[Diversity, Social Justice, and the Educational Leader](https://scholarworks.uttyler.edu/dsjel)

Volume 4 | Number 1 Article 1

February 2020

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Diversity, Social Justice & the Educational Leadership
Spring 2020, Vol. 4, No. 1, pp. 1-11

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Shifts in school demographics toward greater ethnic and linguistic diversity necessitate preparing a workforce of teachers who are skilled in inclusive teaching practices for all students. While improvements have been made over the past two decades, there is still a significant need for programs focusing on the preparation of elementary teacher in becoming capable instructors of STEM content. It is the obligation of all educational leaders to advocate for practices that work to dismantle systemic forms of inequality. This manuscript examines the increasingly significant role of science, technology, engineering and math (STEM) in our society, issues surrounding the performance of diverse American students' STEM achievement and provides recommendations for improvement.

KEYWORDS: Teacher preparation, STEM, culturally responsive teaching

Shifts in school demographics toward greater ethnic and linguistic diversity necessitate preparing a workforce of teachers who are skilled in inclusive teaching practices for all students (Yang, Anderson, & Burke, 2014). Unfortunately, inequitable structures and practices limit diverse students' access to knowledge, resources, and equitable educational experiences (Avendano, Renteria, Kwon, & Hamdan, 2019). It is the obligation of all educational leaders to advocate for practices that work to dismantle systemic forms of inequality (Museus, Palmer, Davis, & Maramba, 2011). This manuscript examines the increasingly significant role of science, technology, engineering and math (STEM) in our society and issues surrounding the performance of diverse American students' STEM achievement.

Technology and its application in everyday life has compelled individuals to become more science and technology literate (Pavitt 1996; Xie & Killewald, 2012). Individuals with limited STEM skills face economic and social disadvantages in a world that is increasingly STEM dependent (President's Council of Advisors on Science and Technology, 2012). Recent research supports that many American students remain ill-prepared for the increasingly science and technology dominated global economy (Parker, Abel, & Denisova, 2015). The Programme for International Student Assessment is an international triennial survey which evaluates educational systems across the world by assessing the knowledge of 15-year-old students (Organisation for Economic Co-operation and Development, 2018). The most recent assessments from 2015 ranked the American students' math performance at an unimpressive 38 out of 71, their performance in science was 24 out of 71 (Organisation for Economic Co-operation and Development, 2016). Compounding this problem, school districts across the United States are experiencing teacher shortages, and these shortages are especially pronounced in STEM content areas (Ledbetter, 2012). Subsequently, STEM courses are often taught by individuals who have not received any preparation in STEM content.

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Efforts to Improve Student Achievement in STEM

Countless initiatives and programs devoted to improving STEM education for PK-12 students have been developed and implemented by a wide range of organizations, institutions, school districts, and even the federal government (Ledbetter, 2012). Some initiatives strive to recruit professionals with strong STEM skills and knowledge to careers in teaching STEM content. Other initiatives have sought to train teachers who are already certified. For example, Hofstra University's Integrating Mathematics, Science, and Technology in Elementary Schools project conducted technology content workshops with hundreds of teachers in New York (Burghardt & Hacker, 2002). Partnerships between school districts and universities can also serve to strengthen STEM curricula and pedagogy in PK-12 classrooms (Parker et al., 2015).

Recognizing that schools across the United States were underperforming in math and science, in 2012 the Next Generation Science Standards were released and are currently being implemented in states across the nation. The standards were developed in a collaborative effort of the National Research Council, the National Science Teachers Association, and the American Association for the Advancement of Science, with 26 states serving as lead partners. The standards were developed to increase the capacity of American workers to excel in today's technology-driven economy. The standards have compelled teacher education programs across the nation to critically examine their elementary teacher education curricula (Rose, Carter, Brown, Shumway, 2015).

Recognizing the need to prepare students to be competitive in an ever-growing STEM job market, STEM education is increasingly emphasized in middle and high schools (Murphy & Mancini-Samuelson, 2012). However, teacher influence on STEM interest and career pursuit is largely overlooked at the elementary level. STEM education remains limited in elementary schools (Hossain & Robinson, 2012; Wenner 2017), with curricular emphasis largely placed on literacy and writing (Rose et al., 2017). For example, an examination of over 900 undergraduate and graduate elementary programs revealed that 47% of the programs' requirements for preservice teachers included very little, if any, elementary math coursework (National Center on Teacher Quality, 2014). The programs also did not require pre-service teachers to take a single basic science course. Instead, most programs provided pre-service teachers with numerous options of irrelevant electives.

