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Out of Left Field? Requiring Expertise to Teach Secondary Science: A Policy Brief

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Introduction

Teachers are considered the most influential factor in student learning outcomes (Burroughs et al., 2019; Luft et al., 2015, 2020). Their influence in the modern science classroom affects academic opportunities and the overall scientific literacy of our future society. Nonetheless, high school science teacher shortages exist across the United States, and minimal subject-specific requirements are the norm for new teachers entering the field. Compounding the problem is the presumption by most states that obtaining the expertise to teach one discipline in science qualifies a teacher to teach any area of science (National Council on Teacher Quality, 2010). Although No Child Left Behind (NCLB) requires teachers to be highly qualified, the definition of this term includes only state certification and strong content knowledge of each subject taught. Clarifying these requirements is left to each state's interpretation of the mastery of subject matter, resulting in various measurement methods for teacher preparedness (Sheppard et al., 2020) and, subsequently, certification. So, how important is discipline-specific science knowledge for teachers? What role does subject matter expertise play in science teacher certification?

Research Overview

The Need for Subject Matter Expertise

Science education researchers agree that high Pedagogical Content Knowledge (PCK) levels are the gold standard for high-quality science instruction (Carlson & Daehler, 2019; Chan & Hume, 2019). PCK represents a transformation of a teacher's content knowledge into an assessable and usable form for student understanding. According to Gess-Newsome (2015), an expert PCK researcher, a teacher's PCK can be regarded as the "knowledge of, reasoning behind,

and planning for teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes" (p. 36). Therefore, expertise in teaching science relates directly to topic and context specificity. As reported by the National Council on Teacher Quality (NCTQ) (Lubell et al., 2017; National Council on Teacher Quality, 2010), state policies for teacher certification do not guarantee that high school science teachers obtain mastery in the disciplines they teach. Unfortunately, many teachers feel compelled to teach science content they have not mastered to fill science teaching gaps in high schools. Hence, these teachers are teaching out-of-field or out of their area of expertise.

The Significance of Out-of-Field Science Teaching

Out-of-field refers to teaching in areas that do not align with a teacher's education or training (Ingersoll, 1998). Traditionally, this situation is associated with teaching outside certification areas; however, it frequently occurs among composite certified secondary science teachers, particularly in the physical sciences (Napier et al., 2020). Teachers are given assignments in chemistry or physics without expertise in those disciplines even though they are considered “qualified” to teach them through composite certification. Having a high level of PCK in one science discipline does not guarantee that same high level of PCK in other science disciplines. Through a six-year longitudinal study, Kind (2014) demonstrated that non-chemists' content knowledge was not adequate to teach many areas of high school chemistry despite degrees in biology or physics. She also found that non-specialist teachers were more dependent on guidance for curricular decisions, less likely to anticipate student misconceptions, and more likely to hold content misunderstandings of their own. Additionally, in a 17-year longitudinal study, Arzi and White (2008) found many instructional deficiencies when teachers did not feel qualified or display significant interest in an area of assigned science teaching. Consequently,

teachers may demonstrate low levels of PCK, lack subject matter expertise, and fail to implement high-quality science instruction when teaching out-of-field.

Out-of-field teaching is a widespread problem in secondary science and, unfortunately, is an accepted norm in the culture of science education. However, it is not spread equally among teachers or schools. New science teachers are more likely than veteran teachers to be teaching out-of-field and are at a disadvantage when it comes to developing PCK. New teachers have less experience, the criterium necessary for PCK development, in their subject areas or out-of-field (Sheppard et al., 2020). They must adjust to being a new teacher and have an added layer of difficulty when teaching out-of-field. Furthermore, teacher turnover requiring more frequent hiring of new science teachers is more prevalent in schools with lower-income students and demographics with higher levels of minorities (Napier et al., 2020). In 2013-2014 high-minority schools had four times more out-of-field teachers than low-minority schools (Sutcher et al., 2016). The lack of highly qualified science teachers significantly impacts the science instruction and student achievement in science at these schools.

Composite Science Certification

Much of the out-of-field teaching in science results from all-purpose certification practices by states (Sheppard et al., 2020). Many states allow for composite or general science certifications with limited credits in particular science content areas (National Council on Teacher Quality, 2010; Sheppard et al., 2020). Although composite certificates and the out-of-field issue for science teachers rose in response to gaps from teacher shortages and staffing issues for administrators, unintended consequences resulted, which negatively impact instructional quality. According to the NCTQ (2010), only 11 states have certification requirements guaranteeing teachers possess the subject matter knowledge necessary to teach

specific science content. In comparison, seven states combine subject-specific certification with general knowledge assessments, and 32 states utilize catch-all science certification criteria with no requirement for exhibiting content-specific mastery or expertise.

General Science Content Testing

One of the problems with the credentialing process for these states designated as inadequate in their preparation is the structure of the content test used. The generalized testing method allows teacher candidates to miss many questions in one subject area yet pass the test. They could then be assigned to teach that subject at the secondary level with insufficient content knowledge (National Council on Teacher Quality, 2010). Secondary science teachers must have a level of understanding of their content beyond the level they teach it to high school students. They must know the subject matter to a depth that allows them to anticipate student difficulties and misunderstandings and access multiple methods of presentation and implementation for diverse learners. Teachers with limited knowledge of their content have low levels of PCK and tend to utilize low-impact strategies and practices that do not support enhanced student outcomes (Arzi & White, 2008). Allowing teachers to teach content they have not mastered can be detrimental to students and science education as a whole.

