camp formats, and the depth of technical content all influence the impact these programs have on young learners.

Methodology

This camp represented the second in a planned series of nine summer camps to be conducted over a five-year period as part of a National Science Foundation (NSF)-funded project. The primary objective of the camp was to enhance public awareness among younger generations in South

Carolina regarding Artificial Intelligence (AI)-enabled devices and humanoid robots. Specifically, the camp sought to introduce participants to applications of AI in healthcare and to promote awareness of the ethical considerations surrounding the adoption of emerging technologies. This second camp is called 2025 camp in the paper.

Participants and Setting:

Initially, the camp targeted underrepresented middle school girls as part of a broader initiative to promote gender diversity in STEM fields. However, due to administrative changes in federal funding, the 2025 camp expanded eligibility to include both girls and boys. Consequently, the age range was adjusted from 12–14 years in the first year to 8–12 years in the second year.

Unlike the inaugural camp held at Citadel, the second-year camp took place at Mt. Moriah Missionary Baptist Church, a venue selected to improve accessibility for students by being closer to their communities. The program was facilitated by a multidisciplinary team of ten faculty members, staff, and volunteers from Citadel, with logistical and administrative support from Mt. Moriah Missionary Baptist Church. Participation was free of charge, and both breakfast and lunch were provided daily. All participants were from underrepresented communities and eligible for free school meals.

Program Design and Curriculum:

A total of 26 students, including 14 girls and 12 boys, attended the four-day camp, held from July 28–31, 2025. The curriculum introduced foundational STEM concepts and focused on topics such as robot design, handling, algorithmic thinking, and programming using Python and Choreograph software. Ethical issues related to robotics were integrated throughout the program to encourage critical thinking about technology's societal impact.

The curriculum was adapted from the Humanoid Engineering and Intelligent Robotics (HEIR) Lab at Marquette University, which had previously offered robotics programs for minority girls in 2015 and 2016. Originally developed by the Dean of the School of Engineering at Citadel[6], this curriculum was modified for the 2025 camp to align with the younger age group and to reflect contemporary socio-political considerations. Additional adjustments were made to reduce emphasis on diversity discussions within the student workbook while maintaining the camp's inclusive spirit.

Learning Activities:

As in the 2024 camp, participants engaged in hands-on learning through small-team projects involving NAO-6 humanoid robots. Prior research highlights the NAO robot's adaptability and multifunctionality, making it a strong candidate for use as a Socially Assistive Robot (SAR) [7]. The NAO robot's compact size also provided flexibility in holding the camp in various venues. Additionally, a larger Pepper robot was used on the final day for demonstration purposes.

Throughout the program, students collaborated to develop a "Robot Rally" performance that showcased their learning. On the first day, teams brainstormed healthcare-related scenarios, followed with designing corresponding robot skits, and programmed the robots to act out their stories in days two and three. On the final day, students presented their performances to parents and guardians, illustrating how humanoid robots can contribute to healthcare innovation. Pictures from camp are shown in Figure 1.

Figure 1: ADAPT-SC Summer 2025 Camp Activities

Evaluation:
To assess the camp's effectiveness in influencing students' perceptions and knowledge of AI and robotics, participants completed pre- and post-assessment surveys identical to those used in the first-year camp, allowing for comparative analysis. The pre-assessment was administered on the morning of the first day before any instruction began, and the post-assessment followed the final session. Parental consent was obtained during registration in compliance with ethical research standards. The results of pre and post survey are presented under "Discussion" section of this paper.

Facilities and Environment:
The camp was held in a large gymnasium that offered ample space for a variety of activities. Students were assigned to four groups based on their age, and one church staff and one faculty or staff from Citadel facilitate activities of each group. Each group sat together at a large round table and were provided with two laptops and one NAO robot for programming. Figure 2 below shows the layout of four student worktables on the left side of the gymnasium, equipped with two television screens and a microphone, while dining tables were placed near the kitchen on the opposite side. The availability of basketball hoops and balls provided opportunities for recreational breaks, helping students remain active and engaged throughout the break time. Regular breaks were scheduled to prevent fatigue and sustain attention. The gym's stage served as the venue for the "Robot Rally" showcase on the final day.

