RESEARCH

Exclusive versus Mixed, General versus CTE: Building a New Taxonomy of STEMM High School Teachers[1]

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ABSTRACT: There has been a recent expansion of high school course offerings in science, technology, engineering, mathematics, and medical/health (STEMM) fields. The large span of courses now offered in STEMM are delineated across STEMM-general courses (i.e., chemistry) and STEMM-CTE courses (i.e., information technology). Little is known, however, about who are the teachers in these courses. This brief addresses this void by developing a taxonomy of the STEMM teaching workforce using statewide data from Maryland. Through this taxonomy, we examine the number of STEMM teachers by whether they teach general versus CTE STEMM courses, and whether they do so exclusively or across both types. We then examine what teaching courseloads look like across these groupings, as well as by qualifications and demographics. The aim of this brief is to understand not only the landscape of who teaches which STEMM courses, but also to identify disparities. This can help inform research on STEMM courses and teachers as well as policy, practice, and professional development.

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In recent decades, there has been growth in the breadth of high school course offerings in science, technology, engineering, mathematics, and medical/health ("STEMM"; Bradby, Pedroso, Rogers, & Hoffman, 2007; National Forum for Education Statistics, 2021). Part of this expansion has emerged from outside of STEMM-general course offerings (i.e., Algebra), where, for instance, United States education has witnessed a growth of STEMM courses from within career and technical education (CTE). Like STEMM-general courses, STEMM-CTE courses, such as Information Technology, also focus on teaching STEMM concepts (Bozick & Dalton, 2013). However, STEMM-CTE courses emphasize the relevance of these concepts to practical experiences by incorporating a more career-focused approach.

The growth in STEMM-CTE courses could be attributed to United States federal policy, namely the Carl D. Perkins Act and its reauthorizations, which

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provided funding and incentives for schools to offer STEMM-CTE courses and particularly to historically underrepresented groups (National Science Foundation, n.d.). As an alternative explanation for the growth in STEMM-CTE courses, Plasman, Gottfried, and Hutt (2020) suggested that more demand for CTE courses have come from a change in sentiment in the United States—that CTE coursework is now perceived differently compared to its predecessor, "vocational" education. Because CTE courses are designed for students at all ability levels and for college and noncollege-going students, there is less perception that CTE courses are tracking students like vocational education did in the 1900s (Plasman, Gottfried, & Hutt, 2020).

To date, we know very little—if anything—about who teaches the full range of these STEMM courses. Exploration of the STEMM-general *and* STEMM-CTE teacher workforce is critical for several reasons, including the fact that expanding STEMM-CTE course offerings necessarily requires either hiring more STEMM-CTE teachers or expanding the set of courses that current high school STEMM teachers (whether in general or CTE courses) teach. This led us to ask two descriptive research questions:

1. How is the teaching workforce partitioned across STEMM-general and STEMM-CTE courses?
2. What are the qualifications and characteristics of these teachers?

A Taxonomy of STEMM Teachers

No research has described the complete landscape of the STEMM teacher workforce. Therefore, a contribution of this brief is understanding where STEMM teachers teach. We divide the STEMM teaching workforce into three categories. First, there are teachers who teach STEMM courses exclusively in STEMM-general courses. They may or may not teach other subjects at school (i.e., English), but when it comes to teaching STEMM courses, they only teach general STEMM classes. Second, there are teachers who teach STEMM exclusively in STEMM-CTE. Again, they may teach other subjects at school, but when it comes to STEMM classes, they only teach in STEMM-CTE. Finally, there are mixed STEMM teachers. These are teachers who teach both general and CTE classes in STEMM. They may also teach in other areas in school, but within STEMM, they have courseloads that include both STEMM-general and STEMM-CTE.

It is entirely unaddressed in the research whether being an exclusive STEMM-general, exclusive STEMM-CTE, or mixed STEMM teacher is best suited to support students' STEMM (and other) outcomes. But, before determining the effectiveness of exclusive versus mixed STEMM teaching on students' outcomes (which is beyond the scope of this brief), it is critical to understand who STEMM teachers are.

