Words Matter: Defining opportunities in STEM to improve rural and urban student outcomes

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Executive Summary: In the United States, significant gaps remain for achieving gender and racial equity in science, technology, engineering, and math (STEM) careers. Although our K-12 education system has made some progress in innovating STEM curricula, the U.S. still lags behind other Organization for Economic Co-operation and Development countries. In addition, the COVID-19 pandemic has introduced new challenges in STEM education, which often require in-person experiential learning. Fortunately, with the advent of COVID-19 more people have come to appreciate the role technology can play in education. While technology certainly has many benefits for the educational process, there is a significant gap in opportunity between those from different socioeconomic and rural backgrounds in the U.S. To ensure the development of a diverse STEM workforce, the House of Representatives needs to take significant action to reduce inequity in STEM learning and outreach. We recommend that **the House of Representatives Committee on Science, Technology, and Space clarify the wording within the Innovation for Informal STEM Learning Act (H.R. 3859) to better target underrepresented populations from both rural and urban communities and the House of Representatives Committee of Education and Labor specify the definition of 'qualified apprenticeship program' within the STEM K to Career Act (H.R.4727).**

I. Current state of STEM education

What is a scientist? If you ask kids, they'll tell you. For over fifty years, students have participated in "draw-a-scientist" activities. Historically, grade-schoolers have predominantly drawn white, middle-aged men wielding flasks of colorful liquid. But over time, children's conception of who can be a scientist has changed to be more gender-inclusive, which reflects an increase in the percent of female workers in science, technology, engineering, and mathematics (STEM) (Finson 2002; Miller 2018; Women's Bureau 2019). However, significant gaps remain for achieving equity in STEM careers. Black and Hispanic workers are still underrepresented in the field, and women remain underrepresented in the physical sciences, computing, and engineering. Additionally, historically marginalized individuals working in STEM are paid less on average (Fry 2021). To achieve equitable representation in STEM careers, we must ensure marginalized students are provided access to programs and opportunities that show them that they too can be scientists, mathematicians, and engineers.

Nearly a decade ago, the National Science Academies introduced the Next Generation Science Standards (NGSS) with the goal of revolutionizing science education to create a more competitive U.S. workforce through inquiry-based learning and investigation (Achieve Inc. 2012). This joint effort by multiple educational associations released the first national standard for science education since the 1990s. These standards gave educators a new set of peer-reviewed tools to build instructional units based on investigation, judge the quality of existing curricula, and ensure that each lesson highlights "Crosscutting Concepts" that apply across STEM disciplines ("Understanding the Standards" 2013).

Although states have widely adopted the NGSS (NSTA 2014), resources to develop lessons are not evenly distributed (Smith 2016), and STEM education at the grade-school level still does not reflect the practice of STEM by professionals in the field. These gaps in access and understanding lead to attrition and loss of interest early in life (Trotman 2017). We cannot afford this attrition given the rate at which our need for STEM professionals is projected to increase in the coming decade (8% vs. 3.7% for all occupations) (Zilberman 2021). By expanding access and quality of programs that directly address the needs of marginalized populations, or programs that connect students and teachers to STEM professionals, we can foster greater understanding of and interest in STEM, leading to a broader diversity of people and ideas entering the STEM workforce.

While the NGSS represent a significant step forward for STEM curricula, the U.S. still lags behind the other 37 countries in the Organization for Economic Co-operation and Development (OECD) in STEM literacy and achievement (Rotermund 2021). In the classroom, there is room for improvement. About a third of fourth- and eighth-graders performed below "Basic" on the science portion of the 2019 National Assessment of Educational Progress, and 30% of fourth-graders and 42% of eighth-graders engaged in inquiry-based activities "never to once in a while" (NCES 2019). In addition, the COVID-19 pandemic has introduced new challenges in STEM education by forcing remote instruction when STEM education often requires in-person experiential learning. However, remote instruction also provides an opportunity to expand the way we connect people, giving STEM teachers the chance to put K-12 students in direct contact with STEM professionals. Connecting students to real people in STEM helps them learn about the diversity of those working in the field, simultaneously building a stronger understanding of academic material while creating a full picture of what it means to be a STEM professional. Short-term virtual classroom visit models like the volunteer-based 'Skype a Scientist' program have seen significant engagement from both classrooms and scientist volunteers (Killgrove 2019), and are not restricted by proximity to a research institution or STEM-associated company. By incorporating and incentivizing longer-term interactions, we may be able to push forward the goals of standards like the NGSS, encouraging more K-12 students to enter the STEM workforce.

