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The Front End of the STEM Teacher Pipeline: Early Career STEM Teachers' Field Experiences and Perceptions of Preparation

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Abstract

A growing quantitative literature finds evidence that student teaching placements predict later outcomes of teacher candidates and their students, but there is little large-scale quantitative evidence about the mechanisms for these estimated relationships. We use data from a survey of STEM teachers in Washington State to better understand how their perceptions of preparation are related to student teaching placements and current classroom environment. We find evidence that the composition of students in student teaching classrooms are predictive of STEM teachers' perceptions of their preparation. For example, STEM teachers who student taught in classrooms with more English Language Learners and economically disadvantaged students reported feeling prepared to teach these specific student populations. Likewise, STEM teachers who student taught in high-poverty classrooms tended to report feeling better prepared to manage their current classroom, particularly if they were currently teaching in a high-poverty classroom.

1. Introduction

Teacher quality plays an integral role in student educational outcomes and has been found to be the most important *school-based* factor for improving student achievement.[1] Therefore, it is not surprising that the quality of the teacher workforce has been the focus of numerous reports and initiatives. The quality of teachers instructing students in science, technology, engineering, and math (STEM) areas has been called out as a particular concern. For example, in the Obama administration's Innovate to Educate Report, *STEM education will determine whether the United States will remain a leader among nations* (Council of Advisors on Science and Technology Policy, 2016).[2]

Several studies over the last decade suggest how specific teacher preparation experiences are generally related to the effectiveness and retention of in-service teachers. Student teaching (also known as clinical practice) looks to be a particularly important aspect of preparation for the development of teacher candidates.[3] For example, quantitative evidence (described in more detail in the next section) finds that the school and classroom in which student teaching occurs and the cooperating teacher are predictive of candidates' perceptions of preparedness, future effectiveness of teacher candidates in STEM subjects, and teacher retention (Bastian et al., 2020; Boyd et al., 2009; Goldhaber et al., 2017, 2020a,b,c; Matsko et al., 2020; Ronfeldt et al., 2012, 2018).

[1] See Goldhaber et al. (1999), Nye et al. (2004), and Rivkin et al. (2005) on the importance and variation in teacher effectiveness on students' test achievement, Jackson (2018) on the effects on short-run non-test outcomes, and Chetty et al. (2014) on the effects of teachers on long-run outcomes.

[2] Large economic benefits tend to be associated with students who obtain STEM degrees (e.g., Dubina et al., 2020), and improvement in the quality of STEM teachers has been identified as one of the three overarching priorities to ensure that more students develop the skills needed to succeed in the STEM fields (The White House, 2010).

[3] Student teaching involves practice in an authentic K–12 setting under the supervision of a mentor (or "cooperating teacher"), assigned by the K–12 school district, and a field instructor assigned by a teacher education program.

Although the above studies suggest that preparation may be a promising policy lever to advance the overall quality of teachers, relatively little quantitative evidence exists about the specific aspects of preservice STEM teacher preparation and early career STEM teacher experiences that promote educator effectiveness. Understanding these connections is crucial because teachers' perceptions predict their early career retention (e.g., Geiger & Pivovarova, 2018) and instructional readiness (Ronfeldt et al., 2020b); however, the mechanisms for these relationships are not clear.

In this paper, we describe research that analyzes the surveys of early career K–12 STEM teachers in public schools in Washington State. The survey asks teachers to describe how well their student teaching experiences prepared them for specific aspects of their current teaching positions. We linked survey responses to administrative data to investigate how STEM teachers' perceptions of teacher preparation and student teaching, and the alignment between preparation experiences and first job contexts, are related to their feelings of preparedness. We answer three specific questions:

1) What types of preservice and current experiences are predictive of STEM teachers' perceptions of how well their field experiences prepared them for teaching?

2) What specific characteristics of student teaching classrooms are predictive of these perceptions?

3) Do these relationships vary depending on the characteristics of the teacher's current classroom?

