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# Broadening Access and Inclusion: Democratization in STEM Education, Research, and Careers

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**Abstract:** ***Democratizing STEM aims to make science education, research, and career pathways more inclusive and accessible. This article examines how democratization strategies like MOOCs, portable research tools, and interdisciplinary collaborations can increase STEM engagement and diversity. By expanding educational resources and career opportunities, democratization can address workforce disparities and advance scientific literacy. The paper calls for substantial support from various sectors to create democratization metrics and strategies, enabling broad and meaningful participation in STEM fields.***

**Keywords:** democratization, STEM education, inclusivity, research accessibility, career pathways

## 1. Introduction

Broadening participation in science, technology, engineering, and math (STEM) is a perpetual goal in the United States and worldwide. The democratization of STEM education, research, and careers is another valuable tool for targeting inclusion in the STEM ecosystem. STEM democratization is operationally defined as making information, services, technology, opportunities, money, and other resources available to many individuals across a broad, diverse, and inclusive segment of the population and not just a selected few or select privileged groups. Expansion of all democratization tools and models will lead to higher gains in participation from students from every demographic, race, and ethnicity. Colleges and universities are advised to create interdisciplinary committees and external advisory boards to stimulate creativity, implementation, and evaluation of beneficial democratization approaches on campus.

Scientific literacy is linked to democratization and is defined as an individual's capacity to understand scientific concepts and science-based issues in a way that provides functional usage in daily life and allows the individual to make informed decisions on the daily problems confronting non-scientists [1]. Scientific literacy is an essential objective for elementary, middle, and high school teachers who engage with students who will not pursue a STEM degree or career later in life but will need a basic understanding of scientific knowledge and the scientific method to make clever decisions regarding health, diet, finances, and lead a productive life in a technologically advanced society. Additionally, entrepreneurship is closely linked to democratization [2]. One of the main problems for STEM-focused individuals seeking to start a company and sell inventions and products to a worldwide customer base is the cost associated with advertising and marketing, managing employees, and implementing a business plan. A surge in open-source virtual tools in marketing, organizational management, spreadsheet programs, and software development platforms will reduce trepidation and accelerate entrepreneurship [3]. Free or low-cost access to online entrepreneurial technology also diminishes the learning curve associated with comprehension of problematic business concepts.

Many science-focused companies are leading the charge in the push to democratize STEM. These companies offer easy-to-use science and technology kits, lab supplies, and miniature portable equipment at a reduced price compared to other suppliers. Companies such as Amplyus (www.minipcr.com), Carolina Biological (www.carolina.com), and Flinn Scientific (www.flinnsci.com) are making it easier to purchase small portable devices that can be used anywhere. There is even video evidence of astronauts using a miniPCR device during long-term space missions. These videos first appeared in 2016 and confirmed the effectiveness of the portable DNA amplifying instrument in outer space (e.g., www.youtube.com/watch?v=hwok8eYXrDk). In general, democratization seeks to bring more people to the table in terms of potentially developing ideas and innovations that produce seismic societal changes that can have tremendous and substantive impacts on human health and well-being, the global economy, and the health of our planet. While democratization will impact all racial and ethnic groups, it is believed that the strategies described in this article will broadly impact underrepresented students and professionals. STEM departments should form committees to draft policies and procedures to better engage all students in the scientific enterprise. Formative and summative assessments at the department level will ensure compliance and efficacy of democratization procedures. The purpose of this article is to explore democratization strategies in STEM education, research, and careers, highlighting approaches to increase inclusivity and broaden participation.

## 2. Democratizing STEM Education

A major successful initiative spearheading the push to democratize STEM education is massive open online courses (MOOCs) [4]. MOOCs are free or inexpensive online individual courses. A collection of specific MOOCs can also lead to certificates that can aid professional development endeavors. A wide variety of STEM-focused MOOCs can be found by accessing www.mooc.org or www.coursera.org. Prestigious universities like Harvard University offer free and low-cost MOOCs designed to have international reach and bring elite-level instruction to a global audience. Moreover, many four-year and two-year colleges offer tuition-free

educational opportunities to underserved and financially disadvantaged students [5]. Another example of excellent free digital STEM content for teachers and students can be accessed at www.labxchange.org. This content provides STEM learning and pedagogical materials consisting of animations, videos, virtual labs, and other tools that can be integrated into any STEM curriculum or used by individual learners to improve their comprehension of core concepts.

