TeachME PROFESSIONAL DEVELOPMENT

Growth

CEUs for Teachers and Educators

Developing STEM Education for Disadvantaged Students

Introduction

"Developing STEM Education for Disadvantaged Students" is a course designed to empower educators with the knowledge and skills necessary to create inclusive, effective, and engaging STEM (Science, Technology, Engineering, and Mathematics) learning environments. This course addresses the unique challenges faced by disadvantaged students and provides practical strategies for overcoming these barriers, ultimately fostering a more equitable and diverse STEM field. STEM education is critical in preparing students for a rapidly evolving job market and fostering innovation and problem-solving skills essential for societal growth. However, access to quality STEM education is often limited for disadvantaged students due to a variety of socio-economic, cultural, and institutional barriers. This course aims to bridge that gap by equipping educators with the tools and strategies needed to support and inspire these students.

Section 1 will define who disadvantaged students are and delve into their unique challenges, exploring the intersectionality of socio-economic status, race, gender, and disability. We will also identify the systemic, cultural, and psychological barriers that hinder their access and success in STEM education. This section also highlights the importance of STEM education for disadvantaged students, discussing its role in personal and professional development, economic mobility, and community growth. We will also examine how STEM skills contribute to innovation, diversity, and inclusive growth. Section 2 will explore effective teaching strategies at the classroom level, such as incorporating real-world applications, fostering critical thinking, and developing inclusive curricula. We will discuss how to engage and motivate students through project-based learning, hands-on experiences, and culturally responsive teaching practices.

Section 3 will cover practical approaches to designing and sustaining impactful STEM programs that engage and inspire disadvantaged students on a larger scale.

We will provide guidance on accessing funding opportunities, collaborating with community organizations and industry partners, training teachers, and building pathways to STEM-focused college programs.

Section 1: Understanding Disadvantaged Students in STEM Education

Understanding the challenges faced by disadvantaged students in STEM education is crucial for fostering inclusivity and equity in our educational systems. STEM (Science, Technology, Engineering, and Mathematics) fields are not only pivotal for economic growth but also offer pathways to higher wages and career opportunities. The demand for STEM professionals is rapidly increasing, with projections indicating continued growth in job availability and earning potential compared to non-STEM fields (Denton, 2021). Despite these advantages, access to quality STEM education remains uneven, particularly for students from low-income backgrounds, racial minorities, females, individuals with disabilities, and other marginalized groups. This section explores the unique barriers these students encounter in pursuing STEM education, highlighting systemic disparities in resources, educational opportunities, and social perceptions that hinder their academic success and career prospects. By addressing these barriers, we can create a more inclusive STEM education landscape that empowers all students to thrive and contribute to the future of innovation and societal progress.

Why STEM? Economic and Social Benefits

Focusing on STEM education for disadvantaged students is essential because of its significant social and economic benefits. Occupations in STEM fields are experiencing significant growth. According to a report by the Pew Research Center, employment in STEM fields grew by 79 percent between 1990 and 2018,

with computer jobs surging by an astonishing 338 percent during the same period (Denton, 2021). This upward trend is projected to continue, with STEM occupations expected to grow by 8 percent from 2019 to 2029, compared to just 3.4 percent for non-STEM occupations (Denton). STEM careers not only offer more opportunities but also command higher wages. In 2020, the median annual wage for STEM occupations was $89,780, more than twice the median wage for non-STEM jobs, which was $40,020 (Denton). Additionally, STEM occupations out-earn non-STEM fields by 12-30% across all education levels, demonstrating the financial benefits of STEM education (Smithsonian, 2024). Despite these high wages, nearly 2.5 million STEM jobs may go unfilled each year (Smithsonian). By offering comprehensive STEM education, low-income school districts can prepare students for high-demand careers and provide them with the essential skills needed for success in the future workforce. Likewise, by investing in STEM education, low-income school districts can increase the chances of their students accessing higher education and breaking the cycle of poverty.

Beyond the economic advantages, focusing on STEM education also has several social and societal advantages. By emphasizing STEM education in low-income school districts, educators can empower underrepresented groups, including girls, minority students, and those from disadvantaged backgrounds, to pursue STEM careers (National Math + Science Initiative [NMSI], 2023). This not only helps bridge the diversity gap in STEM fields but also brings fresh perspectives and innovative ideas, promoting a more inclusive society. Empowering these groups through STEM education can lead to a more equitable distribution of opportunities and resources, fostering social mobility and reducing systemic inequalities. Further, focusing on STEM education prepares students for the future in a technology-driven world. STEM education equips students with the skills and knowledge needed to tackle complex societal challenges such as climate change, healthcare disparities, and technological advancements. An information society

requires a globally literate citizenry capable of making informed decisions about health and safety, participating in public policy decisions and debates, managing daily lives that increasingly rely on technology, and finding solutions for challenges facing our global population (Smithsonian, 2024). By nurturing a diverse group of STEM professionals from low-income school districts, we ensure that a variety of experiences and perspectives are considered in developing solutions. This diversity leads to more comprehensive and effective strategies that address the needs of all communities, not just the privileged (NMSI).

Addressing the availability of a skilled STEM workforce involves enhancing STEM education, particularly for underrepresented and disadvantaged groups. Currently, the U.S. ranks 13th in science literacy and 31st in mathematics literacy among 37 Organization for Economic Cooperation and Development countries (Denton, 2021). Moreover, only about 20 percent of college-bound high school students are adequately prepared for STEM majors, with even lower preparedness among students of color, low-income students, and first-generation college students (Denton). Persistent racial and gender disparities further exacerbate the issue. Despite efforts to attract and retain underrepresented racial groups and women in STEM, these groups remain significantly underrecognized. Cultural stereotypes often depict STEM professionals as white or Asian males, which negatively impacts the attitudes and motivations of Black, Hispanic, and female students toward STEM (as cited in Denton). Additionally, these students typically score lower on standardized math and science tests, partly due to limited access to high-quality STEM education.

These disparities lead to a "leak in the scientific pipeline," where the interest and motivation of minority groups to pursue STEM diminish as they progress through their education (Denton, 2021). This decline starts as early as elementary school and becomes more pronounced over time. However, there is evidence that high-quality STEM education can significantly improve outcomes for all students,

particularly those from disadvantaged backgrounds. Engaging STEM experiences in elementary, middle, and high school can encourage students to pursue STEM careers. By providing these educational opportunities, we can help bridge the gap in STEM fields, fostering a more diverse and inclusive workforce that drives innovation and economic growth.

Identifying Barriers to STEM Education Access

Disadvantaged students are individuals who face systemic barriers and challenges due to factors such as socioeconomic status, race, gender, disability, and other intersecting identities (Whitcomb et al., 2021). These students often lack access to resources and opportunities that are readily available to their more advantaged peers, leading to disparities in educational outcomes, particularly in STEM fields. Each of these factors presents unique challenges that can hinder students' access to quality education and their ability to succeed in STEM fields. Below is a high level overview of some of the unique challenges that disadvantaged and underrepresented student groups face.

Socioeconomic Status

Individuals from low-income families are underrepresented in scientific careers due to various systemic barriers that start early in their academic journey (National Institutes of Health [NIH], 2019). Students from low-income families often have limited access to high-quality educational resources, including advanced coursework, experienced teachers, and extracurricular activities that enhance learning. Further, socioeconomic status significantly impacts students' access to STEM education and their success in these fields. Beginning in elementary school and continuing through their entire academic journeys, children attending the highest-poverty schools face significant disparities in their STEM education opportunities compared to their peers in wealthier schools.

These disparities are particularly pronounced in elementary science education, which has historically been neglected in school reform efforts (Change the Equation, n.d.).

Limited Access to Science Labs and Materials

Elementary students in high-poverty schools have substantially less access to the space and materials necessary for conducting science lab activities. According to data from 2015, only 31% of fourth-graders in schools where more than 75% of students are eligible for free or reduced-price lunch reported having access to space for science labs, compared to 41% in schools where 25% or fewer students qualify for such programs (Change the Equation, n.d.). Similarly, just 43% of students in high-poverty schools had access to necessary supplies and equipment for science labs, versus 61% in low-poverty schools. The lack of access to space and materials for science labs correlates with a reduced frequency of hands-on science activities. In high-poverty schools, only 47% of fourth-graders engage in hands-on science activities at least once per week, compared to 61% of their peers in more affluent schools. These hands-on activities are crucial for building early interest and mastery in science.

Resource Availability for Teaching

Teachers in high-poverty schools often report a lack of necessary teaching materials. In schools where more than 75% of students qualify for free or subsidized lunches, only 62% of eighth-graders have teachers with "all" or "most" of the resources needed for math instruction, compared to 79% in schools with lower poverty levels (Change the Equation, n.d.). For science instruction, the disparity is even more pronounced, with only 49% of eighth-graders in high-poverty schools having adequately resourced teachers, versus 75% in low-poverty schools. These statistics highlight a critical resource gap that hampers the educational outcomes of students in impoverished areas. These disparities

highlight the urgent need for targeted interventions to ensure that students in high-poverty schools receive the same quality of STEM education as their peers in wealthier schools.

Qualified Teachers

Across the U.S., there is a shortage of well-prepared and qualified STEM instructors. This shortage hampers students' ability to meet higher academic standards and pursue STEM careers. According to Athanasia (2022), 74% of students who graduated with a STEM degree identified poor early instruction as a major barrier to their success. Teachers with subject-specific degrees positively impact student achievement in math and science. However, about 28% of U.S. public school teachers hired to teach science in grades 7-12 lack a degree or minor in the sciences or science education (Athanasia). The situation is even more dire in high-poverty schools, where a 2008 study found that 40% of mathematics classes were taught by teachers without a degree in the subject. Conversely, schools with fewer low-income students have a higher percentage of STEM classes taught by teachers with relevant degrees (Athanasia, 2022).

Access to STEM Courses

Another major challenge exacerbated by socioeconomic status is the limited access to essential science and math prerequisites at every academic level. For instance, between 10-25% of high schools nationwide do not offer more than one of the core courses in the typical sequence of high school math and science education, such as algebra I and II, geometry, biology, and chemistry (NIH, 2019). This lack of availability hinders low-income students from taking a science-oriented core curriculum, thereby affecting their readiness for college-level STEM courses and reducing their chances of meeting readiness benchmarks on college entrance exams.

