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Enhancing STEMM Education Through Advanced Technologies and Collaborative Programs

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ABSTRACT

Integrating advanced technologies into STEMM (Science, Technology, Engineering, Mathematics, and Medicine) education is essential for preparing a future-ready, diverse scientific workforce capable of addressing complex global challenges. This paper presents three interconnected programs—BRITE (Biotechnology Research Incubator for Teachers), ASPIRATION (AI-guided Scientist-Mentored Primary Literature Adaptation for STEMM Education), and C-REP (Cancer Research Education Program)—developed through collaborations with Advanced Technology Cores and multi-institutional participation, involving mentors ranging from core directors to graduate and medical students. While initially supported by internal funding, two of these initiatives have since secured NIH grant support. These initiatives provide immersive, hands-on training in genomics, proteomics, metabolomics, flow cytometry, and AI, reaching middle and high school teachers, high school students, and college students, respectively. Each program integrates mentorship, advanced seminars, and core facility tours to bridge the gap between research and education. Beyond enhancing STEMM literacy and technical skills, these initiatives also support core facilities through increased visibility, utilization, and staff development. Early outcomes indicate improved confidence and engagement among participants, while ongoing evaluations aim to assess long-term impact and scalability. Together, these programs represent a sustainable, collaborative model for integrating cutting-edge science into education.

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INTRODUCTION

Integrating advanced technologies into science, technology, engineering, mathematics, and medicine (STEMM) education is critical for preparing future scientists to address complex global challenges. Incorporating tools such as genomics, proteomics, and artificial intelligence (AI) into educational practices enhances critical thinking, problem-solving, and innovation among educators and students.

Several programs, leveraging cancer research expertise and advanced technologies from the Advanced Technology Cores in collaboration with other centers and departments at Baylor College of Medicine (BCM), have been developed to bridge the gap between research, cutting-edge technologies, and education. The programs include the Biotechnology Research Incubator for Teachers (BRITE), the AI-guided Scientist-Mentored Primary Literature Adaptation for STEMM Education (ASPIRATION) initiative, and the Cancer Research Education Program (C-REP). Each of these programs addresses different aspects of STEMM education and training (Figure 1). As part of these initiatives, we have collaborated with seven different core facilities that are essential to cancer research, such as genomics, proteomics, metabolomics, and flow

cytometry, to provide diverse hands-on training and exploration opportunities. These programs include an Advanced Technology and Research Exploration Day (Advanced Technology and Research in Action) for high school students as part of the 8-week virtual ASPIRATION literature adaptation program, a 1-week intensive advanced technology training for college students within the 8-week C-REP Cancer Research Education Program, and 3-week advanced technology immersive experiences for secondary school teachers throughout the BRITE program. Each program is complemented by advanced technology seminars throughout the program, technical instruction sessions led by core directors, and guided tours of Advanced Technology Cores, allowing participants to engage with cutting-edge applications and observe instruments at work in different core facilities. In return, these activities contribute to the development of core facilities and support career development.