A science generalist is not a reality in secondary science education. Although general content testing and composite science certifications help fill the gaps created from teacher shortages (Luft et al., 2020), the flexibility promotes the false idea that an all-purpose science teacher exists and adds to the out-of-field problem. On the other hand, small rural districts argue that this loophole in certification is necessary to solve science staffing issues. Still, it does not benefit the students or teachers in any district to place less than qualified teachers in science

classrooms. Policies must reflect alternative ways to fill the gaps without sacrificing the quality of science education in our schools.

UTeach Program for Content Specialists

The UTeach teacher preparation program (UTeach) was founded at the University of Texas at Austin and successfully replicated at many universities across the country. It focuses on recruiting students in Science, Technology, Engineering, and Math (STEM) majors to receive a degree in their field in addition to a secondary teaching certification without adding time in college (Cade et al., 2019b). UTeach offers STEM students the opportunity to enroll in two one-hour courses for free to help them decide about teaching as a career. The program allows students who never considered teaching an active glimpse into the profession. According to Cade et al. (2019a), of the 1623 STEM students surveyed in the program from 2011-2018, 40% never considered teaching before entering UTeach. This finding represented a significant number of STEM students added to the teaching field. Among those students, 46.5% majored in science, 67.5% were female, and 40.6% were Hispanic. Unfortunately, only 5.1% of the students were African American (Cade et al., 2019a). Although UTeach has made great strides in advancing science and STEM teacher education among diverse student populations, there is significant room for improvement.

Discussion and Analysis

There is a need for a thorough examination of and adjustment to secondary science teachers' preparation and credentialing requirements to ensure a higher level of science instruction in all American high schools. Although some argue that out-of-field teaching results from the STEM crisis, others say that the STEM crisis has partially resulted from the trend of

out-of-field teaching (National Council on Teacher Quality, 2010). It is important to note that generalized science certifications mask the extent to which out-of-field teaching in science exists in states that have this type of certification. For example, the numbers of out-of-field science teachers are low in Texas because composite-certified science teachers are not considered out-of-field when assigned to teach any science subject, even when they lack expertise in the content (Agency, 2020). The out-of-field problem in the states certifying this way could be much more severe than reported. Thus, the adverse impact on science instruction and the future of science literacy in these states could be much more significant than anticipated.

Research Implications

The problem with out-of-field teaching is a lack of subject matter knowledge. Thus, professional development supporting content understanding is necessary for teachers in out-of-field science assignments (Porsch & Whannell, 2019). Policymakers and school administrators must create opportunities for science teachers to increase content knowledge and develop their PCK in all subjects they teach. Additionally, new science teachers are in a unique position to modify their practice at a high rate. Therefore, it is vital to provide guidance and place them in an area consistent with their education and preparation to avoid implementing and repeating poor instructional practices (Luft et al., 2015; Napier et al., 2020). Nevertheless, if new teacher assignments are in out-of-field subjects, consistent support is necessary for all content areas taught. Finally, there is a shortage of highly qualified science teachers in high schools. Teacher educator programs and policymakers must dedicate effort to pursue programs to certify and support content specialists in secondary science classrooms.

Future Research Direction

Based on the research presented on secondary science teacher certification and out-of-field teaching, research and policies should focus on:

1. Professional development opportunities for new and veteran out-of-field teachers:
    - Professional development should focus on content and pedagogy training for teachers emphasizing the development of science PCK.
    - Professional development should be ongoing to support the needs of all teachers, especially in low-income, high-minority schools.
2. Secondary science teacher certification should be subject-specific:
    - Certification tests should be subject-specific or designed for a passing result only with a passing score on all subject areas within the examination.
    - Teacher candidates should take courses in the content they teach to align with content specialist requirements.
3. Implement the UTeach program to recruit content specialists to the science teaching profession:
    - Recruit science majors enrolled in undergraduate programs.
    - Recruit students from high schools to enter college as science majors within the UTeach program.
    - Pursue funding for low-income and minority students to enter the UTeach program as science majors.

Conclusion

From the teacher preparation and certification perspective, programs must propagate the number of science course requirements to remedy the out-of-field problem. Additionally, requirements for certification should include students achieving a passing score for every content

they are to teach. These criteria are necessary to ensure subject matter mastery, increased science PCK, and high-quality science instruction. Also, programs must encourage recruiting content specialists in a manner resembling the UTeach method. Positive results from UTeach are too great to ignore (Cade et al., 2019a, 2019b), and more programs must emulate its processes to help stop the science teacher shortage and improve the level of PCK for secondary science teachers. With the lack of qualified science and STEM teachers, the United States is falling behind the international community in these areas. Consequently, there needs to be an examination of out-of-field science teaching to improve science instruction in American schools. Nonetheless, there must also be adequate support for these out-of-field teachers currently in the classroom until preparation programs supply sufficient numbers of science teachers with high levels of PCK in the areas they teach.

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