Additionally, the disparity extends to Advanced Placement (AP) courses. The College Board reports that each year, hundreds of thousands of students do not participate in AP courses for which they have high potential, largely due to the lower availability of a variety of AP courses in schools with higher numbers of low-income and traditionally underserved minority students (NIH, 2019). This further limits their opportunities to engage deeply with STEM subjects during high school.

After high school, many graduates from low-income families attend community colleges rather than four-year colleges; while community colleges provide valuable education, they often offer limited access to the higher education and research experiences needed for careers in science research (NIH, 2019). This continuation of limited access further perpetuates the underrepresentation of low-income students in scientific careers, highlighting the critical need for targeted interventions to support these students throughout their educational journey.

Race and Ethnicity

A recent study provides compelling evidence of structural racism in STEM education. The study, which analyzed data from 110,000 students across six large research universities, found that white males are significantly more likely to earn STEM degrees compared to their peers from underrepresented groups, even when they have similar academic backgrounds (Jackson, 2022). The researchers controlled for high school preparation, setting a benchmark of an average GPA of 3.57 and ACT scores in the 83rd percentile. Despite these controls, white males received more favorable outcomes in STEM programs compared to Black, Latinx, Indigenous, and female students who started with the same qualifications. Specifically, white males with at least a C in their first-term core courses had a 48% chance of graduating with a STEM degree, whereas Black males and females had only a 31% and 28% chance, respectively (Jackson, 2022).

The authors of the study express that the disparities are so pronounced that they indicate systemic issues within the introductory STEM courses themselves (Jackson, 2022). Co-researcher Chad Topaz highlighted that the study should prompt institutions to re-evaluate their teaching methods rather than attributing disparities to the supposed deficiencies of marginalized students. The study suggests that the educational environment and culture in these courses contribute to the differential treatment and success rates of students from diverse backgrounds (Jackson).

Racial Disparities in Early Childhood STEM

Inequities in science and math achievement begin as early as kindergarten, as revealed by a study conducted by researchers from Penn State, the University of California Irvine, and the University of Texas Health Science Center at Houston (Schwartz, 2020). This study highlights that schools need to provide early support and encouragement for students of color in STEM fields to address these disparities. The research focused on high-performing students, defined as those scoring above the 90th percentile in math or science assessments. Starting in kindergarten, a significantly higher percentage of white and Asian students met this benchmark compared to Black and Latino students. These gaps not only persisted but in some cases widened as students progressed through elementary school.

For instance, in kindergarten, 13% to 16% of white children scored above the 90th percentile on math and science tests, compared to only 3% to 4% of Black or Hispanic children. The study's lead author, Paul Morgan, emphasized the importance of identifying these disparities early on, as elementary school math and science achievement can predict later interest and success in STEM fields. This early onset of discrepancies underscores the necessity for early intervention to provide equitable educational opportunities (Schwartz, 2020). Interestingly, the

study found that when controlling for factors such as socioeconomic status and the average math and science scores at a child's school, the achievement differences between white and Hispanic students disappeared. However, this was not the case for Black students, indicating that while some disparities can be mitigated by addressing these factors, there are additional underlying issues that need to be addressed to support Black students fully (Schwartz).

Hostility in Higher Education

The low percentage of Black and Latinx students in STEM majors is not solely due to academic preparation. Research indicates that systemic hostility within campus culture plays a significant role in discouraging these students from persisting in STEM fields (Jackson, 2022). A Pew survey found that one-third of Black adults working in STEM fields reported being made to feel as though they did not belong in their classes during their STEM education. Black students are almost twice as likely as the average student to be told they do not belong in a class (Jackson).

A 2020 study by researchers at the University of Illinois and the University of Utah highlighted the prevalence of racial microaggressions faced by Black STEM students, who experienced a 57% increased probability of encountering these from instructors, teaching assistants, and advisers (Jackson, 2022). These students frequently overheard racist jokes and comments, experienced racial slurs, and felt both hyper-visible and invisible within their academic environment. Such conditions often led to feelings of exclusion and isolation, exacerbated by discouraging comments from faculty and staff in positions of authority.

Gender

Women face unique challenges and barriers when pursuing STEM careers, despite the high growth and earnings potential these fields offer. Gender bias and stereotypes, which start as early as preschool, undermine women's confidence in

their mathematical and technical abilities (Carlton, 2023). From a young age, girls are often discouraged from pursuing STEM due to these biases. For instance, teachers may award lower grades to girls for the same math work as boys. Such early discouragement contributes to girls opting out of STEM courses, leading to a significant gender gap in STEM fields. This gap is evident in higher education, where women earn only 36% of STEM bachelor's degrees, despite earning more bachelor's degrees overall than men (Carlton).

Women of color encounter even greater challenges. Black, Hispanic, Indigenous, and other underrepresented women of color make up less than 10% of the STEM workforce in the U.S (Carlton, 2023). They also leave STEM career tracks at higher rates at every stage of education and are significantly discounted in leadership roles. The gender wage gap further exacerbates these challenges. Women in STEM earn approximately 82 cents for every dollar earned by men, with the gap being even wider for Black and Hispanic women (Carlton). This wage disparity is partly due to women choosing lower-paying STEM majors and roles, often driven by early stereotypes about their abilities. Even within the same academic majors, women earn lower salaries than their male counterparts, highlighting the pervasive impact of gender bias on women's careers in STEM.

Disability

The Americans with Disabilities Act (ADA) "defines an individual with a disability as a person with a physical or mental impairment that substantially limits one or more major life activities" (as cited in National institutes of Health [NIH], 2024). Students with disabilities often do not receive the necessary accommodations and support to fully participate in STEM education. Physical accessibility, adapted learning materials, and specialized instructional methods are critical to their success but are often lacking. In secondary education, students with disabilities earn comparable credits in English to their peers but significantly fewer in math

and science, which are crucial for STEM pathways (Schneiderwind & Johnson, 2020). This disparity perpetuates the misconception that students with disabilities are less capable in STEM fields, leading to a cycle of low expectations and underperformance. The expectancy effect further exacerbates this issue. This psychological phenomenon suggests that individuals perform according to the expectations set for them by society, media, and themselves (Schneiderwind & Johnson). If students with disabilities are expected to perform poorly in STEM, they are likely to internalize these beliefs, resulting in lower test scores and diminished interest in STEM subjects. Although most research on the expectancy effect focuses on racial and ethnic minorities or gender, it is reasonable to assume similar negative impacts on students with disabilities.

Stereotypes, a lack of mentors, and insufficient understanding of the ADA requirements are additional challenges that individuals with disabilities face in STEM education (NIH, 2024). To build a diverse STEM workforce, it's essential to tackle the persistent underrepresentation of people with disabilities. This can be achieved through effective program interventions, the use of assistive technologies, and evidence-based education and communication strategies at every academic state. Additionally, educators often lack the training or resources to accommodate the unique needs of students with disabilities, making STEM content less accessible (Schneiderwind & Johnson, 2020). This lack of support means that many students with disabilities cannot fully participate in STEM courses, further decreasing their representation in these fields.

Section 1 Conclusion

Understanding and addressing the challenges faced by disadvantaged students in STEM education are crucial steps toward fostering a more equitable and inclusive society. The barriers related to socioeconomic status, race, gender, disability, and

other factors underscore the urgent need for targeted interventions to ensure all students have access to quality STEM learning opportunities from an early age. As highlighted throughout this section, disparities in access to resources such as science labs, qualified teachers, and advanced coursework significantly impact students' readiness and interest in STEM fields. These inequities not only hinder educational outcomes but also perpetuate underrepresentation in STEM professions. Moving forward, Section 2 will explore effective strategies for teaching STEM to disadvantaged students. By focusing on innovative approaches, equitable resource allocation, and culturally responsive teaching practices, educators can empower students from all backgrounds to succeed in STEM.

Section 1 Key Terms

Advanced Placement (AP) Courses - College-level courses and exams offered in high school that can potentially earn students college credit and/or advanced placement in college.

Americans with Disabilities Act (ADA) - A law that prohibits discrimination against individuals with disabilities in all areas of public life, including jobs, schools, transportation, and all public and private places open to the general public.

Assistive Technologies - Devices or software used to aid individuals with disabilities in performing tasks that might otherwise be difficult or impossible.

Barriers - Obstacles that hinder access to opportunities or success, such as those based on socioeconomic status, race, gender, disability, or other factors.

Diversity Gap - The underrepresentation of certain groups in specific fields or areas, such as women, racial minorities, or people with disabilities in STEM fields.

Disadvantaged Students - Individuals who face systemic barriers and challenges due to factors like socioeconomic status, race, gender, disability, and other intersecting identities.

Expectancy Effect - The phenomenon where individuals perform according to the expectations set for them by society, media, and themselves.

Gender Bias - Prejudices or discrimination based on a person's gender that can limit their opportunities and success.

Inclusivity - The practice of ensuring all individuals, regardless of their backgrounds or identities, have equal access to opportunities and resources.

Marginalized Groups - Communities that experience discrimination and exclusion due to unequal power relations across economic, political, social, and cultural dimensions.

Microaggressions - Subtle, often unintentional, discriminatory comments or actions directed at members of specific, typically minority, groups.

Socioeconomic Status - An individual's or group's position within a hierarchical social structure, often determined by factors like income, education, and occupation.

STEM (Science, Technology, Engineering, and Mathematics) - Academic disciplines that are key to economic growth, innovation, and high-paying careers.

Systemic Disparities - Inequities that are deeply embedded in the policies, practices, and cultural norms of a society or institution.

Underrepresented Groups - Populations that have lower representation in certain areas compared to their numbers in the general population, often due to historical and systemic discrimination.

Section 1 Reflection Questions

1. Reflect on the current state of STEM education at your school. How equitable is access to advanced coursework, experienced teachers, and extracurricular activities?

2. Analyze the representation of different racial and ethnic groups in your school's STEM programs. What trends do you notice, and what might be contributing to these trends?