Previous research has examined exclusive versus mixed teaching, though this has been examined between fields (i.e., teaching both reading and math) rather than within a single field like STEMM (e.g., Fryer, 2018; Jacob & Rockoff, 2011). Here, we conceptualize why distinguishing between exclusive or mixed—within STEMM—might matter at all. To begin, all STEMM teachers must teach skills related to core STEMM knowledge, and STEMM-CTE teachers must then apply this knowledge to real-world tasks. Therefore, without contest, having STEMM content knowledge is a crucial aspect to being any STEMM teacher (Baumert et al., 2017; Metzler & Woessmann, 2012). In addition, there are three qualifications supported as critical for STEMM teachers: years of experience, subject-specific certification, and education (Wayne & Youngs, 2003). How these three qualifications play out might influence how we begin to think about the taxonomy of exclusive versus mixed STEMM teaching.

For instance, more teaching experience helps teachers generate the skills they need not only to support students' outcomes but also to engage students in classroom activities (Hanushek, Kain, O'Brien, & Rivkin, 2005; Ost, 2014). In the context of STEMM, teachers with more experience in one exclusive area (e.g., general) likely can sharpen their own practices and develop content in areas in which they have extensive experience (Fryer, 2018). On the other hand, gaining experience in teaching a mixed combination of STEMM-general and STEMM-CTE courses may equip teachers to draw distinctions between general and CTE content. That is, experience as a mixed STEMM teacher may improve "code switching" abilities between general and CTE, thereby making their practice in each area more distinct. Additionally, having experience with a mixed courseload in STEMM might help teachers build general skillsets, which can be applied across STEMM (Ost, 2014).

Certifications and degrees are important considerations in ensuring that teachers have the relevant training, while also providing them the tools to reinforce course content (Jacques & Potemski, 2014). STEMM teachers who teach exclusively in the area in which they have subject certifications or degrees, such as math, may therefore be more likely to help students master specific skills. Yet on the other hand, STEMM teachers who have a mixed courseload might be able to help broaden students' skills. For instance, mixed STEMM teachers with math training can support students' math skills in both STEMM-general and STEMM-CTE courses, given that the basis for many STEMM-CTE courses is rooted in math (Gottfried, Bozick, & Srinivasan, 2014).

Method

Source of Data

We relied on the Maryland Longitudinal Data System (MLDS). The MLDS is an exceptionally rich source of data which links all K-12 teachers to classes taught across

the entire state. We relied on grades 9–12 teachers and course data from 2012–13 to 2018–19 school years. In each year, we identified which specific teacher taught which specific course, for a total of *N*=98,130 teacher observations across our years.

We first identified the set of courses every teacher taught each year. STEMM-CTE courses were coded based on identifiers in MLDS for (1) whether or not the course was part of an approved Maryland CTE program of study, and (2) whether the course fell into one of the three career clusters—defined by the state of Maryland as related to STEMM (i.e., health and biosciences; information technology; manufacturing, engineering, and technology). STEMM-general courses were coded based on the School Courses for the Exchange of Data (SCED) taxonomy. With SCED and CTE coding, we also identified non-STEMM-general and CTE courses. After identifying all courses, we captured whether in each year, teachers taught STEMM-general and no STEMM-CTE (i.e., "exclusive STEMM-general"), STEMM-CTE and no general STEMM (i.e., "exclusive STEMM-CTE"), or both (i.e., "mixed STEMM").

We then identified key characteristics of the teachers in our dataset, based on the discussion in the above section on the taxonomy. This included whether or not the teacher was novice (fewer than five years of experience) and whether the teacher had a graduate degree, certification in STEMM, and/or certification in Professional or Technical Education. Finally, we included demographic information, namely whether the teacher was Black or White as well as female.