Despite the growth in STEM careers and the United States' investment in training and increasing the pipeline of underrepresented populations in STEM majors and careers, efforts to improve these rates through peripheral fixes have not produced meaningful improvements. For example, in California, a state in which 77% of students identify as students of color (California Department of Education, 2019), data from the 2017 end-of-year assessments indicate that 4th grade and 8th students performed lower than the national average on the mathematics and science assessment of the National Assessment of Educational Progress. Only 31% of 4th grade students, and only 29% of 8th grade students performed at the "Proficient" level on the mathematics assessment (National Center for Education Statistics, 2017). On the science assessment only 24% of 4th graders scored at or above "Proficient" in comparison with 37% nationally, and among 8th grade students 24% scored at or above proficient in comparison with a 33% national average. Furthermore, data supports that nationwide, students of color are particularly underserved as a perpetual gap exists between the STEM achievement of students of color and their white peers, and between students from high-income homes and those from homes with low incomes (Darling-Hammond, 2014). While improvements have been made over the past two decades, there is still a significant need for programs focusing on the preparation of elementary teacher in becoming capable instructors of STEM content (Kim, Kim, Yuan, Hill, Doshi, & Thai, 2015; National Center on Teacher Quality, 2014; York, 2018), and the lack of improvement perpetuates the underrepresentation of diverse students in completing STEM degrees and entering STEM careers (Carpi, Ronan, Falconer, & Lents, 2017; Rawson & McCool, 2014).

Challenges in Higher Education STEM Courses

Taking into consideration that pre-service teachers often complete a very limited amount of STEM coursework (National Center on Teacher Quality, 2014), it is imperative that the coursework they do complete is taught by effective instructors. However, because of career pathways leading to academia, STEM experts often enter the professoriate with extensive content knowledge but limited pedagogical skills to address the diverse needs of their students (Mansour, 2009; Sunal et al., 2001). For example, a qualitative study of STEM instructors' perceptions of the characteristics of successful STEM students and the barriers to STEM students' success found that STEM faculty identified skills and characteristics they believed could be developed among their students (Ghandi-Lee, Skaza, Marti, Schrader, Orgill, 2015); however, the faculty repeatedly made reference to the belief that students should develop these traits outside of the college classroom, perhaps even before beginning college. STEM faculty with this mindset did not consider the ways in which they could structure their teaching methods classroom in order to help students develop these desirable characteristics. Knowing that these roadblocks to students' achievement in STEM areas has persisted in higher education, it is imperative that institutions of higher education develop pathways to success for these students (Winkelmes, Bernacki, Butler, Zochowski, Golanics, & Weavil, 2016). Research supports that faculty have a significant impact on how students understand and experience STEM content, especially in students' early college years (Astin & Astin, 1992; Newman, 2011).

Considering the challenges faced by diverse students, both elementary school students and students in higher education, the literature base was searched for promising practices for both sets of students regarding STEM education. A significant amount of research examines STEM teacher preparation at the secondary level and professional development for secondary and elementary school teachers. However, the purpose of this manuscript is to examine issues that are less frequently examined: effective pedagogy among faculty in higher education and pre-service STEM preparation for future elementary school teachers. These areas are explored because they are intertwined: pre-service elementary teachers may "shy away" from content they perceive to be beyond their capabilities (Simon, Aulls, Dedic, Hubbard, & Hall, 2015). However, when evidence-based teaching practices are implemented in higher education STEM coursework, even students who may have been underprepared can evidence increases in academic achievement (Winkelmes, et al., 2016). Subsequently, the achievement and self-efficacy beliefs of diverse elementary school students will also be positively impacted when they are taught by teachers who are confident in their own STEM capabilities (Ledbetter, 2012). Leaders in higher education curriculum development and in pre-service teacher education can take action that will result in improvements in STEM achievement among diverse students.