3. Reflect on your personal teaching practices. How do you support disadvantaged students in STEM education? What more could you do to create an inclusive learning environment?

4. How does your school address systemic disparities in STEM education? What policies or practices could be implemented to promote equity?

5. How does your school support students with disabilities in STEM education? What additional accommodations or resources could be provided to ensure their success?

Section 1 Activities

1. **Inclusive Language:** Review your classroom language and materials for inclusivity. Make adjustments to ensure all students feel represented and valued.

2. **Data Analysis:** Analyze standardized test scores in math and science for different student demographics. Identify trends and propose interventions to address disparities.

3. **Equity Analysis:** Analyze enrollment data for STEM courses at your school, focusing on representation across different racial, gender, and socioeconomic groups. Present your findings.

4. **Student Survey:** Develop and administer a survey to your students to gather their perceptions and experiences related to STEM education. Use the data to inform your teaching practices.

5. **Digital Divide Assessment:** Evaluate the access to technology among your students. Develop a plan to address any digital divides that may hinder STEM learning.

Section 2: Teaching STEM to Disadvantaged Students

In the pursuit of excellence and innovation in STEM education, ensuring equity and inclusivity is not just a moral imperative but a strategic necessity. This section delves into critical facets of fostering equitable access and cultivating diversity within STEM curriculum and instruction. From understanding the barriers faced by disadvantaged students to exploring effective pedagogical approaches that promote engagement and motivation, this section aims to illuminate pathways toward a more inclusive STEM education landscape.

The discussion begins with an examination of learner-centered approaches and consequential learning strategies that empower students, particularly those from underrepresented backgrounds, to take ownership of their educational journeys. Emphasizing the importance of decriminalizing classrooms, this section explores how proactive measures can dismantle systemic barriers and promote a supportive learning environment conducive to all students' success. Furthermore, it delves into best practices in STEM pedagogy, advocating for student-centered, authentic learning experiences that not only enhance academic proficiency but

also cultivate essential 21st-century skills. By integrating these principles into STEM education, educators can foster a culture of innovation and prepare a diverse cohort of students to thrive in an increasingly complex global landscape.

Through these explorations, this section seeks to equip educators and stakeholders with actionable insights and strategies to build more inclusive STEM classrooms, where every student has the opportunity to excel and contribute meaningfully to the future of science, technology, engineering, and mathematics.

Addressing Equity and Diversity in STEM Curriculum and Instruction

Despite the increased focus on quality STEM education, substantial gaps persist, particularly impacting Black, Latinx, and other students from underrepresented communities (Basile et al., 2020). These disparities, often perpetuated by systemic issues rather than student deficiencies, highlight the need for a reimagined approach to STEM education that prioritizes equity and inclusion. Addressing these challenges involves not only scrutinizing and restructuring current educational practices but also implementing specific, targeted interventions that recognize and value the unique experiences of all students. To truly address the gaps in STEM education, educational policies must be restructured to support diverse, equitable, and inclusive learning environments. Only through such nuanced and equitable approaches can we hope to create a STEM education system that is truly inclusive and supportive of all students. To improve equity and inclusion in STEM education, specific teaching practices need to be transformed to better support marginalized students.

Here, we will explore learner-centered approaches and strategies to decriminalize classrooms within the context of STEM education. These practices aim to create inclusive environments that support marginalized students, fostering equity,

diversity, and a sense of belonging crucial for their academic success and future careers in STEM fields.

Learner-Centered Approaches

Learner-centered teaching, as defined by Duncan et al. (2023), prioritizes student engagement, active learning, and the integration of diverse perspectives within the classroom. This approach positions teachers as facilitators of learning, guiding students through collaborative activities and interactions that enhance their educational experiences. Later, we will explore learner-centered approaches from a pedagogical lens, whereas this section focuses on the approaches from an equity and inclusion lens. Central to learner-centered teaching is its focus on aligning students' strengths, interests, and preconceptions with their academic tasks and learning goals. This connection fosters meaningful learning experiences that are relevant and authentic to students. By valuing students' cultural backgrounds as assets rather than obstacles, this teaching approach encourages the generation of multiple solutions and perspectives, promoting inclusivity and creativity in problem-solving.

In learner-centered classrooms, various participation forums are provided to accommodate diverse learning styles and cultural norms. This includes using non-traditional discourse styles that allow students to communicate in culturally responsive ways, thereby validating alternative forms of knowledge (Duncan et al., 2023). Engagement strategies that promote equitable participation, such as individual reflection followed by group discussions, facilitate deep learning and personal connections to course material. Furthermore, peer interactions are fostered through cooperative learning activities, creating collaborative rather than competitive classroom dynamics. Teachers play a critical role in these environments by transitioning from experts to facilitators of collaborative learning, sharing authority with students and empowering them to take

ownership of their learning journey. However, it is important for teachers to be mindful of the limitations of learner-centered teaching. For instance, implementing cooperative learning without considering contextual issues may inadvertently reinforce stereotypes and inequalities (Duncan et al.). Additionally, challenges such as student feelings of isolation in group settings or assumptions about students' prior knowledge need to be addressed through thoughtful group formation and adequate preparation time.

Consequential Learning

Consequential learning is an equity-focused, student-centered approach where students design their own educational journeys to explore topics that are meaningful to them and their communities (Kim, 2024). It prioritizes the importance of human actions and interactions within the learning environment. It recognizes that students' educational experiences are significantly shaped by the power dynamics in their interactions with peers, educators, and the resources available to them. This approach critiques traditional hierarchical educational structures that often treat students, especially those from marginalized groups, as passive recipients of information. Instead, it promotes active engagement and values students' unique perspectives and contributions to the learning process. In STEM education, the following principles of consequential learning apply (Kim):

- **Student Empowerment:** Students are recognized as legitimate contributors to their own learning. They are encouraged to engage with science in ways that matter to them personally and within their communities. This principle shifts the role of students from passive consumers to active producers of knowledge.

- **Relevance to Students' Lives:** STEM education should connect with students' existing knowledge, experiences, and cultural practices. This

relevance makes science more meaningful and applicable to their daily lives, thereby fostering deeper engagement.

- **Teacher as Facilitator:** Teachers play a crucial role in disrupting traditional power hierarchies in the classroom. They must continuously engage in reflective practices to create an inclusive environment that supports all students in their scientific endeavors.

To implement consequential learning in the science classroom, teachers can adopt several strategies:

- **Community-Engaged Projects:** Incorporating projects that address local community issues can make science learning more relevant and impactful. For instance, students might work on environmental projects that benefit their neighborhoods, thereby seeing the direct application of their scientific knowledge (Kim, 2019).

- **Bridging Knowledge:** Encouraging students to draw connections between scientific concepts and their personal experiences helps them see the value of science in their own lives (Kim). This approach not only makes science more accessible but also empowers students to take ownership of their learning.

- **Action-Based Learning:** Students should be given opportunities to take action based on their learning. This might involve designing and conducting experiments that address real-world problems they care about, further solidifying their role as active participants in the scientific community (Kim).

By adopting consequential learning, students become more engaged and motivated in their science education. They develop a sense of agency and responsibility toward their learning, which can lead to higher achievement and a greater interest in pursuing STEM careers. Furthermore, this approach helps to

create a more inclusive and equitable classroom environment, where all students feel valued and supported (Kim, 2019).

Decriminalizing Classrooms

Decriminalizing classrooms is a vital strategy for promoting equitable STEM education, particularly for Black and Latino boys who are disproportionately affected by punitive school practices (Besile et al., 2020). According to studies, current punitive practices significantly contribute to the school-to-prison pipeline. Research shows that educators who adopt decriminalizing practices can effectively disrupt this harmful trajectory. Decriminalizing practices, derived from a multi-site, mixed methods longitudinal study, include the following (Besile et al.):

1. **Structural and procedural changes:** Modifying rules and the physical environment to reduce opportunities for criminalization. For example, setting up classroom activities where students can immediately engage upon arrival, rather than requiring strict silence for instructions.

2. **Honoring space:** Allowing students to use physical space for acts of expression that do not disrupt others. For instance, permitting a student to move around unused space during group activities.

3. **Assuming brilliance:** Approaching interactions with all students by assuming their actions and contributions are intelligent and valuable.

4. **Highly respectful interactions:** Engaging all students with language and tone that convey genuine care and respect, recognizing their agency in interactions. For example, explaining classroom procedures thoughtfully to foster understanding.

5. **Positive reframing:** Transforming negative incidents into positive learning experiences. For instance, celebrating a student's engineering enthusiasm rather than focusing on a tool breakage incident.

6. **Repair:** Actively addressing instances of criminalization through reflection and reconciliation. This may involve apologizing for misunderstandings and acknowledging systemic disparities that led to punitive actions.

These practices not only mitigate the impact of punitive measures but also foster an inclusive learning environment where all students feel safe and as a result, can thrive. Besile et al. (2020) emphasize the transformative potential in promoting educational equity and dismantling systemic barriers in science classrooms.

Teacher Agency

Understanding the importance of Faculty Agency and Action (FAA), also referred to as teacher or educator agency, is pivotal for equity in STEM education. According to Duncan et al. (2023), the concept of FAA emphasizes the critical role educators play in shaping the classroom climate, structure, and policies. Educator agency involves the dynamic interplay of internal and external factors influencing teachers, their awareness and analysis of classroom experiences, and the intentional management of classroom environments. This key concept encompasses themes such as classroom climate, structure, cultural competency, microaggressions, and stereotype threat and bias, which are essential for fostering a positive and equitable learning experience for all students. Recognizing and empowering teacher agency is crucial for creating an educational environment where every student can thrive.

Classroom Climate

The concept of classroom climate revolves around the methods educators employ to establish a welcoming, trusting, and respectful community that ensures

students feel safe and valued (Duncan et al., 2023). This environment is shaped by the general atmosphere of the class, influenced by educator-student verbal interactions and peer relationships (Dewsbury, 2020). A supportive classroom climate is characterized by care, support, and psychological safety, where students are treated with dignity and respect. Building strong educator-student relationships infuses learning with emotional elements of care and respect, enhancing the educational experience. Educators should deliberately connect personal, intellectual, and experiential aspects to create a multidimensional and inclusive learning environment (Cook-Sather & Des-Ogugua, 2019). Trust, fostered through sharing personal experiences and self-awareness, is essential for a successful student-instructor relationship. Facilitating peer interactions and collective work builds a sense of community, which is a crucial aspect of a positive classroom climate (Dewsbury). Additionally, educators should engage classroom conflict constructively to support learning and community growth.