Analysis

The work in this brief was descriptive. The first research question was addressed with tabulations of teachers by category of taxonomy. Following this, we calculated the average courseloads by STEMM and non-STEMM courses, general versus CTE. The second research question was supported by descriptive statistics of the qualifications and characteristics.

Findings

Research Question 1

Using our taxonomy, the landscape of the STEMM teacher workforce is depicted in Figure 1. In the figure, we begin with all teachers in our dataset—approximately 98,130 teacher-year observations across all subjects taught in Maryland. Within this, there is a subset of teachers that teach STEMM classes (general, CTE). This group is 38,951 teacher-year observations, approximately 40% of the teachers in Maryland. The final right portion of our taxonomy shows two groups—exclusive versus mixed. Within the former, approximately 33,092 STEMM teachers only teach STEMM-general, representing 85% of the STEMM teaching workforce. 1,666 STEMM teachers only teach STEMM-CTE, representing approximately 4% of the STEMM teaching workforce. The final subset of STEMM teachers are mixed.

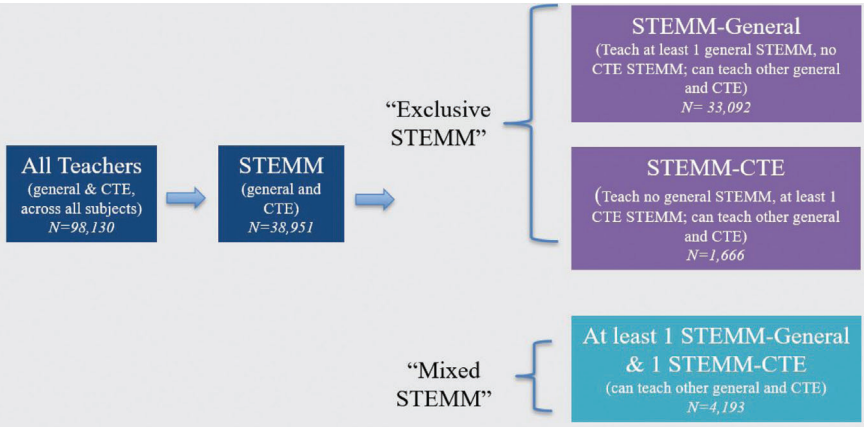

Figure 1: Taxonomy of STEMM teachers AuQ3

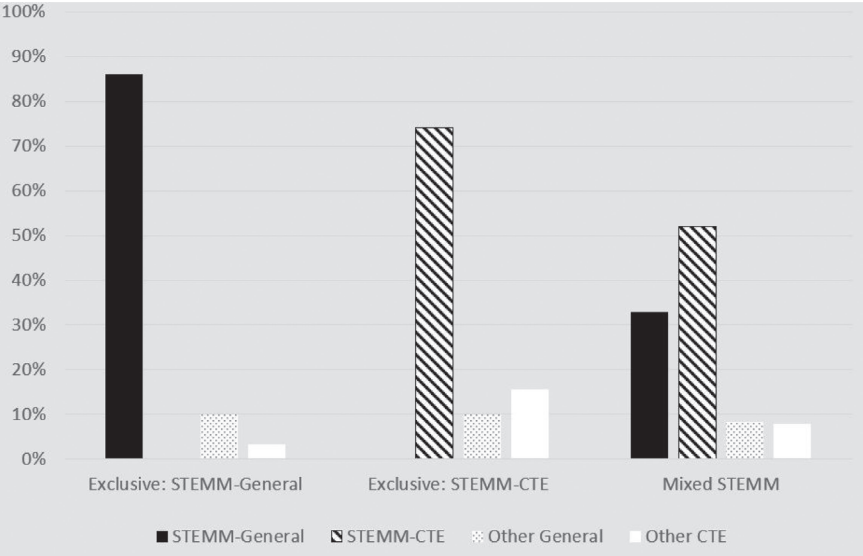

Figure 2: Courseloads within the STEMM teacher taxonomy

Figure 2 presents the teaching loads of exclusive versus mixed STEMM teachers. The first group are exclusive STEMM-general teachers, where approximately 86% of their workload is teaching STEMM-general classes. This group teaches approximately 10% other non-STEMM-general classes and 3% other non-STEMM-CTE classes, though there is no systematic pattern to what is beyond taught outside of STEMM (a consistent pattern across all groups of STEMM teachers). The middle AuQ4