Recommendation 1: Evidence-Based Pedagogy in STEM Higher Education Coursework

The first recommendation is to support college and university STEM instructors in developing effective, evidence-based teaching methods to meet the needs of diverse students. Being expert in a content area is not necessarily correlated with having the skills to teach post-secondary students effectively (Mansour, 2009; Sunal et al., 2001). Leaders in higher education (e.g. deans, department chairs, faculty professional development personnel) must advocate for innovation in college level STEM instruction; implementing instructional practices that are grounded in evidence is imperative for improving learning among diverse students (Association of American Universities, 2013; Wieman, 2017). Improvements in teaching strategies, even small improvements, such as an instructor's enthusiasm for the course (Watkins & Mazur, 2013) can have a significant impact on whether students persist in STEM coursework (Ghandi-Lee et al., 2015).

The urgent need for evidence-based teaching methods in STEM college courses is increasingly evident as research supports that traditional teaching methods such as lecture-based approaches unintentionally marginalize students (Basile & Lopez, 2015). Lecture-based teaching tends to be especially pervasive in introductory STEM courses which generally provide little scaffolding for students (Stains et al., 2018). Evidence-based teaching practices move away from the instructor presenting information in lecture format and toward strategies that encourage the students to take an active role in their learning during each class meeting.

A meta-analysis examined the impact of active learning strategies versus lecture-based methods in STEM courses on exam scores and rates of course failure (Freeman et al. 2014). The active learning teaching strategies included group problem-solving, written activities that were completed during class, use of clickers, and workshop course designs. Results found that courses using active learning strategies resulted in an almost 6% increase in examination scores in comparison with exam scores in lecture-based courses. The study also found that students in lecture-based courses were more likely to fail the course in comparison with their peers in the active learning courses.

In the study, *A Modeling-Based College Algebra Course and its Effect on Student Achievement* (Ellington, 2005), faculty input was used to redesign a college level algebra I course. The redesign included adding modeling, collaboration, and communication features and was delivered to 284 students in eight sections. During the same semester, 989 students were enrolled in 28 sections of the traditional college algebra course. Based on a placement test, all students entered the course with similar levels of mathematical knowledge and skills. Because students registered for the class based on their individual schedules and course availability, the study design was quasi-experimental. In the redesigned course, each 75-minute class period consisted of a 5 – 10-minute review of homework problems that covered previously presented material followed by a 10 – 15-minute presentation of new material with examples provided by the instructor. During the remaining 50 minutes, students worked in groups of two to four on problems, and there were pauses as needed for whole- or partial-class discussion on questions that arose or addressing skills that needed to be reinforced. Results of the intervention are as follows: (a) 71.83% of students earned a grade of C or better in the redesigned course in comparison with 49.70% in the traditional course and (b) 89.6% of the students in the redesigned course sections took the final exam with 5.63% withdrawing from the course and 4.77% not taking the final exam, in comparison with the traditional course in which only 71.33% of the students took the final exam with 20.34% withdrawing from the course and 8.33% not taking the final exam.

Recommendation 2: Culturally Responsive Pedagogy

Institutions of higher education are continually evolving in terms of students' race and ethnicity, native language, ability, and economic status (Montenegro & Jankowski, 2017). Leadership at institutes of higher education must take action to support faculty in developing and implementing instructional strategies that address the needs of diverse student populations in order to support the learning of all students. While culturally responsive pedagogy originated to address the needs of K-12 students, its use is also imperative in higher education (Larke, 2013) as data demonstrates that Black, Hispanic, Native American, and Pacific Islander students are much less likely to complete a four-year college degree in comparison with their white and Asian classmates (U.S. Department of Education, 2018).

It is common for undergraduate students to experience difficulty in making the transition from high school student to college student and they may feel a disconnect from instructors who they perceive as "other" (Davis, Hauk, & Latioiliais, 2009). This feeling of otherness may stem from the student's perception that a professor is someone they cannot relate to at all, or may stem from cultural, gender, or linguistic differences. Culturally responsive pedagogy is necessary to support and ensure equitable educational outcomes for all students. Culturally responsive pedagogy is conceptualized using Gay's (2018) definition, "Simultaneously develops, along with academic achievement, social consciousness and critique, cultural affirmation, competence, and exchange; community building and personal connections; individual self-worth and abilities; and an ethic of caring" (p. 52).