Classroom Structure

Classroom structure refers to the organizational patterns, layouts, and resources that influence student navigation and learning experiences (Duncan et al., 2023). A flexible classroom organization allows diverse learners to engage with the curriculum in unique ways. Furthermore, incorporating Universal Design for Learning (UDL) principles ensures the curriculum is accessible to everyone. Educators should demystify processes by clearly explaining classroom procedures and setting explicit expectations to minimize confusion and set students up for success.

Beyond the classroom level, schools must address and rectify any practices that create barriers to STEM education. This includes analyzing course schedules, prerequisites, and other systemic issues that may prevent equitable access to STEM classes (Moore and Valenzuela, 2020). Collaboration between counselors,

administrators, and other stakeholders is essential to make necessary changes and ensure all students have access to high-quality STEM learning experiences.

Cultural Competency

Cultural competency involves the ability to understand, communicate with, and interact effectively with people from diverse cultures (Duncan et al., 2023). Culturally competent educators are informed about the history and culture of different groups, aware of their own worldview, and appreciate cultural diversity. This competency enhances inclusive environments through cultural scaffolding, socio-cultural consciousness, and a commitment to culturally relevant pedagogy (Dewsbury, 2020). Recognizing cultural capital as a success strategy and connecting culturally responsive teaching to specific subjects deconstructs dominant narratives and makes science more inclusive. Inclusive educators integrate multicultural perspectives and culturally diverse examples into the curriculum, fostering discussions of diverse ideas and creating identity-safe learning environments (Duncan et al.). Deconstructing the course content and norms to address silences, exclusions, and unconscious biases helps create a more comprehensive and inviting classroom structure. Educators should reflect on their privileged identities and biases, understand their social positioning, and consider the impact on student relationships and interactions (Dewsbury). Addressing personal and professional shortcomings through continuous learning about race, racism, and other social issues helps educators create more equitable learning environments.

Microaggression Intervention

Microaggressions, subtle and often unintentional discriminatory comments or actions, are a critical aspect of educator awareness in fostering an inclusive environment (Duncan et al., 2023). Educators must recognize and address these everyday exchanges that can send denigrating messages based on group

membership. Awareness and intervention in instances of microaggressions are essential for maintaining an equitable classroom. Strategies include proper name pronunciation, avoiding reinforcement of stereotypes through tasks or roles, and respecting students' pronouns. Continuous professional development and self-reflection help educators identify and mitigate these behaviors, thereby fostering an environment where all students feel respected and valued (Duncan et al.).

Stereotype Threat and Bias

Stereotype threat and implicit bias are pervasive issues that educators must actively confront to create equitable learning environments. Stereotype threat occurs when students fear that their actions will confirm negative stereotypes about their social group, potentially hindering their performance and participation (Duncan et al., 2023). Implicit bias, the unconscious attribution of particular qualities to members of specific social groups, can lead to lowered expectations and inaccurate judgments about students' abilities and motivations. Educators must be vigilant in recognizing potential STEM talent in all students and encouraging their participation. Implicit biases can lead to overlooking students who do not initially appear to be STEM candidates, which is especially true for young women, African-Americans, and Hispanic/Latinx students in fields like computer science (CS) (Moore and Valenzuela, 2020). Teachers should reflect on their own biases and the classroom environment they create to ensure all students feel they belong and are equally encouraged. Additionally, teachers can combat these issues through self-reflection and by adjusting practices to provide low-stakes, multiple opportunities for students to demonstrate mastery. This approach helps build students' confidence and reduces the impact of stereotype threat, ensuring that all students have the opportunity to succeed (Duncan et al.).

High Expectations for All

High expectations are crucial in K-12 STEM classrooms, as emphasized by Duncan et al. (2023). These expectations not only create challenging learning environments but also foster opportunities for success among all students. Upholding high expectations involves more than just aiming for academic rigor; it influences the entire classroom climate, promoting inclusivity and enabling students to achieve their educational goals while enhancing their cognitive skills and knowledge. Teachers play a pivotal role in maintaining high expectations for all students. They should consistently teach their content to the highest standards and believe unwaveringly in the potential for success among all learners. This belief is foundational, as it underpins the creation of challenging learning environments that stimulate higher-order thinking and critical inquiry.

Setting intentional and deliberate high expectations communicates to students that their success is both anticipated and achievable (Duncan et al., 2023). It is essential for teachers to explicitly convey the rationale behind these expectations, fostering student understanding of their significance. Effective communication of expectations, combined with teachers' confidence in students' capabilities, further strengthens the learning environment and encourages student engagement. To ensure equitable high expectations, teachers should challenge traditional academic norms and embrace a "brilliance discourse," as mentioned above, that acknowledges and values diverse forms of intelligence and achievement. This approach helps dismantle barriers to success based on background or perceived abilities, promoting an inclusive and supportive classroom environment.

Cultivating STEM Interest and Motivation Among Disadvantaged Students

Cultivating interest and motivation in STEM subjects among disadvantaged students is crucial for more equitable STEM learning. Affective learning, an approach that encompasses students' emotional engagement, values, motivation, and attitudes toward learning, plays a pivotal role in creating inclusive and equitable STEM classrooms, particularly for disadvantaged students (Duncan et al., 2023). This approach emphasizes the importance of integrating students' affective experiences with the academic content, thereby enhancing their overall learning outcomes, motivation and sense of belonging. In STEM education, affective learning influences students' engagement through various themes identified in meta-synthesis studies. These themes, such as choice, competence, growth mindset, motivation, personal relevance, science identity, self-efficacy, and sense of belonging, highlight critical factors that contribute to students' academic success and persistence in STEM fields.

- **Choice in learning activities** empowers students by allowing them to select tasks and materials that resonate with their interests and backgrounds. This autonomy fosters increased engagement and comfort in the classroom (Duncan et al., 2023). Additionally, teachers can adapt assessments to recognize diverse forms of achievement, promoting a more inclusive learning environment.

- **Competence** is nurtured when teachers design courses that scaffold learning experiences, provide varied assessment methods, and acknowledge students' existing knowledge. This approach helps mitigate barriers faced by historically marginalized groups and enhances their ability to engage effectively with STEM content (Duncan at al.).

- **Growth mindset** is crucial for fostering resilience and perseverance in students, especially when they encounter challenges in STEM subjects (Duncan et al.). Educators can cultivate a growth mindset by promoting belief in students' capacity for improvement through dedicated effort, thereby enhancing their self-efficacy and confidence in scientific inquiry.

- **Motivation** is key to student engagement and persistence in STEM disciplines. By creating inclusive learning environments that respect students' perspectives and incorporate culturally relevant examples, educators can inspire intrinsic motivation (Duncan et al.). This approach encourages students to connect course material with their personal experiences and community contexts, thereby deepening their interest in STEM subjects.

- **Personal relevance in teaching** acknowledges and integrates students' cultural identities into instructional practices. Educators can achieve this by using inclusive examples, cultural scaffolding, and personalized learning experiences that resonate with students' backgrounds (Duncan et al.). Such practices help students see the relevance of STEM to their lives and aspirations, promoting a more meaningful educational experience.

- **Science identity development** is critical for students to perceive themselves as capable participants in STEM fields. By highlighting diverse role models and incorporating culturally relevant content, educators can help students envision themselves as integral members of the scientific community (Duncan et al.).

- **Self-efficacy** is bolstered when students perceive themselves as capable of mastering STEM concepts and skills. Teachers can support this by modeling confidence in students' abilities, providing constructive feedback, and

creating a supportive learning environment where students feel empowered to take risks and persist in their studies (Duncan et al.).

- **Sense of belonging in STEM classrooms** is crucial for student retention and success. Educators can cultivate a supportive environment by building relationships with students, addressing stereotype threats, and promoting equity and inclusivity in classroom interactions (Duncan et al.). This inclusive approach helps students feel accepted and valued, fostering a community where diverse perspectives are respected and encouraged.

By prioritizing emotional engagement and creating inclusive learning environments, educators can help students from diverse backgrounds see themselves as capable and valued members of the scientific community. Ultimately, this approach not only enhances individual student outcomes but also contributes to a more diverse and innovative STEM workforce.

Role Models and Mentors

Establishing ongoing relationships with STEM-engaged adults offers several benefits within the framework of effective STEM promotion programs. These relationships enable students to develop a positive identification with STEM content, thereby increasing their engagement and motivation (Duncan et al., 2023). Research in the United States has shown that emotionally satisfying relationships centered on science, math, and engineering activities significantly shape students' likelihood of identifying with these fields and participating in related activities (Duncan et al.). When students form strong, supportive bonds with mentors, they are more likely to see themselves as capable and enthusiastic about pursuing STEM careers. This positive identification is crucial for maintaining their interest and commitment to STEM subjects over time.

Mentors also help dismantle negative stereotypes about STEM industries. By representing these fields in a positive light, mentors can challenge and change students' preconceived notions, making STEM careers more appealing and accessible (Duncan et al., 2023). This exposure to role models who are actively engaged in STEM helps students visualize their own potential paths within these fields, fostering a sense of belonging and possibility. Furthermore, mentors can increase engagement by providing personalized guidance and support, which is particularly important for students from disadvantaged backgrounds who may lack access to STEM resources and networks. Mentors can introduce students to hands-on STEM activities, facilitate participation in STEM-related events, and offer advice on educational and career pathways.

STEM Pedagogy Best Practices

STEM pedagogy best practices focus on creating an inclusive and dynamic learning environment that prepares all students for future challenges. By emphasizing interdisciplinary approaches, hands-on and problem-based learning, and the integration of 21st-century skills, these practices aim to foster a deep understanding of STEM concepts while cultivating critical thinking, creativity, and collaboration. The National Science and Technology Council outlines national goals for STEM education, which aim to ensure the following (Denton, 2021):

1. **Strong Foundations for STEM Literacy:** Every American should have the opportunity to master basic STEM concepts, including computational thinking and digital literacy. This foundation prepares the public to adapt to rapid technological changes and actively participate in society.