	Exclusive STEMM-General	Exclusive STEMM-CTE	Mixed STEMM
Novice	23%	23%	23%
Graduate Degree	74%	67%	70%
STEMM Certification	74%	27%	68%
CTE Certification	1%	21%	6%
White	71%	66%	70%
Black	16%	30%	23%
Female	61%	59%	40%

Table 1: Qualifications and characteristics within the taxonomy
Note: The percentages represent the fraction of that group within that specific teacher group.

group in the figure are exclusive STEMM-CTE teachers, who also teach a high percentage of STEMM-CTE, approximately 75%. They do teach around 10% other academic classes and 15% other CTE. Finally are the mixed STEMM teachers who teach 85% of their courses in STEMM—approximately 85% (33% as STEMM-general and 52% as STEMM-CTE). This STEMM-dominant teaching load is consistent with the exclusive groups. Approximately 16% of their teaching is in other non-STEMM areas, split almost equally between other academic and other CTE.

Research Question 2

Table 1 has several noteworthy findings. First, across all three groups, few STEMM teachers are novice, and most have graduate degrees. Second, STEMM certification is more likely seen in teachers who teach STEMM-general classes—exclusive and mixed teachers. As for CTE certification, it is not very common for any teacher to have a CTE certification, with, as might be expected, the largest prominence in the exclusive STEMM-CTE group. Finally, Black teachers are less likely to be represented in the groups where STEMM-general courses are being taught. Women are less likely to be represented in the groups where STEMM-CTE courses are taught. As a note, for both research questions one and two, we looked over time, and the patterns did not change.

Discussion

We developed a new taxonomy of STEMM teachers by delineating across general versus CTE and exclusive versus mixed. The taxonomy itself helped us to understand STEMM teaching in new ways, namely that exclusive STEMM-general teachers mostly teach STEMM-general courses, exclusive STEMM-CTE teachers mostly teach STEMM-CTE courses, and mixed STEMM teachers are fairly split between STEMM-general and STEMM-CTE courses. Yet, the taxonomy allows us to see key differences. For instance, exclusive STEMM-CTE teachers were much less likely than their counterparts in either of the other two groups to have

a certification in STEMM or CTE. Also, Black teachers were less represented in categories where STEMM-general courses are taught.

These conclusions raise further questions that necessitate future consideration. First, with this taxonomy, future research should look to empirically determine whether having an exclusive or mixed STEMM teacher may better support students' outcomes—a question that has never been asked, yet the answers would have implications for both policy, practice, finance, teacher preparation, and professional development. As mentioned above, a theoretical argument could be made to support either type of teacher, but we lack empirical evidence.

Second, this taxonomy sheds light on gaps in qualifications across categories of teachers as well as disparities in demographic representation of teachers. For instance, the underrepresentation of Black teachers in the teaching categories that include STEMM-general courses requires further inquiry in order to reduce these disparities. We propose future work to better understand what may be underlying these, such as barriers to entry. The disproportionate rates of teachers by race or ethnicity and gender across the taxonomy may underscore the opportunity for ethno-racial or gender matching between student and teacher in STEMM—and specifically in STEMM-CTE.

Ultimately, the goal of this brief was to shine light on these different categories of STEMM teachers. This can provide researchers and policymakers with a taxonomy by which to understand where STEMM teachers are found. This ultimately can motivate future work's assessment of the influences of these different teachers and provide researchers, policymakers, and practitioners with a tool for better understanding of the topography and, ultimately, impact of the workforce.

Note

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