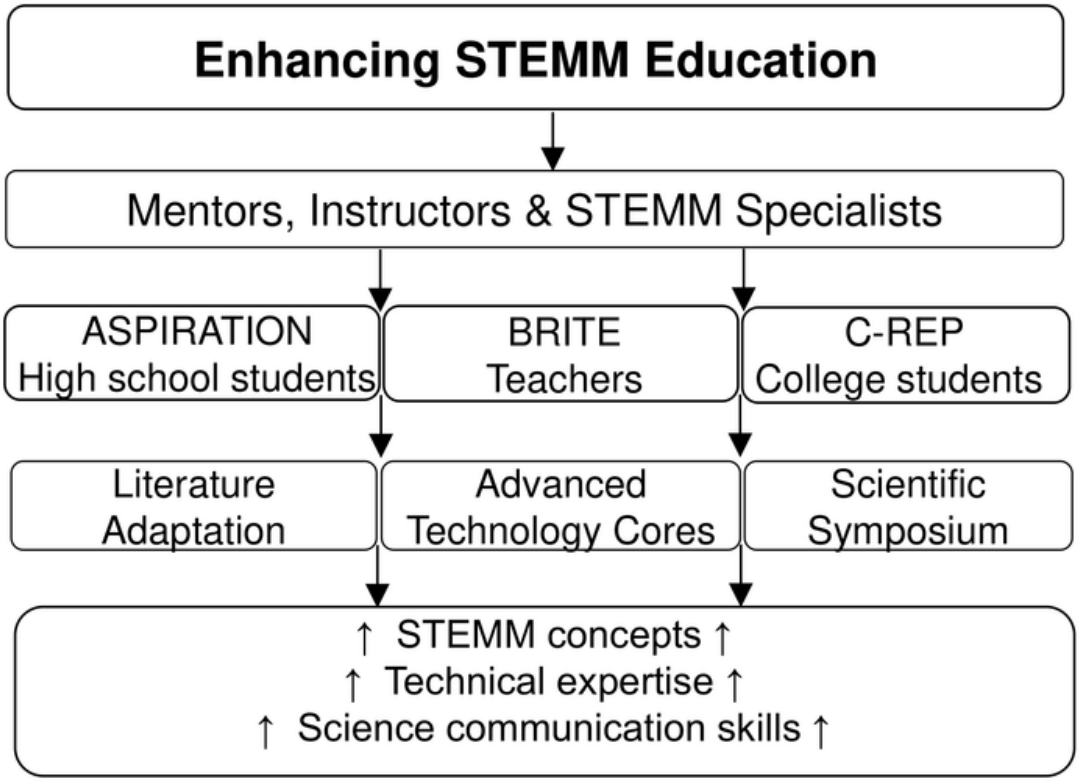

Figure 1

Overview of STEMM education programs and training structure. Three programs — BRITE (for middle and high school teachers), ASPIRATION (for high school students), and C-REP (primarily for college students) — provide integrated advanced technology training and mentorship supported by faculty, trainees (including graduate students, medical students, and postdoctoral fellows), and STEMM specialists primarily from BCM. The curriculum includes hands-on experiences, exposure to advanced technologies, adaptation of primary scientific literature, and participation in scientific symposiums. Program goals are to (1) enhance trainees' understanding of biotechnology, research design, and technology literacy across different educational levels and (2) support teachers in developing research-related lesson plans for classroom implementation.

ASPIRATION: AI-guided Scientist-Mentored Primary Literature Adaptation for STEMM Education initiative; BCM: Baylor College of Medicine; BRITE: Biotechnology Research Incubator for Teachers; C-REP: Cancer Research Education Program; STEMM: science, technology, engineering, mathematics, and medicine.

BRITE TRAINING PROGRAM

The BRITE program, provides middle and high school teachers with a 3-week summer experience, introducing them to advanced laboratory techniques, such as protein array technology, next-generation sequencing, flow cytometry and cell sorting, and bioinformatics and data analyses. Participants also engage with mentors to

analyze relevant scientific literature and collaborate with STEMM specialists to brainstorm preliminary lesson ideas, enabling them to translate research experiences into problem-based lesson plans. This approach equips teachers with both technical expertise and practical strategies for classroom implementation.

Comment Box 1: BRITE Teacher Testimonials

- *Through the BRITE program, I had the opportunity to engage with advanced medical research at BCM. Not only did I gain a deep understanding of complex concepts in a clear and accessible way, but I also learned how to incorporate what we learned into our lesson plans. This experience greatly boosted our confidence in teaching STEM subjects.*
- *I could relate my lessons to the real-world needs more tightly. Cancers are challenging the entire human society. It is our task to educate our new generations.*

Over 3 years, the BRITE pilot program trained 10 teachers, with participants reporting increased confidence and improved understanding of STEMM concepts. Teachers developed lesson outlines based on their experiences, with 43% of them creating specialized teaching units, such as a middle school unit on cancer development, a high school module on protein expression and purification, and another high school lesson focused on omics data analysis, emphasizing heatmaps and high-throughput data visualization. The comprehensive data has been published separately (Shi et al., 2025), and here we present the feedback from the teachers through their comments; an example is shown here in Comment Box 1. The program has since expanded, supported by a 5-year National Institutes of Health Research Education Program (NIH R25) Science Education Partnership Award (SEPA). This funding enables the inclusion of 12-16 teachers annually in a comprehensive program aligned with Next Generation Science Standards, emphasizing sustainable integration of research experiences into classroom education.

ASPIRATION PROGRAM

The ASPIRATION program combines mentorship and AI to help high school students engage with scientific literature. Over an 8-week period, under the mentorship of 25 graduate and medical students as well as research scientists, 38 high school students successfully adapted primary scientific articles into simplified language appropriate for their peers. AI tools generated initial drafts, which were refined by students and mentors, while infographics were created to enhance accessibility.

The program is integrated with a high school biotechnology research symposium, with over 70 high school students participating. The majority of students created posters to present their understanding of, and simplified versions of, scientific articles, while a few attended as participants. The event featured oral presentations, lightning talks, and poster sessions, with 76.5% of students reporting that they participated in a scientific symposium for the first time. Feedback from students suggests that the ASPIRATION program provided appropriate training to help them understand scientific literature, primary research, and the workings of advanced technologies. The program also featured a dedicated Advanced Technology and Science in Action

Day, offering students exposure to advanced technologies like genomics, proteomics, and metabolomics through presentations and facility tours at related Advanced Technology Cores. Students engaged in discussions with experts and explored ongoing research projects, providing valuable insights into practical scientific applications and cutting-edge advancements. This ASPIRATION program experience helped build students' confidence and enhanced their understanding of STEMM fields. The data will be published separately (Bullock et al., unpublished). Comment Box 2 highlights the students' engagement and examples of takeaways from the program, including the impact of the advanced technology exposure, teamwork, presentations, and symposium experience.