2. **Increased Diversity, Equity, and Inclusion:** It's essential to provide lifelong access to high-quality STEM education for all Americans, especially those historically underserved and underrepresented in STEM fields and jobs.

Achieving this goal ensures the full potential of the nation's STEM capabilities is realized.

3. **Prepared STEM Workforce:** Preparing a future-ready STEM workforce involves creating authentic learning experiences for both college-educated practitioners and skilled tradespeople. A diverse, STEM-literate talent pool is vital for sustaining national innovation, supporting key economic sectors, and driving scientific and technological advancements.

Modern perspectives on STEM literacy extend beyond proficiency in mathematics and science or technological navigation. Instead, the broader goals encompass cultivating "fulfilled, productive, knowledgeable citizen[s]," who can solve problems in their daily lives and contribute positively to society (Denton). Discussed below are some essential components, or what Denton refers to as, "What is needed in STEM education."

Interdisciplinary and Integrated

Over the past two decades, the perception of STEM as an integrated meta-discipline has gained traction due to the inherent connections among science, technology, engineering, and mathematics. This comprehensive approach dismantles the traditional boundaries between these fields, encouraging innovation and the application of knowledge to solve complex, real-world problems (Kennedy & Odell, 2023). It promotes problem-solving and critical thinking skills that are not only essential for academic success but also valuable in everyday life. Implementing integrated STEM education requires shifts in pedagogy and curricula, as well as strong professional development for educators to ensure high-quality learning experiences (Denton, 2021). Despite the challenges, the positive impacts on students' achievement and preparedness for the workforce make integrated STEM approaches essential for modern education.

Student-Centered and Authentic Pedagogy

Previously, we explored student-centered approaches from an equity lens, and here we will look at it from a pedagogical lens. Building creative problem solvers into STEM-literate citizens requires more engagement than traditional teaching approaches provide. According to Denton (2021), students benefit significantly from working on projects that are meaningful and relevant to their lives. Therefore, STEM education must adopt authentic, student-centered approaches. Student-centered pedagogy incorporates interdisciplinary approaches, as discussed above, cultural relevance, hands-on and problem-based learning, and a supportive, collaborative environment.

Problem-Driven and Hands-On

Authentic STEM learning involves hands-on, experiential activities that engage students in problem-solving and inquiry-based approaches (Denton, 2021). Project-based learning (PBL), a dominant strategy in STEM education, has been shown to significantly improve academic outcomes, as well as Problem-based learning (PrBL), and Phenomenon-based learning (PhBL) (Denton). These methods are particularly beneficial for English language learners (ELLs), minoritized students, and students with disabilities, as they allow for self-driven learning and engagement with STEM content in ways that are accessible and meaningful to them (Denton).

Schools that emphasize STEM education are increasingly adopting this type of inquiry-based, interdisciplinary approach. These methods make STEM education more relevant and applicable to real-world contexts (Kennedy & Odell, 2023). Specialized STEM school models often engage students through inquiry-based learning frameworks such as the 5E Model of instruction. This model includes five phases: Engage, Explore, Explain, Elaborate, and Evaluate. It provides a logical progression that mirrors the natural process of learning, thus fostering deeper

understanding and retention of knowledge (Kennedy & Odell). This approach not only enhances students' academic skills but also prepares them to apply their learning in practical, innovative ways.

Project-Based Learning (PBL)

Project-Based Learning (PBL) is a student-centered instructional method that allows students to actively engage in real-world and meaningful projects (Kennedy and Odell, 2023). Unlike traditional learning, which often relies on passive lectures and rote memorization, PBL emphasizes hands-on, experiential learning. Although lectures are not entirely excluded, they are used strategically within the PBL framework to introduce concepts, develop necessary skills, provide guidance, and offer reflections. Key characteristics of PBL include (Kennedy and Odell):

- **Real-World Relevance:** Projects are designed to address real-world problems or questions, making learning more meaningful and applicable to students' lives.

- **Inquiry-Based Learning:** Students are encouraged to ask questions, conduct research, and explore topics collaboratively, promoting deeper learning and critical thinking.

- **Collaboration:** Students work in groups, mirroring real-life work environments, fostering teamwork, idea-sharing, and problem-solving skills.

- **Student Ownership:** PBL allows students to take charge of their learning by providing choices in the project direction and encouraging the development of soft skills such as time management and goal setting.

- **Interdisciplinary Approach:** PBL often requires students to integrate knowledge and skills from multiple disciplines.

- **Assessment:** Evaluation focuses on the quality of the final project, with requirements and rubrics guiding the expected outcomes.

- **Reflection:** Students reflect on their learning process, with checkpoints to gauge progress and prepare for high-stakes tests.

- **Public Presentation:** Students present their projects to peers, teachers, and experts, enhancing their presentation and communication skills.

PBL is seen as an effective way to foster critical thinking, creativity, problem-solving, and a deeper understanding of subject matter, preparing students for real-world challenges.

Problem-Based Learning (PrBL)

Problem-Based Learning (PrBL) is similar to PBL but starts with a complex, real-world problem (Kennedy & Odell, 2023). Students explore, analyze, and solve this problem over a specified period, often with the teacher acting as a facilitator rather than a traditional instructor. This approach is particularly common in medical schools and K-12 mathematics classrooms. Unique features of PrBL include (Kennedy & Odell):

- **Teacher as Facilitator:** Teachers provide support and resources but do not dictate solutions.

- **Assessment:** Assessment focuses on the quality of proposed solutions and the learning process, often through presentations, written reports, and discussions.

- **Reflective Thinking:** Students assess their learning process, identify knowledge gaps, and set goals for further learning.

PrBL helps students develop a deep understanding of content, critical thinking, and self-directed learning skills, preparing them to address complex real-world problems.

Phenomena-Based Learning (PhBL)

Phenomena-Based Learning (PhBL) expands on PBL and PrBL by focusing on complex, real-world phenomena that are relevant to students (Kennedy & Odell, 2023). Initiated by Finland's educational system, PhBL immerses students in contextual situations aligned with real-life issues, encouraging them to apply knowledge and skills from multiple disciplines. Unique aspects of PhBL include (Kennedy & Odell, 2023):

- **Central Phenomenon:** Learning begins with a phenomenon relevant to students' lives or the curriculum, serving as the anchor for exploration.

- **Application of Knowledge:** Students address real-world problems related to the phenomenon, making learning more meaningful.

- **Personal Impact:** Projects often start with phenomena that personally impact students, such as the COVID-19 pandemic, engaging them in designing solutions to related challenges.

An example of PhBL in a middle school classroom might be investigating a local lake that has experienced a sudden increase in algae growth, which has impacted fish populations and water quality. The objective for students would be to explore the causes and consequences of this phenomenon by investigating ecosystem dynamics, human impact, and environmental factors.

Benefits for Disadvantaged Students

Project-Based Learning (PBL), Problem-Based Learning (PrBL), and Phenomena-Based Learning (PhBL) are particularly beneficial for disadvantaged students due

to their engaging, relevant, and supportive nature. These methods integrate real-world relevance into the learning process, making education more meaningful and applicable to students' lives (Kennedy & Odell, 2023). For example, PBL involves students in projects that reflect real-life challenges, enhancing their motivation by demonstrating the practical importance of their education. Similarly, PrBL starts with a real-world problem, encouraging critical thinking and problem-solving, which helps students see the value in addressing real-life issues. PhBL focuses on exploring phenomena relevant to students' experiences, which increases engagement and impact.

Furthermore, these methods foster inquiry and ownership, empowering students to ask questions, conduct research, and explore topics collaboratively. This active participation in their own learning process is crucial for disadvantaged students, who often feel disconnected from traditional educational approaches (Kennedy & Odell, 2023). The collaborative nature of PBL, PrBL, and PhBL helps build a sense of community and support among students, offering a support system that might be lacking outside of school. These approaches also emphasize interdisciplinary learning, requiring students to integrate knowledge and skills from multiple subject areas. This holistic approach helps students understand the interconnectedness of different disciplines, providing a richer educational experience. In addition, PBL, PrBL, and PhBL focus on developing essential skills such as critical thinking, problem-solving, and creativity. Disadvantaged students, who may have fewer opportunities to develop these skills outside of school, benefit greatly from this emphasis on practical, transferable skills valuable in both academic and real-world contexts.

Incorporates 21st Century Skills

To effectively prepare students for work and life in the modern world, STEM education must go beyond teaching isolated STEM knowledge and integrate 21st-

century skills, sometimes referred to as soft skills. As Denton (2021) highlights, these skills are essential for today's job market and encompass critical thinking, creativity, collaboration, communication, information literacy, media literacy, and technology literacy. Additionally, flexibility, leadership, initiative, productivity, a positive attitude, social skills, teamwork, and a strong work ethic are crucial. Authentic STEM learning experiences naturally align with these 21st-century skills. For instance, by working on real-world problems, students develop communication skills and learn to navigate information and media literacy. Technology literacy is also inherent in STEM activities, ensuring students are proficient with the tools and resources essential in the modern world.

Moreover, these student-centered learning methods foster a growth mindset by providing opportunities for students to encounter challenges and persevere through failures (Denton, 2021). This resilience is a key aspect of 21st-century skills, as it prepares students to adapt and thrive in dynamic environments. Importantly, focusing on these skills can significantly benefit minoritized students. When these students receive support in building higher-order thinking skills, they are better equipped to succeed in STEM fields, promoting greater diversity and inclusion in STEM careers.

Section 2 Conclusion

Bridging the gaps in STEM education for disadvantaged students requires a multifaceted approach that addresses both systemic issues and individual needs. By rethinking and restructuring policies and practices, educators can create more equitable and inclusive learning environments that support the diverse experiences of all students. Culturally responsive teaching, learner-centered approaches, and the decriminalization of classrooms are essential strategies for fostering an atmosphere where every student can thrive. Moreover, the emphasis

on equity and inclusion not only benefits marginalized groups but also enriches the STEM fields with diverse perspectives and innovative solutions. Through dedicated efforts to implement these inclusive practices, we can ensure that all students have the opportunity to succeed in STEM, thereby contributing to a more just and competitive society. Section 3 will further explore how to build effective STEM programs for disadvantaged youth.