2. Background

Research across several states has estimated average differences in teacher effectiveness across teacher education programs (TEPs) (Boyd et al., 2009; Gansle et al., 2012; Goldhaber et al., 2013; Henry et al., 2013; Koedel et al., 2015; Mihaly et al., 2013). Although the differences in teacher effectiveness across programs varies somewhat from state to state, a common conclusion is that there is far more variation in teacher outcomes within programs than across them. In a recent review of the quantitative evidence on TEPs, Goldhaber (2019) finds limited large-scale empirical evidence about *specific experiences* (i.e., the features of teacher education that may explain the within-TEP variation) that predict the effectiveness of teacher candidates; this limits our ability to clearly articulate *how* to better prepare preservice teachers.

That said, there are a few exceptions specific to STEM teacher preparation. For example, Monk and King (1994) find that pedagogical coursework specific to math education is predictive of student achievement in math at the high school level. When looking at qualitative studies, research suggests that the more content education that teachers receive during their preparation, the greater their confidence in their abilities to teach STEM-related content (Nadelson et al., 2013).

Another feature of teacher education that varies within TEPs is the specific student teaching experiences of the teacher candidates. Anderson and Stillman (2013) suggest that "student teaching—as the component wherein preservice teachers are challenged most explicitly to put the educational theories and the specialized equity-minded goals of their TEPs into practice—plays a major role in preservice teacher learning" (p. 3). Although evidence is limited, the available literature suggests that teacher candidates become effective teachers when they are required to link their clinical experiences to their teacher training and when student teaching is done in a supportive environment. Boyd et al. (2006), for instance, find that teachers are more effective (judged by their contribution to student achievement on standardized tests) when they are required to complete a capstone project that links their student teaching to their TEP coursework and when their student teaching is well supervised. Ronfeldt (2012) finds that student teachers tend to learn more and become more effective when their student teaching is done at a school where teachers want to stay (as measured by having a nonretirement attrition rate).[4]

Our consideration of cooperating teacher characteristics is motivated by teacher reports on the important role of their cooperating teachers in career development (e.g., Ganser, 2002). Indeed, recent evidence that gets at the nature of the mentor–mentee relationship exemplifies the importance of alignment between the two: Windschitl et al. (2020) find that teacher candidates are more likely to co-plan with a mentor, take up lesson planning responsibilities, and report receiving useful feedback from mentors when they perceive their placement as congruent with the vision of good teaching in their TEP.

Literature is increasingly connecting cooperating teachers' characteristics to later outcomes of the teacher candidates that they supervise. For example, Bastian et al. (2020), Goldhaber et al. (2020a), and Ronfeldt et al. (2018) find that teacher candidates who are supervised by more effective cooperating teachers, as measured by their performance ratings and/or value added, are more effective once they have their own classroom responsibilities. These findings, which are based on observational data and thus are not causal in nature, are bolstered by two recent experiments that find that candidates randomly assigned to higher-quality field placements (judged primarily on the attributes of cooperating teachers) tend to feel

[4] Ronfeldt (2015) also attributes collaboration among teachers to teacher candidates becoming more effective teachers.

more prepared to teach (Ronfeldt et al., 2020a,b) and show greater development of teaching skills during their clinical practice (Goldhaber et al., 2020d).

Recent work in Washington State (Goldhaber et al., 2017, 2020c; Krieg et al., 2020a) provides direct motivation for our focus on alignment between preparation and early career teaching experiences. Using data on teacher candidates from TEP samples, these papers suggest that teachers are more effective at improving student achievement in math and are more likely to stay in the teaching workforce when they teach in the same grade as, same school level as, and in a classroom with similar student demographics as their student teaching classroom. These findings are also consistent with evidence based on findings from survey data (Boyd et al., 2009) that teachers who see “congruence” between their current teaching position and their student teaching position are more effective at improving student achievement in both math and reading, as well as on recent work probing the mechanisms for these relationships, such as congruence between the “visions of good teaching” in different settings (Windschitl et al., 2021).