Historically, introductory courses in STEM areas have been used to "weed out" students from seeking degrees in these areas, with many instructors not perceiving a need to alter the status quo (Farrell & Minerick, 2018; Mervis, 2011). To this end, the "transmission" model of mathematics instruction is common in lower division math courses (Davis et al. 2009). In this model, students are empty vessels to be filled with the instructor's knowledge, which is delivered via lecture based on information in a textbook. Student learning is assessed via a midterm and final exams. In culturally responsive college STEM courses, instructors appreciate and value the diverse ways in which cultural and individual identities impact cognitive engagement, and instructors explicitly acknowledge and design their instruction to address multiple modes of learning. Culturally responsive instructors are cognizant of and accommodate for differences in how students understand questions, activities, directions, assignments, and feedback (Montenegro, & Jankowski, 2017). Likewise, student learning is assessed in ways that account for the wide-ranging needs of diverse students. For example, student learning can be assessed using multidimensional formats including portfolios, projects, reflective and explanatory writing, collaborative assignments, discussions, and peer- and self-evaluated work (Davis et al., 2009).

Recommendation 3: Specialized STEM Majors for Pre-Service Teachers

Elementary school teachers are expected to teach STEM content, however, the extent of their knowledge in these subjects is limited to the exposure they have had to these content areas (Kim et al., 2015). Therefore, leaders in elementary teacher preparation programs must ensure that pre-service teachers are provided an education in which they develop strong STEM content knowledge. Likewise, elementary teacher education programs must ensure that pre-service teachers learn effective practices for lesson planning, developing confidence in their ability to teach STEM subjects, and developing effective pedagogy skills related teaching STEM content (Hallman-Thrasher, Connor, & Sturgill, 2019).

Rinke, Gladstone-Brown, Kinlaw, & Cappiello, 2016), analyzed the effects of a new preservice teacher education model with a STEM emphasis via quasi-experimental study. The new model combined two traditional science and mathematics methods courses into a single STEM block. Students in the new STEM block were taught engineering and technology content that was not presented in the traditional math and science methods courses. The study analyzed students' performance and beliefs in the traditional courses in comparison with students in the new STEM block and investigated teaching efficacy, reported and exhibited pedagogical practices, and STEM literacies. Linear regression models supported that students in both the traditional courses and the STEM block demonstrated substantial growth, however, students in the STEM block reported significantly greater gains in STEM teaching efficacy in comparison with the students in the traditional courses. Additionally, the lesson planning artifacts of students in the STEM block demonstrated increased use of content integration, engineering, and design.

Kolbe and Jorgenson (2018) studied the relationship between differences in teacher preparation and the teachers' subsequent use of effective teaching strategies via quasi-experimental study. The researchers examined data from a large national sample of eighth-grade science teachers and focused on teachers' (a) degrees and coursework in science and engineering; (b) education-related degrees and coursework, specifically science education; and (c) overlapping degrees in both science content areas and education. The findings of the analysis support that teachers with a science education major, minor, or concentration were more likely to use inquiry-oriented teaching strategies in science in which students actively construct knowledge through experiences building, evaluating, and applying knowledge rather than simply learning skills and memorizing facts.

Conclusion

The need to improve diverse students' performance in STEM content to produce citizens who are STEM-literate and to increase the STEM workforce necessary for future global competitiveness is apparent. To achieve this, the STEM competency of elementary school teachers must be improved upon. Students' early exposure to STEM content lays the proverbial foundation for later success, yet unfortunately a multitude of elementary school teachers are lacking knowledge and skills to deliver effective instruction in STEM areas.

To change the trajectory of diverse students in STEM careers and competency, systemic changes must occur that invest in and promote the use of evidence-based teaching strategies to engage a population of students that is truly representative of the diversity of the United States (Association of American Colleges and Universities, 2014). Faculty must be supported in learning evidence-based, culturally responsive teaching practices. This could be actualized through professional learning communities, monetizing training, and rewarding faculty for growth in students' achievement (Bathgate et al., 2019). Universities across the nation must also consider redesigning the undergraduate coursework requirements for pre-service elementary teachers to in order to provide them with a strong foundation in the content knowledge they need to teach STEM content to mastery (Kim et al., 2015). Actualizing the recommendations presented here requires institutional commitment to dedicating adequate time, resources, and coordination to these to implement these changes.

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