Section 2 Key Terms

21st-Century Skills - Essential abilities for the modern job market, including critical thinking, creativity, collaboration, communication, and technology literacy.

Affective Learning - An educational approach that integrates students' emotional engagement, values, motivation, and attitudes with academic content.

Classroom Climate - The overall atmosphere of the classroom, characterized by care, support, and psychological safety, where students feel safe and valued.

Classroom Structure - The organizational patterns, layouts, and resources in a classroom that influence student navigation and learning experiences.

Consequential Learning - An equity-focused, student-centered approach where students design their educational journeys around topics meaningful to them and their communities.

Cultural Competency - The ability to understand, communicate with, and interact effectively with people from diverse cultures.

Decriminalizing Classrooms - Strategies that reduce punitive practices in schools, promoting a supportive learning environment, especially for marginalized students.

Faculty Agency and Action (FAA) - The role educators play in shaping classroom climate, structure, and policies to support equitable learning environments.

Implicit Bias - Unconscious attitudes or stereotypes that affect understanding, actions, and decisions in an educational setting..

Interdisciplinary Approaches - Teaching methods that integrate knowledge and skills from multiple disciplines to provide a richer educational experience.

Learner-Centered Teaching - An approach that prioritizes student engagement, active learning, and diverse perspectives within the classroom.

Microaggressions - Subtle and often unintentional discriminatory comments or actions that can send denigrating messages based on group membership.

Section 2 Reflection Questions

1. Examine the barriers that disadvantaged students face in accessing STEM education. What specific barriers have you observed in your own school or classroom?

2. Consider the importance of decriminalizing classrooms. How might your school's disciplinary practices impact marginalized students, and what changes could create a more supportive environment?

3. How can learner-centered approaches be adapted to support diverse cultural norms and learning styles in your classroom?

4. Examine the structural and procedural changes suggested for decriminalizing classrooms. What specific changes could be implemented in your school to support this goal?

5. How do you currently utilize interdisciplinary approaches in your teaching? What benefits have you observed, and what challenges have you faced?

6. Reflect on the role of high expectations in your classroom. How do you convey belief in the potential of all students, and how does this impact their performance?

7. Analyze your current use of project-based learning (PBL) or problem-based learning (PrBL) methods. How do these approaches enhance engagement and understanding for disadvantaged students?

Section 2 Activities

1. **Equity Audit:** Conduct an equity audit of your STEM curriculum to identify and address gaps that may disadvantage certain student groups.

    a. **Resource Curation:** Curate a list of culturally relevant STEM resources that reflect the diverse backgrounds of your students.

2. **Classroom Observation:** Observe a peer's classroom to see how they implement learner-centered teaching and decriminalizing practices. Discuss your observations with your peer and reflect on what you can adapt for your own teaching. Alternatively, record one of your own lessons and reflect on it.

3. **Peer Collaboration:** Partner with a colleague that teaches a different subject, to co-create and implement an interdisciplinary STEM project that emphasizes problem-based learning.

4. **Classroom Climate Assessment:** Using a free assessment tool that you find through a Google search, conduct an assessment of your classroom climate, focusing on how welcoming and supportive it is for all students.

5. **Policy Review:** Review your school's policies and practices related to discipline and inclusivity, and propose changes that could support a more equitable learning environment.

6. **Student Engagement Analysis**: Conduct an analysis of student engagement levels in STEM classes, focusing on strategies that effectively engage disadvantaged students. Propose adjustments to teaching methods based on your findings.

7. **Case Study Analysis:** Analyze case studies of successful STEM programs that have effectively addressed equity and inclusion. Extract key strategies to apply in your own teaching context.

Section 3: Developing Effective STEM Programs for Disadvantaged Students

Developing effective STEM programs for disadvantaged students requires a multifaceted approach that addresses the unique challenges these students face. This section explores key strategies, including establishing a task force, securing funding, adopting standards like the Next Generation Science Standards (NGSS), focusing on teacher recruitment and training, and fostering community partnerships. Ensuring that disadvantaged students have access to high-quality STEM education is crucial for preparing them for future academic and career success.

Establishing a Task Force

A task force, composed of diverse stakeholders, ensures a comprehensive and collaborative approach to building robust STEM initiatives that cater to the needs of all students, particularly those from underrepresented and disadvantaged

backgrounds (Chambers, 2020). Here are key reasons why forming a task force is essential:

- **Diverse Perspectives and Expertise:** A task force brings together individuals with varied backgrounds, including educators, industry professionals, community leaders, and policymakers (Chambers). This diversity of perspectives ensures that the STEM program addresses multiple facets of education, from curriculum development to real-world applications, making it more comprehensive and effective.

- **Holistic Needs Assessment:** Task forces are well-equipped to conduct thorough needs assessments, identifying gaps in current STEM education offerings and understanding the specific needs of different student populations. This assessment allows for the creation of targeted strategies that address these gaps, ensuring that the STEM program is inclusive and equitable.

- **Strategic Planning and Implementation:** A task force can develop a clear and strategic plan for the STEM program, outlining goals, timelines, and measurable outcomes. This structured approach ensures that the program is implemented systematically and effectively, with continuous monitoring and evaluation to track progress and make necessary adjustments.

- **Sustainability and Scalability:** Building a sustainable and scalable STEM program requires long-term planning and commitment. A task force can develop strategies for maintaining and expanding the program over time, ensuring that it continues to evolve and adapt to changing educational needs and technological advancements..

- **Accountability and Transparency:** With a task force in place, there is a clear structure for accountability and transparency in the development and

execution of the STEM program. Regular meetings, progress reports, and stakeholder communications ensure that all parties are informed and that the program stays on track to meet its objectives.

The need for a dedicated task force is a principle successfully demonstrated by Broward County Public Schools in Florida (Milenkovich, 2024). Broward County, the sixth-largest school district in the United States, serves a diverse student population of over 250,000 across 326 schools in the Fort Lauderdale area. The district's commitment to equitable skill-building and STEM opportunities highlights the importance of inclusive program design. In 2013, Broward County's STEM and Computer Science (STEM+CS) team was established to implement an interdisciplinary K-12 STEM program. Separate from traditional core subjects and Career Technical Education (CTE) programs, this initiative aimed to reach all students. Over the past decade, the program has grown substantially, benefiting hundreds of thousands of students and enhancing district-wide STEM opportunities and outcomes.

Funding STEM Programs

Securing funding for STEM programs is essential for providing high-quality education, but it presents several challenges, especially for schools in disadvantaged areas. Quality STEM education demands up-to-date materials and technology to prepare students for the modern world. However, computer science equipment, engineering kits, and scientific tools are often costly, posing significant financial burdens on primary and secondary schools, particularly those serving low-income communities. Despite these challenges, the growing awareness and support for STEM education have created numerous opportunities for funding (CircuitMess, 2024). Here are several notable funding opportunities available for STEM programs:

- **State Funding:** Many states offer specific grants for STEM education, ranging from supporting science fairs to integrating technology in classrooms. For example, a state might offer a grant to implement robotics programs in middle schools. To explore what your state has to offer, you can use tools like STEMfinity, which allows you to click on your state and see all the grants and funding options available specifically for your area (CircuitMess, 2024).

- **Federal Grants:** The U.S. government provides substantial funding for STEM initiatives through agencies like the National Science Foundation (NSF) and the Department of Education. These grants often focus on large-scale projects or research, such as an NSF grant for developing new engineering curricula (CircuitMess, 2024). Federal grants are particularly important for fostering inclusivity and equity because they often prioritize underrepresented groups and underserved students.

- **Corporations:** Big tech and engineering companies often offer STEM funding to encourage students to explore future careers in the industry. For instance, General Motors has partnered with organizations like DonorsChoose and AI4ALL to provide immersive STEM learning activities and curricula to diverse groups of students (CircuitMess, 2024). Local tech companies may also offer grants, equipment, or mentorship programs .

- **Foundations and Non-Profit Organizations:** Numerous private foundations are dedicated to advancing STEM education. The Simons Foundation, the Amgen Foundation, and the Gates Foundation are just a few of the major contributors to this cause (CircuitMess, 2024). These foundations typically award grants to non-profit organizations dedicated to education, rather than funding individual schools or educators directly.

Identifying the Right STEM Grants

Identifying the right STEM grants begins with defining your objectives and understanding your program's purpose (CircuitMess, 2024). Studying grant requirements in detail and exploring past awardees can help align your applications with the preferences of funding organizations, increasing your chances of success.

Strategies for Winning STEM Education Grants

Once you've identified a grant to pursue, crafting a compelling proposal is the next crucial step. Your proposal is your opportunity to convince grantors that your STEM education program is worth their investment. CircuitMess (2024) offers key strategies for securing STEM grants:

1. **Crafting a Quality Proposal:** Your proposal should clearly communicate the value of your program, detailing your needs and budget. Strict formatting rules must be followed, and the right content must be included, sprinkled with a bit of storytelling. A simple online search will reveal numerous proposal template options.

2. **Building a Strong Case:** Your proposal needs to stand out among many others. One effective way to achieve this is by telling your story. Describe how your STEM project came into existence, the challenges it addresses, and your vision. Including anecdotes, past student success stories, and acknowledging potential challenges with solutions can make your proposal more personable and persuasive. Use images, charts, graphs, or infographics to visualize your message and illustrate key points.

3. **Collaborating with Community Partners:** Partnerships can strengthen your proposal. Collaborating with other organizations dedicated to education, such as local schools, community groups, or experts in youth education, can

enhance the impact of your STEM program. Highlighting these partnerships in your proposal can demonstrate a broader support network and increase the likelihood of funding.

4. **Focusing on Outcomes:** Funders want to see tangible results and positive impacts from their investments. Emphasize specific, detailed, and measurable outcomes of your program. Avoid vague statements and use concrete metrics, timelines, and clear goals. This approach shows that you have a well-thought-out plan and are committed to achieving measurable success.