Figure 2: ADAPT-SC Summer Camp 2025 site layout

Discussion

The pre- and post-survey results provide insight into changes in participants' self-perceptions, comfort with technology and AI, and career-related aspirations following participation in the AI+ Health and Humanoids camp. Overall, the findings suggest that the camp had a positive impact on students' confidence, technical self-efficacy, and awareness of STEM- and health-related pathways, while shifts in long-term career intentions were more modest and nuanced.

Analysis of Pre and Post Assessment Survey of the 2025 Camp:

This year, the pre-assessment survey was completed by 25 students, as one participant missed the first day of the camp. The post-assessment survey received 23 responses, excluding one student who did not attend the camp and two students who left before the survey administration. Table 1 presents the aggregated pre- and post-survey results. To protect student privacy, participants were assigned unique camp identification numbers on the first day of the program, which were used to complete both surveys in lieu of student names.

Participants entered the camp with relatively high baseline self-confidence and comfort with technology, which limited the magnitude of observable change. Nevertheless, positive shifts were evident. The percentage of students who "always or strongly agreed" that they were proud of who they are increased from 48% pre-camp to 56.5% post-camp, while overall agreement (strongly + mostly) remained high (84% pre, 82.6% post). Comfort with trying new things showed improvement in response strength: "always or strongly agree" increased from 32% to 39.1%, and disagreement responses (12% combined pre) dropped to 0% post-camp. These results suggest reinforcement of positive self-concept and increased willingness to engage in unfamiliar learning activities.

More clear changes occurred in domain-specific technical self-efficacy. Comfort with coding/software showed a substantial improvement, with "always or strongly agree" increasing from 20% to 39.1% and "never or strongly disagree" decreasing from 20% to 0%. Comfort handling robots remained high overall but shifted toward stronger agreement, with combined agreement increasing from 84% to 91.3% and no post-camp disagreement reported. Comfort working with artificial intelligence showed a reduction in uncertainty: undecided responses decreased from 20% pre-camp to 8.7% post-camp, while combined agreement increased from 68% to 82.6%. In contrast, comfort with general technology use remained consistently high (92% pre, 91.3% post), indicating a ceiling effect.

Career-related intentions showed mixed but informative patterns. Interest in working in a STEM field showed little change in strong agreement (12% pre, 13% post) and increased undecided responses (20% to 39.1%), suggesting more reflective consideration rather than disengagement. However, strong agreement with pursuing careers involving engineering, programming, AI, or robotics to help the community increased markedly from 8% to 30.4%, while undecided responses decreased from 36% to 21.7%. Agreement that attending a STEM-focused high school is important also increased, with combined agreement rising from 48% to 65.2% and undecided responses falling from 24% to 8.7%. Post-survey-only items further support program impact, as 65.2% of participants agreed that they learned something about themselves they were proud of, 65.2% reported increased interest in learning more about robotics and healthcare, and 60.9% indicated they would recommend the camp to peers.

Implemented changes to the 2025 camp:

2025 Camp codirectors implemented several improvements in the 2025 camp based on feedback from the 2024 camp counselors. One key change was increasing the number of laptops available for programming activities. In 2025, each team was provided with two laptops, and two camp counselors were assigned to each team to support students during the programming process.

Because the 2025 participants were younger than those in the 2024 cohort, the camp workbook was revised to reduce technical complexity. Advanced content, such as detailed Python programming concepts and code debugging, was removed to better align with the developmental level of younger students.

Table 1: 2025 ADAPT-[State] AI + Humanoid Robtic Camp Pre & Post Assessment Survey Results