Comment Box 2: ASPIRATION Student Testimonials

- *I enjoyed learning about various advanced technologies, from genomics to proteomics to metabolomics, that I had not encountered before. Learning about these technologies at BCM's Advanced Technology Cores and visiting real science labs helped me understand scientific literature better by seeing the real-world applications and witnessing advanced technologies in action.*
- *What I love about the ASPIRATION program are the unique opportunities it provides. First, it uses AI to simplify complex scientific articles, which allows me to understand and transform challenging content into engaging multimedia stories. Second, I get the chance to be mentored by scientists from Baylor College of Medicine. Their guidance helps me grasp the material and learn how to use AI tools effectively, making it a true collaborative experience. Finally, the program's focus on developing STEM literacy resources at different reading levels means I'm contributing to a larger goal of building well-informed communities. These aspects make the program incredibly fulfilling and inspiring for someone passionate about science and communication.*
- *Enjoyed learning how to use AI to simplify and comprehend research articles and compile them into a poster and lightning talk.*
- *Enjoyed the well-organized symposium, especially the opportunity to see other students present.*

C-REP PROGRAM

The C-REP program is a component of the NIH-funded initiative, Collaborative Union for Cancer Research, Education, and Disparities (CURED). This partnership focuses on cancer research, education, and community outreach, to train college and graduate students from Texas Southern University, a Historically Black College and University (HBCU). The program is a collaboration between Texas Southern University and BCM, with equal partnership between the two institutions (see “Acknowledgments”).

Each year, the program enrolls about 20 participants, including rising freshmen, current college students, and graduate or PharmD students, in an intensive 8-week cancer research experience. One of the key features of the program is a 1-week, hands-on training session in Advanced Technology Cores, such as proteomics, metabolomics, flow cytometry, and genomics, providing participants with valuable technical skills and exposure to cutting-edge methodologies. The program concludes with a research symposium where

participants present their findings, followed by ongoing mentorship and opportunities to engage in further research activities.

Preliminary feedback suggests that the program provides participants with valuable technical skills and builds their confidence, effectively preparing them for careers in STEMM fields. The data will be published separately. Comment Box 3 provides the students' insights and primary outcomes following their participation in the Advanced Technology Core training. In the program's end-of-survey response (Comment Box 3), one student shared that the experience solidified their career goal of utilizing multiomics for cancer research. The student highlighted the various -omics technologies that they were trained on, including hands-on bioinformatics training, and designed a comprehensive project modeled after real-world scientific research. The technologies reflected in the student's career goals were all introduced during Technology Week, with a focus on their applications in cancer research. Students were organized into groups of up to four, with each group having intensive training in a single specific core, related to their research project, followed by a hands-on session on bioinformatics and -omics data analysis on the final day of the week. During the week, they toured all participating cores. Throughout the 8-week program, participants attended seminars led by core directors and scientists from BCM, thus gaining comprehensive exposure to advanced technologies and their real-world applications.

Comment Box 3: C-REP Program Student Testimonials

- *The hand-on-hand training on those advanced technology increased my understanding about medical research.*
- *I particularly enjoyed the talks on next-generation sequencing and cancer research.*
- *Really enjoyed all the hands-on activities and attempts for our preceptors to help us understand the technology.*
- *Liked the presentations at the beginning of the week where I got to learn about what each core facility does.*
- *Liked learning about microscopic and fluorescent methods associated with the study of Tubulin Associated Unit [TAU, isoform of microtubule-associated protein tau].*
- *My career goal is utilizing multiomics for cancer research, obtain specialized training in multiomics technologies, including genomics, transcriptomics, proteomics, and metabolomics, along with mastering bioinformatics tools and computational biology techniques to analyze multiomics data effectively.*

BENEFITS TO CORE FACILITIES AND MENTORS

In addition to training educators and students, the programs also provide benefits to the participating Advanced Technology Cores and the core scientists in various ways. For example, these activities have enhanced the communication skills of core staff and supported the career development of core scientists as detailed in the paper *Biotechnology Research Incubator for Teachers (BRITE) Pilot Program: Advancing Technology Research Education for Secondary School Teachers* (Shi et al., 2025). Comment Box 4 presents perspectives from core directors and a representative STEM specialist mentor who participated in BRITE mentoring and regularly mentors high school and college students. Notably, faculty in core facilities benefit from including

teaching as part of their promotion portfolios, and these programs offer a valuable opportunity to do so. Additionally, we requested funding in the NIH grants to cover reagents and instrument usage for the training programs, which has increased the utilization of core facilities and supported their operations. The training sessions have also led to refinements in core protocols, driven by insightful questions from teachers and students. By making biotechnology education more accessible and demonstrating their sustainability, these initiatives represent a win-win model for both education and core facility development.