5. **Reporting and Accountability:** Once you have the funds, prepare regular, detailed reports showing that you are using the money appropriately. Provide detailed financial statements and describe the impact of your STEM program using qualitative and quantitative data. Highlight success stories and describe how the grant has contributed to your program's goals. If you encounter unexpected challenges, communicate these to the grantor, as they may provide guidance or flexibility.

By following these strategies, you can enhance your chances of securing funding for your STEM education programs and ensure that the funds are used effectively to achieve your educational goals.

Adopting Standards

Adopting standards like the Next Generation Science Standards (NGSS) is a critical part of developing a quality STEM program, as it ensures a consistent, high-quality framework for science education across different schools and districts. These standards are designed to prepare students for college, careers, and citizenship by emphasizing inquiry-based learning and integrating science and engineering practices (Denton, 2021). By adhering to these standards, educators can provide a

structured and comprehensive approach to STEM education, which is particularly beneficial for disadvantaged learners. Although the NGSS focus primarily on science and engineering, their principles can be extended to broader STEM learning, promoting a more integrated and interdisciplinary approach. This alignment ensures that students receive a well-rounded education that prepares them for future challenges and opportunities in the STEM fields.

For disadvantaged learners, the consistency and rigor provided by standards like NGSS help level the playing field. These students often face educational disparities and may not have access to the same resources or opportunities as their more advantaged peers. By implementing NGSS, schools can ensure that all students, regardless of their background, receive a high-quality science education that includes critical thinking, problem-solving, and collaborative skills (Denton, 2021). This structured approach helps mitigate the variability in educational quality that disadvantaged learners might encounter. Moreover, the focus on inquiry-based learning and real-world problem-solving in NGSS aligns well with the needs of all, including disadvantaged learners. The NGSS also encourages the development of 21st-century skills such as critical thinking, creativity, collaboration, and communication (Denton, 2021). These skills are essential for success in today's workforce and are highly valued by employers. By focusing on these skills, NGSS helps prepare disadvantaged students not just for academic success, but for long-term career success as well. This holistic preparation can open up new opportunities for these students and help break the cycle of disadvantage.

Teacher Recruitment and Training

Well-prepared educators are essential for delivering high-quality STEM education. Effective teachers have a deep understanding of STEM subjects and the pedagogical skills needed to engage students and foster a love for science,

technology, engineering, and mathematics. This is particularly important for disadvantaged students, who may lack other resources and opportunities to explore these fields. Programs like the National Science Foundation's Robert Noyce Teacher Scholarship and initiatives such as 100Kin10 provide significant support for aspiring STEM teachers; these efforts ensure that new educators are not only knowledgeable in their subjects but also equipped with the latest teaching strategies and tools to effectively reach diverse learners (Kennedy and Odell, 2023). Moreover, ongoing professional development helps current teachers stay updated with advancements in STEM education, thus continuously improving their instructional practices.

Additionally, teacher training programs should, and often do, include components that address the unique challenges faced by students in high-needs schools. This specialized training helps educators develop culturally responsive teaching methods and create inclusive learning environments that support all students, regardless of their socioeconomic background, race, gender, or ability level (Kennedy and Odell, 2023). Skilled and motivated teachers can inspire students, breaking down barriers to STEM fields and encouraging a more diverse range of students to pursue STEM careers. This, in turn, helps build a competent workforce equipped to tackle the technological and scientific challenges of the future.

Collaborating with Community Organizations

To enhance STEM education's impact, schools can forge community partnerships with local businesses, research institutions, and non-profit organizations. These collaborations leverage the expertise and resources of these entities to provide students with hands-on experiences that apply their classroom learning to real-world challenges in a controlled environment (21stCentEd, 2023). Community

partnerships in STEM play a crucial role in boosting student engagement by making learning more practical and relevant.

Benefits of Partnerships

Community partnerships play a crucial role in enhancing STEM education by providing schools and students with a range of opportunities and advantages. These collaborations not only broaden access to diverse resources and experiences but also foster inclusivity and prepare students for real-world applications of STEM knowledge. 21stCentEd (2023) highlights the following benefits:

- **Greater Access to Diverse Resources:** Partnerships with local businesses and nonprofits enrich STEM education by exposing students to cutting-edge technology and current research, essential for thriving in modern workplaces.

- **New Clubs, Activities, and Extracurricular Experiences:** Additional financial support allows schools to expand STEM programs, offering students opportunities to participate in clubs, workshops, and competitions that deepen their mastery of STEM principles.

- **Improved Inclusivity of STEM Education:** Partnerships provide virtual learning options, scholarships, and mentorship programs, ensuring equitable access to advanced STEM education for underserved students. They also introduce diverse role models, making STEM careers more relatable and accessible.

- **Real-World Experiences:** Internships, job-shadowing, and collaborative projects with professionals offer students practical insights into STEM careers, honing their problem-solving and critical-thinking skills for future success.

Community partnerships are indispensable for preparing a skilled workforce and promoting STEM education that is inclusive, practical, and aligned with real-world demands. These collaborations empower students to excel in STEM fields by bridging classroom learning with hands-on experiences and ensuring equitable access to opportunities for all learners.

Community Partnership Tips

Establishing effective community partnerships is crucial for enriching STEM education experiences. These collaborations bring together schools and various organizations to enhance learning opportunities and foster student engagement. Ashbrook (2019) provides practical tips for establishing and maximizing the benefits of community partnerships in STEM education:

1. **Identifying Potential Partners:** When establishing community partnerships for STEM education, it's crucial to consider potential collaborators who can mutually benefit from shared goals and activities. Look for organizations like museums, science centers, zoos, and aquariums that can offer unique educational experiences such as tailored field trips and interactive classroom visits with live specimens and artifacts. Partnerships with PBS stations can provide access to funding and educational resources aligned with STEM-focused content, enhancing learning through various programs.

2. **Approaching Partners Strategically:** Communicate educational needs and scheduling constraints clearly to ensure activities align with curriculum goals and logistical requirements. Partnerships should ideally cater to the developmental needs of students, leveraging the partner's expertise in child-friendly activities or curriculum development.

3. **Emphasizing Local Relevance:** Emphasizing local relevance in STEM activities—like focusing on ocean science in coastal communities or

watershed perspectives inland—enhances students' engagement by connecting learning to their immediate surroundings.

4. **Planning Sustainable Activities:** When planning joint activities, it's beneficial to prioritize activities that can be sustained over time or integrated into existing school events, ensuring lasting educational impact. Activities can range from family science events celebrating environmental awareness to teacher-focused webinars and field trips that extend classroom learning. Supplement one-time experiences like field trips with additional learning opportunities, such as preparatory visits or follow-up classroom activities provided by partners.

5. **Managing Resources Effectively:** Coordinate with partners to manage supplies, costs, and time commitments associated with implementing STEM activities in schools.

By implementing these strategies, schools can forge meaningful partnerships that enrich STEM education, empower students with practical skills, and foster a lifelong appreciation for science and technology. These collaborations not only enhance learning but also strengthen community ties and support educational success.

Creating College Pathways

STEM-focused schools, or STEM-focused programs within public or charter schools can significantly enhance STEM opportunities for disadvantaged students, preparing them to enter and succeed in college STEM programs. According to Kennedy and Odell (2024), these specialized programs increase the number of students passing Advanced Placement (AP) and International Baccalaureate (IB) science and mathematics courses, thereby enlarging the pipeline of students equipped for college-level STEM studies.

Recommendations for STEM-focused Schools

Statewide Specialty High Schools can immerse students in high-quality STEM education, fostering future leaders in science, technology, and mathematics. They also serve as venues to test teaching materials and provide training for teachers. Kennedy and Odell (2024) share the following are various models for STEM-focused schools:

- Residential State STEM Academies

- Schools within a School

- STEM Magnet Schools

- Early College High Schools (ECHS)

- University Affiliated Laboratory Schools

These models vary in their admission and enrollment criteria, with some implementing open enrollment and others using a lottery system to manage student intake. For example, the University of Texas at Tyler University Academy is an open enrollment, K-12 public school that offers pathways to engineering and biomedical sciences, allowing students to earn college credits and participate in unique research opportunities on a university campus while still in high school (Kennedy and Odell).

Impact on College Enrollment

Research has shown that students attending STEM-focused schools or pursuing STEM pathways in traditional schools are more likely to enroll in college STEM programs (Kennedy and Odell, 2024). For instance, the most recent graduating class of the UT Tyler University Academy saw 100% of its graduates pursuing postsecondary education, with 87% enrolling in STEM degree programs. However,

it's important to note that other factors such as personal interests, family support, and socioeconomic conditions also influence students' decisions to pursue STEM degrees.

Section 3 Conclusion

Developing effective STEM programs for disadvantaged students is essential for ensuring that all students have the opportunity to succeed in these fields. By forming a task force, securing funding, adopting standards like NGSS, focusing on teacher recruitment and training, and fostering community partnerships, schools can create inclusive and equitable STEM education environments. Additionally, creating STEM-focused school pathways can further enhance these efforts, providing students with advanced learning opportunities and preparing them for college-level STEM studies. Through these strategies, we can help bridge the gap in STEM education and empower the next generation of innovators and problem-solvers.

Section 3 Key Terms

Community Partnerships - Collaborations with local businesses, institutions, or organizations to enhance STEM education by providing resources, expertise, and real-world learning opportunities.

Holistic Needs Assessment - Comprehensive evaluation of educational needs, considering various factors impacting students, to tailor programs that address specific gaps and challenges.

Interdisciplinary - Integrating knowledge and methods from multiple academic disciplines to create a holistic approach to STEM education.

NGSS (Next Generation Science Standards) - Standards that define the expectations for what students should know and be able to do in science and engineering fields, emphasizing inquiry-based learning and application of knowledge.

Sustainability - The ability of a STEM program to endure over time, effectively utilizing resources and adapting to changing educational needs and advancements in technology.

Workforce Readiness - The preparation of students with the skills, knowledge, and abilities needed to succeed in future STEM careers and meet industry demands.

Section 3 Reflection Questions

1. How does your school currently secure funding for STEM programs? What are some innovative approaches or partnerships that could enhance your funding efforts?