	Pre-Survey (25 responses)					Post-Survey (23 responses)				
	Always or Strongly Agree	Mostly or Agree	I don't know or Undecided	Rarely or Disagree	Never or Strongly Disagree	Always or Strongly Agree	Mostly or Agree	I don't know or Undecided	Rarely or Disagree	Never or Strongly Disagree
I am proud of who I am.	48%	36%	12%	4%	0%	56.5%	26.1%	13%	4.3%	0%
I am comfortable trying new things.	32%	48%	8%	8%	4%	39.1%	43.5%	17.4%	0	0
I am comfortable with using technology.	84%	8%	0	4%	4%	78.3%	13%	0	4.3%	4.3%
I am comfortable handling robots.	52%	32%	8%	8%	0	43.5%	47.8%	8.7%	0	0
I am comfortable coding/software.	20%	32%	20%	8%	20%	39.1%	30.4%	21.7%	8.7%	0
I am comfortable working with artificial intelligence.	40%	28%	20%	4%	8%	39.1%	43.5%	8.7%	4.3%	4.3%
I plan to work in a S.T.E.M. (Science, Technology, Engineering, or Math) field when I grow up.	12%	24%	20%	28%	16%	13%	13%	39.1%	13%	21.7%
I can see myself creating technology for healthcare needs when I grow up.	8%	40%	16%	28%	8%	13%	21.7%	26.1%	8.7%	30.4%
I can see myself programming robots to help people when I grow up.	16%	40%	20%	12%	12%	13%	30.4%	17.4%	17.4%	21.7%
I plan to choose a career path that involves pre-engineering, programming and software development, artificial intelligence, or robotics to help my community.	8%	28%	36%	12%	16%	30.4%	17.4%	21.7%	8.7%	21.7%
I plan to choose a career path that involves biomedical sciences or health science and technology to help my community.	12%	28%	32%	20%	8%	13%	30.4%	21.7%	8.7%	26.1%
Attending a high school that has a S.T.E.M. or technology education program is important to me.	16%	32%	24%	12%	16%	30.4%	34.8%	8.7%	8.7%	17.4%
I learned something about myself that I am proud of at the AI+ Health and Humanoids camp.						30.4%	34.8%	13%	4.3%	17.4%
Camps like this make me want to learn more about robotics and healthcare.						21.7%	43.5%	17.4%	4.3%	13%
I plan to recommend the AI+ Health and Humanoids camp to other kids.						34.8%	26.1%	17.4%	8.7%	13%

Administrative changes in 2025 expanded camp eligibility from girls only (2024) to both girls and boys. As a result, the program workbook and previously designed activities were revised to ensure gender neutrality. Content specific to a girls-only audience was removed and replaced with inclusive videos, images, and activities. In addition, learning modules that previously emphasized community inclusion and equity were reoriented to focus on ethical considerations in robotics and AI, particularly the importance of avoiding bias in robot programming. For example, the 2024 "Emojis" activity (focused on representation through skin-tone customization) was replaced with the "Squishmallow" activity. In this revised activity, students examined plush toys with unique shapes and associated identity tags describing each toy's personality and background. Students first inferred personality traits based on appearance, then compared their assumptions with the information provided on the tag, followed by a discussion on how programmer bias can influence robotic decision-making and behavior. Figure 2 presents examples of the Squishmallow toys and sample identification tags.

Figure 3: Sample Squishmallow toys and their ID tags

Comparing 2024 camp and 2025 camp assessment data:

The 2024 camp participant were 16 middle school girls. Comparison of the pre-survey results indicate notable baseline differences between the 2024 and 2025 cohorts, which is consistent with the younger age of the 2025 participants. In 2025, students entered the camp with higher initial comfort using technology (92% combined agreement vs. 87.6% in 2024) and handling robots (84% vs. 56.3%), whereas 2024 participants reported higher initial confidence in coding/software undecided or neutral responses were substantially higher in 2024 for several items (e.g., 43.8% undecided in coding/software vs. 20% in 2025). In contrast, 2025 pre-survey responses showed lower initial clarity around long-term STEM and healthcare career intentions, with higher disagreement or indecision for working in STEM (44% disagreement in 2025 vs. 12.6% in 2024) and creating healthcare technology (36% disagreement in 2025 vs. 12.6% in 2024). These patterns suggest that younger participants entered the 2025 camp with stronger general technology familiarity but less formed career aspirations.