Moreover, free job-focused community college or four-year college programs that target underrepresented communities are likely to impact society's STEM career diversity, equity, and inclusion goals. Reducing the costs of obtaining a STEM degree will also enhance democratization efforts. Moreover, improving educational technology, improving Wi-Fi access to remote and rural areas, and making learning management technology more accessible and user-friendly will also move the needle in the right direction. Early college programs at high schools would also increase democratization efforts by exposing more students to college life and preparing students for the challenges of obtaining a college degree. Early college programs often involve collaborations with middle schools, high schools, and two-year and four-year undergraduate institutions and producing promising results [6-8]. The emergence of widely available science, math, engineering, and coding boot camps offers another approach to providing open access to educational opportunities. Boot camps can be beneficial if time on tasks focuses on specific career-related activities, focusing more on application than theoretical underpinnings.

To defy ominous predictions regarding STEM teacher shortages worldwide, educational centers at the high school and college level should consider instituting clubs, work-study activities, or other formal student organizations that give students opportunities to assist in the teaching process and instill future teaching aspirations [9].

Additional democratization strategies in STEM education could involve increasing the amount of tutoring, summer courses, advising, utilization of learning cohorts, and the number of bridge programs to simplify the transition process. Finally, providing more prospects for students to pursue graduate education and modifying eligibility barriers such as reducing entrance exam requirements, qualifying scores, and GPA requirements would be beneficial. It is widely known that some students can succeed in graduate and professional school but need help performing well on standardized tests. Moreover, in the undergraduate sector, a move from objective tests to authentic assessments (e.g., projects, oral presentations, skills assessment, case studies, posters, proposals, and software development) to evaluate student learning will ultimately improve the GPA of students griped with insurmountable test anxiety and may augment academic self-efficacy, academic persistence, and intrinsic motivation.

## 3. Democratizing STEM Research

As mentioned in the previous section of this article, the infusion of grants for students, educators, researchers, and other stakeholders will encourage a larger swath of the population to enter the research and development space. Additional infrastructure grants would defray the cost of the purchase of instrumentation and supplies necessary to establish a basic laboratory at primary undergraduate institutions. The development of virtual research training programs will also promote the democratization of STEM research by mitigating physical and logistical barriers to student and professional research training. While there has been an uptick in virtual training programs in technology fields, more work is needed to develop virtual research training programs in the sciences, engineering, and math fields. Course-based undergraduate research experiences (CUREs) are a clever approach to democratize STEM research at middle schools, high schools, and two-year and four-year institutions. CUREs utilize lecture and laboratory course time to infuse novel instructor-mentored research endeavors into the curriculum [10-11]. CUREs could be designed for one course or multiple courses over multiple years.

Research experiences also enhance scientific communication skills that lead to additional scholarship opportunities. From an anecdotal point of view, student learning outcomes are enhanced through completing a research project and communication of their research journey through written (e.g., research article) and oral communication (e.g., poster sessions) activities. Development of an undergraduate STEM research podcast where students discuss their research, share learned experiences, and discuss their research projects in the virtual domain could be instrumental. At its core, STEM democratization is about using every available tool, be it physical or virtual, to bring more people into the STEM tent with the understanding that increased participation will lead to more fruitful advances, cures, technology, and new companies at a more rapid pace.

Closing the facility and instrumentation distribution gap between minority and non-minority-serving educational communities is paramount. Many disadvantaged institutions of higher learning possess dilapidated and antiquated research environments with a nonexistent or modest research infrastructure and scientific spaces. There must be significant funding investments at the educational level to provide massive monetary infusion to improve neglected instructional settings (e.g., buildings, laboratories, equipment) in which students lack STEMployable hands-on training experiences that facilitate success in graduate school or selection from hiring managers [12].

A novel democratization strategy for STEM research is to purchase portable research equipment for underrepresented students in vulnerable educational communities and train them to conduct research.

Create rubrics for assessments to evaluate hypothesis development, data collection, and data presentation would improve student skill development.

Fortunately, there has been an uptick in the availability of small portable research instruments, kits, and supplies spurred by the pandemic and the need for students to conduct scientific experiments during the quarantine periods. Interestingly, many portable devices and DIY kits are inexpensive, even on a college student's budget.

At the institutional level, investments in portable research tools would give students a unique opportunity to conduct research anywhere, in rural, industrial, aquatic, or urban environments at any time. Increased usage of research apparatuses and scientific methods would improve student comprehension of how to conduct STEM research; the distribution of laptops, tablets, and mobile wi-fi hotspot devices to students could potentially infect students with the motivation and curiosity required of top-notch STEM professionals in today's competitive society. Moreover, since conducting research experiments can be somewhat challenging without proper guidance, unabated access to STEM experimental videos and video platforms such as the Journal of Visualized Experiments (JOVE) is required to aid students.