Comment Box 4: Core Facility and Mentor Testimonials

- *The teachers were incredible, asking insightful questions that prompted us to revise our protocols to make them more understandable.*
- *Our core staff benefited greatly from explaining advanced technologies to high school students, enhancing their communication skills.*
- *The TSU students at our core were highly engaging, and we would love to have them return next year.*
- *Thank you for the opportunity to train both teachers and students. My technical director and I can include this experience in our teaching portfolios for promotion.*
- *As a STEM specialist, I find immense fulfillment in mentoring the next generation of scientists and educators. It's incredibly rewarding to witness their growth, spark their curiosity, and empower them to develop engaging and effective STEM lessons that will inspire future learners. Mentoring is about more than just sharing knowledge; it's about fostering a passion for science and creating impactful learning experiences.*

CHALLENGES AND FUTURE DIRECTIONS

While the programs have shown promise, challenges remain. For example, teacher recruitment faced difficulties, with some teachers withdrawing at the last minute. Although we have always had more applicants than available spots, and admitted a couple more each time, the last-minute withdrawals sometimes prevented us from filling the spots due to logistical constraints and administrative paperwork requirements. In our NIH-funded BRITE project starting this summer, we have taken proactive measures, including initiating recruitment early—by sending out flyers in February and early March—and incorporating in-person sessions to enhance engagement and excitement. Since financial constraints could also be a contributing factor, we have allocated a higher amount of stipend to alleviate financial burdens. Additionally, our 3-week timeline has been designed to accommodate teachers' availability; it is scheduled 2 weeks before the school year starts and the week following the end of summer school, aligning with most school districts' calendars. For lesson plans, some school district regulations can limit the implementation of specialized lesson plans developed by teachers. Addressing these barriers through collaboration with educators is a priority. To ensure alignment and relevance, we have included two teachers on our NIH-funded grant advisory committee and meet with them twice a year to seek their feedback and guidance, which we incorporate into our program. Ongoing evaluation and adaptation of these programs are essential to ensure their effectiveness and relevance. Future efforts will focus

on expanding the integration of advanced technologies into education, fostering partnerships, and creating inclusive opportunities for students and educators alike.

The high school student program aims to cultivate students' interest in STEMM. Our primary objective is to inspire and support students by providing scientific experiences that enhance their enthusiasm for learning and encourage future educational aspirations. Ideally, students who participate in the program would demonstrate higher STEMM graduation rates and increased college enrollment compared to non-participants. However, we recognize that participation may be self-selective, as students who choose to engage in such programs are often already motivated to pursue higher education in STEMM fields. Additionally, as the program is relatively new, we are still exploring effective methodologies to assess its long-term impact. We remain committed to evaluating the program's effectiveness and are actively considering strategies, such as longitudinal studies and comparisons with matched control groups, to provide a more comprehensive understanding of its impact.

These three programs are the result of broad collaborations among investigators across departments and institutions (manuscripts and publications are being prepared separately). They are supported by diverse funding sources, including internal funding from BCM, support from neighboring institutions, and NIH grant funding. With our proven success in designing and implementing impactful training programs—as well as our track record in securing federal support—we have obtained additional internal funding to sustain and expand these efforts. This includes departmental contributions and private donations.

Recognizing the importance of long-term sustainability, we have made it a strategic priority. To that end, we are actively diversifying funding sources and exploring additional approaches to long-term support. For example, we plan to further develop the programs to support new grant proposals and extend their scope to include medical education for K-12 students, as well as research and technology training for medical students. Where appropriate, we may also implement participant fees to help offset program costs. This growing diversification contributes to the financial sustainability of the programs.

Interest from teachers and students continues to grow, driven by positive experiences and the demand for high-quality training programs, further reinforcing the programs’ relevance and impact. Institutional support—including access to core facilities, staff engagement, and faculty mentorship—has further strengthened long-term integration and institutional value.

Collectively, these elements establish a strong foundation for sustainability while we continue to pursue strategic partnerships and cost-effective models to ensure the programs’ longevity and scalability.

CONCLUSION

Programs like BRITE, ASPIRATION, and C-REP highlight the potential of integrating advanced technologies into STEMM education to enhance scientific literacy, inspire innovation, and promote equity. These initiatives not only equip teachers and students with critical skills but also lay a foundation for addressing pressing global

challenges through a well-prepared and diverse scientific workforce. Continuous efforts to evaluate and refine these programs will be vital for maximizing their long-term impact.

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