Post-survey comparisons show that both camps positively influenced participants, but the nature of impact differed. The 2025 camp produced larger gains in technical self-efficacy: strong agreement with comfort coding/software increased to 39.1% in 2025, compared to 0% in 2024, and strong agreement with careers involving engineering, programming, AI, or robotics rose to 30.4% in 2025 versus 12.5% in 2024. This could be a result of including complex coding section for 2024 camp which made them uncomfortable with coding concept. Meanwhile, 2024 participants showed stronger post-camp shifts toward general interest and affirmation, with higher combined agreement for comfort with AI (100% in 2024 vs. 82.6% in 2025) and learning something they were proud of (75% in 2024 vs. 65.2% in 2025). Overall, the 2025 camp, serving a younger cohort, was more effective in building foundational technical confidence and awareness, while the 2024 camp, serving older students, elicited clearer affirmation of interests and learning outcomes. Together, the results suggest that camp impact is developmentally sensitive, supporting age-appropriate growth in confidence, understanding, and STEM-related self-concept rather than uniform changes across cohorts.

The percentages of “Always/Strongly Agree responses” in each pre-assessment and post-assessment survey of 2024 and 2025 camp were depicted in the Figure 3 below.

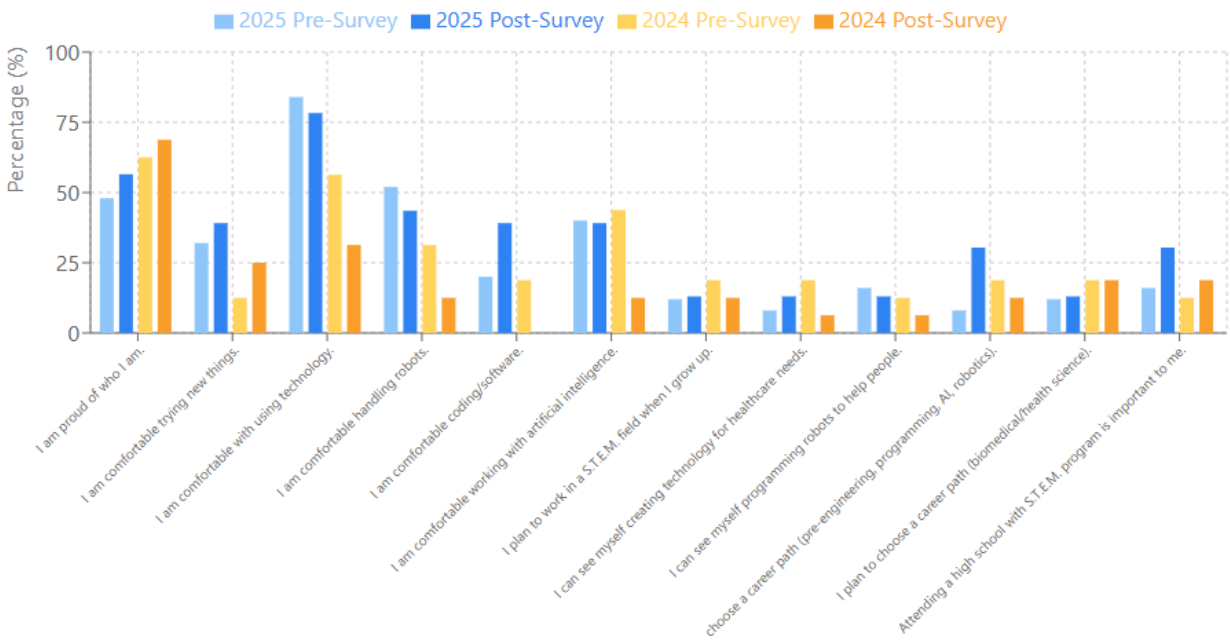

Figure 4: Pre-assessment vs Post-assessment Survey results in 2024 and 2025 camp: "Always/Strongly Agree" Responses (%)

Robot Rally performances:

Each group developed creative and engaging ideas for their robot, and with support from camp counselors, students successfully programmed their robots within the limited time available. The following themes were performed during the 2025 camp:

- “Dr. Robot”: A therapist robot that empathetically approaches and counsels patients, with guidance tailored to the specific illness being treated. (11-year-olds)
- “Gubby”: A babysitter robot designed to entertain children and encourage movement by engaging them in music and dance. (9–10-year-olds)
- “Dr. Coconuts”: A healthcare-support robot that explains cancer development and promotes treatment through music and guided physical activities. (8–9-year-olds)
- “Bulldog”: A fitness-focused robot that encourages children to stay active by teaching dance and movement exercises. (8-year-olds)