## 4. Democratizing STEM Careers

Current STEM career demographic evidence suggests that more diversity is needed in the workforce. Data shows that African Americans have higher unemployment rates and lower employment rates in STEM careers compared to white STEM professionals [13]. Democratizing STEM careers involves making career opportunities available to more people and increasing the number of professional skills development programs and paid and non-paid internship opportunities. Another approach for democratizing STEM careers could involve free company tours in which students could schedule opportunities to tour the facilities of a particular company to learn what an average day on the job consists of. Tours could be either in person or done virtually. Virtual tours would be a more efficient way to accommodate larger groups. To streamline the process, companies could create videos about specific jobs within an organization and post them on platforms such as YouTube, Vimeo, or Twitch. Video job tours for new careers or low-diversity occupations could enhance student interest in STEM careers. A quick search online can yield some very informative career videos; however, more can be done to cover more careers and companies. The creation of millions of virtual or work-from-home STEM jobs could also provide supplementary avenues to improve diversity and democratize STEM careers. Additionally, creating occupations that do not require a degree for entry-level employment would give greater access to individuals with abundant skills but who lack advanced STEM degrees.

Effective mentoring has always played a critical role in the long-term success of STEM graduates seeking and maintaining a STEM career [14-15]. An often-overlooked factor that may improve the democratization of STEM careers is developing methods that enhance access to effective mentoring. Unfortunately, many underserved students lack access to quality mentoring and, therefore, fail to benefit from the advice and insight harvested from quality mentored relationships. The solution lies in creating worldwide digital mentoring platforms that allow resourceful mentors to form mentoring relationships with eager students regardless of geographic location.

It is widely known that barriers to student career interest relate to basic career knowledge. Some students become disillusioned about pursuing STEM careers simply because they need help navigating the educational and training obstacles necessary for career attainment. Free national and international online career fairs in which companies make themselves available to present employment opportunities and meet prospective employees in the virtual world to evaluate potential fit would democratize STEM careers.

## 5. Conclusion

Broadening participation at the institutional, national, and international levels is critical to the prosperity of society's economy and technological future. Implementation of democratization STEM education and research strategies can broaden participation, especially if executed at minority-serving institutions (MSIs) such as historically black colleges and universities (HBCUs), tribal colleges and universities (TCUs), and Hispanic-serving institutions (HSIs). Successful integration of democratization techniques in these ecosystems will impact students' academic success, retention, research skills, and ability to navigate entry into graduate school or the workforce. Increasing access for first-generation or first-year students has the added benefit of reducing student stress and negative stereotypes associated with student perceptions regarding their preparation for the future. Students in MSI environments often feel that their academic and professional training levels are not on par with their non-MSI counterparts. These perceptions may lead to imposter syndrome that can manifest itself in graduate school or during the first few years of STEM employment and affect psychological factors and attrition [16-17]. In terms of academic campuses, artificial intelligence, next-generation data analytics, machine learning, and other cutting-edge technological solutions can be applied to improve students' ability to access campus resources and student affairs to enhance various student development factors that impede retention, academic success, and post-graduate awareness [18-19].

Further, a driver of democratization in STEM involves the establishment of STEM centers on high school and college campuses equipped with specialized equipment, expertise, and software coupled with a relevant curriculum, career development strategies, authentic assessments, and a mixed methods evaluation framework, thus forming the basis of an occupation aligned STEM instructional system (OASIS). The OASIS concept will be elaborated in future scholarly articles; however, OASIS refers to a complex interconnected system of strategies implemented on campuses that focuses on the campus-wide deployment of techniques designed to improve STEM students' knowledge acquisition, research skills, and career exploration competencies. STEM centers would also be the site of makerspaces on campus. Makerspaces have been shown to improve democratization, fuel creativity, develop team-building skills, and ignite the entrepreneurial spirit [20]. Finally, STEM democratization will eventually lead to the next generation of inventors and entrepreneurs and enhance scientific literacy in all communities and educational levels. Furthermore, solving issues such as economic disparity, technology equity, food insecurities, climate change, and global pandemics will require perspectives and contributions from more elements of society. Examining the efficacy of STEM democratization efforts at the institutional, national, and international levels through qualitative and

quantitative studies will help uncover the benefits, challenges, and limitations of STEM democratization.

Democratizing STEM aims to make science education, research, and career pathways more inclusive and accessible. This article examines how democratization strategies like MOOCs, portable research tools, and interdisciplinary collaborations can increase STEM engagement and diversity. By expanding educational resources and career opportunities, democratization can address workforce disparities and advance scientific literacy. The paper calls for substantial support from various sectors to create democratization metrics and strategies, enabling broad and meaningful participation in STEM fields.

**Compliance with ethical standards**

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