2. In what ways does your school align with or could benefit from adopting standards like the Next Generation Science Standards (NGSS) in STEM education?

3. Share examples of successful community partnerships your school, or other schools that you have observed, has established. How have these partnerships enriched STEM learning opportunities for students?

4. Reflect on the impact of funding on STEM equity in your school. How do financial resources influence the quality and accessibility of STEM education for all students?

5. How does your school support the professional development of STEM educators? What professional learning opportunities could be introduced to strengthen STEM instruction?

6. In what ways can educators advocate for policy changes or community support to improve STEM education for disadvantaged students? What steps could be taken at local, state, or national levels to enhance STEM equity?

Section 3 Activities

1. **Funding Opportunities Audit:** Audit current funding opportunities available at the state and federal levels for STEM education. Identify relevant grants and develop a plan to apply for one that aligns with your school's needs.

2. **NGSS Alignment Analysis:** Analyze how your current STEM curriculum aligns with the Next Generation Science Standards (NGSS). Identify areas for alignment improvement and develop a plan to integrate NGSS principles more effectively.

3. **Teacher Training Review:** Review your school's current professional development offerings for STEM educators. Identify gaps and propose new training modules or resources to enhance STEM instruction.

4. **Community Partnership Proposal:** Develop a proposal outlining potential community partnerships that could enhance STEM learning opportunities for your students. Include specific organizations and potential collaborative projects.

5. **Budget Proposal for STEM Equipment:** Develop a budget proposal outlining the costs and benefits of acquiring new STEM equipment or updating

existing resources. Justify the need based on educational outcomes and student needs.

6. **STEM Career Exploration Fair:** Organize a STEM career exploration fair for students, featuring guest speakers from diverse STEM fields. Coordinate with community partners to ensure representation and provide networking opportunities.

Course Conclusion

Developing STEM Education for Disadvantaged Students" is not just a course but a transformative journey aimed at equipping educators with the tools to create inclusive and engaging STEM learning environments. By addressing the unique challenges faced by disadvantaged students and providing practical strategies for overcoming these barriers, we aim to foster a more equitable and diverse STEM field. In Section 1, we defined who disadvantaged students are and explored the intersectionality of socio-economic status, race, gender, and disability. We identified the systemic, cultural, and psychological barriers that hinder their access to and success in STEM education, emphasizing the critical importance of STEM for personal and professional development, economic mobility, and community growth.

Section 2 explored effective teaching strategies at the classroom level, emphasizing real-world applications, critical thinking, and inclusive curricula. We discussed engaging and motivating students through project-based learning, hands-on experiences, and culturally responsive teaching practices, ensuring that every student sees the relevance and potential of STEM in their lives. Finally, Section 3 provided practical approaches to designing and sustaining impactful STEM programs. We highlighted the importance of building a task force, accessing funding opportunities, collaborating with community organizations and industry

partners, training teachers, and building pathways to STEM-focused college programs. Upon course completion, the goal is for educators to be empowered to create STEM programs that not only educate but also inspire and uplift disadvantaged students, paving the way for a more inclusive, innovative, and equitable future in STEM.

Case Example

Mr. Filo, a dedicated science teacher at a middle school in an underserved community, is determined to build a STEM program for his diverse group of students. Recognizing the potential of STEM education to transform lives and communities, he embarks on this journey with a vision of providing his students with the skills and opportunities they need to succeed in a rapidly evolving job market. However, Mr. Filo faces numerous challenges along the way.

One of the primary obstacles Mr. Filo encounters is a lack of resources. His school has limited funding for STEM programs, making it difficult to acquire necessary materials, technology, and training. This scarcity is compounded by the socio-economic challenges his students face, including limited access to technology at home and fewer opportunities for extracurricular enrichment. Additionally, Mr. Filo must navigate systemic barriers, such as standardized testing pressures that prioritize rote learning over hands-on, inquiry-based approaches. Cultural and psychological barriers also pose significant challenges. Many of Mr. Filo's students come from backgrounds where higher education and STEM careers are not commonly pursued, leading to a lack of role models and a pervasive belief that STEM fields are not accessible to them. Furthermore, implicit biases and stereotypes within the broader educational system can undermine students' confidence and interest in STEM subjects. Despite these hurdles, Mr. Filo is committed to finding solutions.
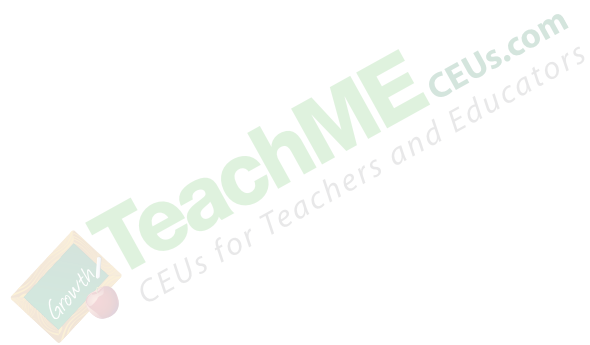
References

21stCentEd. (2023, May 23). *The importance of community partnership in advancing STEM education.* https://21stcented.com/the-importance-of-community-partnerships-in-advancing-stem-education/

Ashbrook, P. (2019, August 10). *Partnering with community organizations to support science learning: Research-based tips for forming partnerships.* National Science Teaching Association [NSTA]. https://www.nsta.org/blog/partnering-community-organizations-support-science-learning-research-based-tips-forming

Athanasia, G. (2022, April 1). *The US should strengthen STEM education to remain competitive globally competitive.* CSIS. https://www.csis.org/blogs/perspectives-innovation/us-should-strengthen-stem-education-remain-globally-competitive

Basile, V., Birmingham, D., & Lee, D.H. (2020, August 31). *Transforming and improving STEM education for minoritized students.* Colorado State University. https://www.chhs.colostate.edu/rise/wp-content/uploads/sites/23/2020/09/RISEreport_STEM-Ed-Brief.pdf

Carlton, G. (2023). *3 biggest barriers for women in STEM.* BestColleges. https://www.bestcolleges.com/blog/barriers-for-women-in-stem/

Chambers, A. (2020, June 12). *Task forces and pilot programs: Two strategies to enable future-focused, student-centered k-12 education.* Aurora-Institute. https://aurora-institute.org/blog/task-forces-and-pilot-programs-two-strategies-to-enable-future-focused-student-centered-k-12-education/

Change the Equation. (n.d.). *Ending the double disadvantage: Ensuring stem opportunities in our poorest schools.* https://www.ecs.org/wp-content/uploads/CTE_STEM-Desert-Brief_FINAL.pdf

Cook-Sather, A., and Des-Ogugua, C. (2019). Lessons we still need to learn on creating more inclusive and responsive classrooms: recommendations from one student–faculty partnership programme. *Int. J. Incl. Educ. 23*, 594–608. doi: 10.1080/13603116.2018.1441912

CricuitMess. (2024, February 5). *How to get your STEM program funded: Step-by-step guide.* LinkedIn. https://www.linkedin.com/pulse/how-get-your-stem-program-funded-step-by-step-guide-circuitmess-8w5kf/

Denton, A. (2021, July). *The state of STEM learning.* Education Northwest. https://6302909.fs1.hubspotusercontent-na1.net/hubfs/6302909/VSE-2021-WhitePaper-State-of-STEM-Learning.pdf

Dewsbury, B. M. (2020). Deep teaching in a college STEM classroom. *Cult. Stud. Sci. Educ.* 15, 169–191. doi: 10.1007/s11422-018-9891-z

Duncan, V. L., Holt, E. A., & Keenan, S. M. (2023). Creating an equitable and inclusive STEM classroom: A qualitative meta-synthesis of approaches and practices in higher education. *Frontiers in Education*, 8. https://doi.org/10.3389/feduc.2023.1154652

Jackson, D.Z. (2022, October 26). *A new study confirms: Structural racism in STEM programs needs fixing.* Union of Concerned Scientists. https://blog.ucsusa.org/derrick-jackson/a-new-study-confirms-structural-racism-in-stem-programs-needs-fixing/

Kennedy, T.J., & Odell, M.R.L. (2024, January 3). *Integrating STEM: An interdisciplinary approach to PreK-12 education.* DOI: 10.5772/intechopen.114009

Kim, W.J. (2019). Teacher as change agent for consequential learning: One Korean teacher's autoethnography on the Dance-with-Science Project. *Forum for International Research in Education, 5*(2), 79-96. https://files.eric.ed.gov/fulltext/EJ1233680.pdf

Milenkovich, L. (2024, May 15). *The impact of inclusive STEM education.* EdSurge. https://www.edsurge.com/news/2024-05-15-the-impact-of-inclusive-stem-education

Moore, M., & Valenzuela, J. (2020, February 19). *Equity literacy for STEM educators.* ISTE. https://iste.org/blog/equity-literacy-for-stem-educators

National Institutes of Health [NIH]. (2024). *Diversity Matters.* https://extramural-diversity.nih.gov/diversity-matters

National Math + Science Initiative [NMSI]. (2023, November 27). *The importance of STEM education for K-12 Students in low-income school districts.* https://www.nms.org/Resources/Newsroom/Blog/2023/November/The-Importance-of-STEM-Education-for-K-12-Students.aspx

Schneiderwind, J., & Johnson, J. (2020, July 27). *Why are students with disabilities so invisible in STEM education?* EducationWeek. https://www.edweek.org/education/opinion-why-are-students-with-disabilities-so-invisible-in-stem-education/2020/07

Schwartz, S. (2023, January 19). *Racial disparities in STEM start as early as kindergarten, new study finds.* EducationWeek. https://www.edweek.org/teaching-learning/racial-disparities-in-stem-start-as-early-as-kindergarten-new-study-finds/2023/01

Smithsonian. (2024). *The STEM imperative.* https://ssec.si.edu/stem-imperative

Whitcomb, K. M., Cwik, S., & Singh, C. (2021). Not all disadvantages are equal: Racial/ethnic minority students have the largest disadvantage among demographic groups in both STEM and non-STEM GPA. *SAGE Open*, *7*(1), 1–16. https://doi.org/10.1177/23328584211059823