Lessons learned

After finishing the camp, the counselors were asked to fill in a lessons-learned survey to be implemented in the future camps. Their feedback indicates that the camp was largely successful in its overall design, logistics, and learning environment. The selected venue was consistently identified as a major strength due to its cleanliness, ample space, reliable infrastructure, and supportive on-site staff. Camp duration and daily pacing were generally appropriate, with activities flowing smoothly and sufficient breaks provided for students and staff. Hands-on components, particularly arts, crafts, robotics, and the Robot Rally performance, were highly engaging and contributed positively to student enthusiasm and participation. Group sizes were appropriate, and older students demonstrated meaningful learning gains, including an understanding of basic programming concepts and responsible use of technology.

Despite these strengths, several challenges emerged that need attention in future implementations. The most significant issue concerned the inclusion of younger participants (8 to 9 year old), whose developmental readiness did not align well with the camp's programming and instructional materials. Camp counselors reported that these students struggled with sustained attention, abstract programming concepts, and time-constrained activities, particularly during robot programming and performance preparation. The workbook content was perceived as overly complex for younger learners, and craft materials sometimes distracted students during instructional periods. These challenges suggest a misalignment between age range, curriculum rigor, and instructional pacing despite the adjustment activities

Feedback also highlighted opportunities for improvement in planning, staffing, and scheduling. Staff emphasized the need for early communication regarding final enrollment numbers and age distributions, earlier preparation of materials, and advance testing of audiovisual equipment. Although a training was provided for Citadel faculty and staff before the camp, there was a request to involve church in-site facilitators in the trainings Several respondents recommended shorter, morning-focused sessions spread over five days to enhance engagement, as well as limiting future camps to a narrower age range (with 9–10-year-olds identified as the most appropriate). Collectively, these lessons underscore the importance of tighter alignment among target audience, curriculum design, staffing preparation, and logistical planning to strengthen future camp outcomes.

Conclusion

This paper documented the implementation and evaluation of the second robotics and AI-focused summer camp from series of 9 summer camps in [The state] aimed at increasing early awareness of AI-enabled technologies, humanoid robots, and their societal and ethical implications among youth. Camp counselors and staff's feedback and observational data indicate that the camp was largely successful in meeting its core objectives, particularly in engaging students through hands-on activities, robotics programming, and performance-based learning experiences such as the Robot Rally. The selected venue, group sizes, and overall logistical arrangements effectively supported learning, while older participants demonstrated meaningful gains in understanding foundational programming concepts and responsible technology use. These findings reinforce prior work in informal STEM education suggesting that experiential, activity-based learning environments are well suited for introducing complex technological concepts at an early age.

At the same time, the evaluation represents limitations and constraints related to participant age range, curriculum alignment, and instructional pacing. The inclusion of younger students, particularly ages eight to nine, introduced challenges related to attention span, developmental readiness, and classroom management that limited their engagement with programming-intensive activities. These results highlight the importance of age-appropriate materials, and clearly defined target demographics when designing AI and robotics outreach programs. Without such alignment, even well-designed content risks being inaccessible or ineffective for portions of the intended audience.

Overall, the lessons learned from this camp provide actionable guidance for future iterations and for similar outreach initiatives seeking to broaden participation in AI and robotics education. Key recommendations include older kids in narrower age group, pre-camp staff training for all facilitators, and adopting shorter daily schedules within a five-day format. While shorter days may improve engagement, they may also affect participation, as some families prefer full-day camps.

From a broader perspective, this work contributes to the growing body of evidence on informal AI and robotics education by illustrating both the potential and the practical challenges of delivering advanced technological concepts to younger learners. Future camps and research efforts should build on these insights to develop scalable, developmentally appropriate models that effectively support early engagement, equity, and sustained interest in emerging STEM fields.

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AI Use Disclosure

Artificial intelligence–based LLMs were used to assist with grammatical editing and clarity of paper, as well as preliminary chart formatting. The authors reviewed, revised, and validated all content and figures and take full responsibility for the accuracy, interpretation, and integrity of the work.

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