i. Aiding and educating our educators in the classroom
Expansion of outreach and continuing professional development (PD) to minority educators can strengthen students' grasp of vocational skills. Of all STEM workers, only 27% identified as women with an even smaller percentage identifying as women of color or coming from a low socioeconomic status (Martinez 2021). At public schools with a high proportion of minoritized students or a high level of poverty, fewer mathematics and science teachers hold master's degrees, higher education training, or teaching certificates. Instruction needs to reflect distinct cultural nuances between communities arising in both urban and rural environments (Starrett 2021).

Advancing science literacy, STEM achievement, and matriculation of students into STEM-related fields requires instruction from confident and proficient educators in interdisciplinary STEM subjects beginning at the elementary level (Madden 2016; Madden 2020). Currently, there is no standard for how to prepare teachers to instruct STEM related subjects, leaving teachers feeling unprepared and unconfident (Nadelson 2013a; Baxter 2014; Thibaut 2018; Fauth 2019). Integrating explicit STEM content within teacher development increases confidence, self-efficacy, and pedagogical and STEM literacy (Varma 2009; Rinke 2016). Both pre-service and practicing teachers enhanced their competence and ability to implement STEM curricula in a classroom setting after participating in STEM preparation programs (Thomson 2019; Vasconcelos 2020; Yip 2020; Akiri 2022). Kirtman (2021) reported the effectiveness of increased teacher preparedness after participating in Jackson State University's Minority Advancement through Recruitment and Retention in Science via Outreach Program (MARRS-OP), which provides PD programs designed for 6th-12th science teachers in under-resourced Mississippi even in the virtual setting. Thus expanding the professional development opportunities for both pre-service and practicing teachers in STEM will help to increase teacher competence and implementation of STEM curricula.

ii. Education in the age of technology

Since the beginning of the 21^{st} century, access to knowledge and technology has greatly increased through the digital age. With the advent of COVID-19, more people have come to appreciate the role technology can play in education, including television shows, educational apps/software, virtual tutoring, conferencing tools, and many more. But even before the pandemic, the market for online education was booming, with global education technology investments reaching upwards of $18.66 billion in 2019 (Insider 2019). The incorporation of different types of technology into the classroom has helped move the classroom experience from a classic teacher-centered one into student-centered, giving students the ability to take a more active role in their learning (Why Technology Is Essential to a 21st Century Education, 2021). This ability to take an active role in their education has led students to become more creative, one of the main factors attributed to success in STEM as it is closely linked with the ability to create or build up existing knowledge (Henriksen 2018; Aguilera 2021).

While technology certainly has many benefits for the educational process, it also comes with many challenges. In the U.S., there is a significant technology gap between those from privileged and disadvantaged backgrounds. In a 2020 study, only 25% of respondents from disadvantaged backgrounds reported having access to a computer, and 17% of teens said they are often unable to complete homework assignments because they do not have reliable access to internet connection. Black and Hispanic teens report having higher rates of in-access to the internet than their Caucasian counterparts (Auxier 2020). In conjunction with socioeconomic status, the location of housing communities also provides a technological challenge. Despite the recent growth in technology and internet services in rural communities due to the passing of the Infrastructure and Investment and Job Act (IIJA) (H.R. 3684, Division F Sections 60101-60604), rural Americans consistently rank lower in technology ownership and high-speed internet usage than urban- and suburbanites (Vogels 2021).

Although studies have reported overall positive educational outcomes through online education (Schutte 1997; Kirtman 2009; John Lemay 2021), these results varied by age group and subject matter. Studies found that for lab-based courses the general knowledge and concepts of practical techniques could be provided through online platforms and virtual software, but hands-on laboratory exercises in the learned material were essential in practical application and troubleshooting (Potkonjak 2016; Estriegana 2019). However, to achieve true scientific literacy for all, expanding the professional development opportunities for teachers and better establishing education initiatives surrounding the needs of rural and urban communities may serve a fundamental role in providing widespread quality STEM education.

II. Policy options

Here we present two suggested policy options which clarify the verbiage in bills related to STEM education and learning. Through these changes we aim to acknowledge the differences between communities while better suiting their needs regardless of geographical locations and resources availability.

i. Policy Option 1: Clarify the wording within the Innovation in Informal STEM Learning Act (H.R. 3859)

At present, this bill employs the umbrella term “underrepresented and rural students” to encompass an array of communities that often face disadvantages in STEM. While the focus on under-resourced groups is essential, combining these terms fails to recognize the vastly different needs from urban to rural populations, all of which include diverse groups of underrepresented students. By acknowledging the differences and treating them as independent entities, policies can better address those issues unique to each student group through targeted programs and resource allocation.

Advantages

This clarification would specifically identify and allocate funding towards the needs of students in rural communities, typically neglected when grouped in the broader category of underrepresented populations. This clarification would require minimal work, as it simply dictates a separation of sections using the terms “underrepresented and rural students” into sections targeted toward urban and rural populations. This will significantly improve access to innovation for informal STEM learning, as already outlined within the bill, by incorporating specific details about how to best serve each population.

Disadvantages
This clarification may require reallocation and potential increases in funding to the identified populations. Additionally, reallocation of funding can be subjective based on potential impact and population served, which could exacerbate the inequities already experienced by one or both groups. In conjunction with potential increases in funding, separating the identified populations into multiple sections would increase the number of working person hours necessary to tackle the outlined goals within the bill.

ii. Policy Option 2: Specify the definition of 'qualified apprenticeship program' within the STEM K to Career Act (H.R.4727)
It is not clear what programs administered by the Department of Labor would include STEM teacher apprenticeship programs. Furthermore, there is not an easily accessible list of criteria defining qualified apprenticeships as per the Department of Labor. As it currently stands, teachers may not be able to determine if they qualify for a tax credit, reducing participation. By establishing criteria to define which apprenticeship programs would be approved by the Department of Labor, it would also be possible to collect information on the distribution of apprenticeships across the country, allowing better distribution of resources and an emphasis on school districts where a large portion of the students are under the poverty line.

Advantages
A more concise definition of which programs qualify teachers for tax credits will ensure all those involved have equal access to opportunities presented in this bill. As a consequence, more teachers at all levels will be incentivized and motivated to join programs aimed to increase teacher confidence and preparedness to instruct STEM subject material. Apprenticeship programs should include on-side research experience where a STEM educator is placed in a lab or research group at a local institution for a duration of the year or being paired with local professional researchers in a field relevant to their subject material. Information about the geographical location of each program ensures alternative programs are available if a local institution or research group is not easily accessible.

Disadvantages
If the definition of what qualifies as an apprenticeship program is made too specific, it may exclude programs that would otherwise serve the same purpose. Programs are going to operate differently based on the region they are found in and the teachers they are working with. Additionally, this suggestion assumes that there will be centralized information of what qualifies as an apprenticeship and where it requires person hours to manage.

iii. Consequences of inaction
In today's educational climate, teachers are expected to stay on top of academic material while managing the health and safety of their classrooms, meeting diverse learners' needs, and keeping up with emerging and developing pedagogical practices. For educators to do this work to the best of their ability, they must have equal access to technology, both inside and outside of the classroom, and be adequately prepared to guide the next generation of STEM professionals. Without equal access to innovative forms of STEM education in schools nationwide, a diverse STEM workforce will remain out of reach, leading to a greater loss of productivity and decline in technological advancement.

IV. Policy recommendations
We recommend that the House of Representatives Committee of Science, Technology, and Space approve policy option one and clarify the wording within the Innovation for Informal STEM Learning Act (H.R. 3859). We further recommend the Committee of and Education and Labor approve policy option two to specify the definition of 'qualified apprenticeship program' within the STEM K to Career Act (H.R.4727). While many programs are in place to serve underrepresented communities, specifically allocating funding to identified populations of underrepresented people between rural and urban areas will better accomplish the goals of serving their individual STEM learning needs. Along with establishing criteria for STEM apprenticeship programs that qualify teachers for tax credits, we may incentivize participation and make programs more accessible to all groups regardless of location.

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