Our study builds most closely off the work by Matsko et al. (2020), who investigated which characteristics of cooperating teachers lead to student teachers’ perceptions of their preparedness to teach. Matsko et al. (2020) find that student teachers felt better prepared for their classroom environment when their cooperating teacher received stronger observation ratings overall in instruction and in the classroom environment. They also felt better prepared to take on their own teaching responsibilities when they perceived their cooperating teachers’ instructions more favorably. This prior work illustrates the importance of better understanding early career teachers’ perceptions of preparedness, as supported by the data described in the next section.

3. Data

3.1 Administrative Data

This study combined four data sources to construct a longitudinal dataset that describes the district, school, and classroom characteristics for early career STEM teachers in Washington State. Three datasets were provided by the Washington State Office of Superintendent of Public Instruction: the Washington State S-275 personnel report, the Comprehensive Education Data and Research System (CEDARS) database, and the Washington State eCert system. These three datasets can be linked together through state-assigned teacher certification numbers. We linked these three (also by teacher certification numbers) to an original survey that we had administered to early career STEM teachers, "The Washington STEM Teacher Survey" (WSTS), which is described in more detail in Section 3.2 below.

The Washington State S-275 contains a record of all certified employees in public schools, their highest degree earned, teaching experience, demographic characteristics, and a range of other employment details. We used the position and full-time-equivalent (FTE) variables to eliminate any individuals with an instructional (i.e., classroom teaching) FTE less than half time, and we used the measure of years of teaching experience to focus on "early career" teachers—that is, those with 3 years or less of credited teaching experience. We also used the S-275 to identify observable measures of cooperating teachers, such as the cooperating teacher's experience and degree level.

We utilized data from the 2017–18 CEDARS database to identify the sampling frame for the WSTS. We restricted sampling to only teachers who were observed teaching in the Grades 1–12 in a Washington State public school in the 2017–18 school year and who had either (1) received a STEM teaching credential with three or fewer years of teaching experience (i.e., graduating after 2014)[5] or (2) were observed teaching at least one math or science course during the 2017–18 school year.[6] We identified STEM courses from string searches within state course codes in the 2017–18 Washington State Course Catalog. We derived teacher endorsement and credential information from the state's eCert system. All endorsements that were identified as STEM were put into science, math, and technology "bins." This information allowed us to eliminate any teachers who did not have a credential or endorsement in STEM. These restrictions resulted in a sample of 4,594 early career STEM teachers in Washington State and is the sampling frame for the WSTS, which we describe in the next section.

We also used the CEDARS database to create measures of the classroom demographics of each STEM teacher's classroom in the 2018–19 school year (the year the survey was implemented), as well as their student teaching classroom, as identified from the cooperating teacher and the year of student teaching provided in the survey. The measures included such demographics as the percentage of students eligible for free or reduced-price lunch, henceforth called economically disadvantaged students (EDS), and the percentage of students receiving special education (SPED) or English Language Learner (ELL) services.

3.2 Washington STEM Teacher Survey

In spring and early summer 2019, we administered the WSTS to roughly 4,600 early career STEM teachers who were identified as eligible to answer the survey. The survey asked teachers about their perspectives on their teacher preparation programs and STEM subject-

[5] Teachers were considered for the sample if they had received their teaching certification after January 2014; however, they were dropped from the sample if they had more than three years of teaching experience since that time. This accounted for teachers who may not have gotten a teaching job right after graduation as well as several other situational factors.
[6] For example, we generated the variable "engineering" by enlisting variables such as "cad design and software," "drafting-architectural," and "aerospace technology," etc. Once STEM courses were cleaned and organized by science, technology, engineering, and math, the dataset was merged with the 2017–18 Teacher Courses database by state course codes.

specific preparation, with a focus on their student teaching experiences.[7] Consistent with the American Association of Public Research (AAPOR), we calculated the overall survey response rate by dividing the number of surveys returned (2,302) by the total number of surveys sent out to eligible STEM teachers (4,587), resulting in a response rate of 50.42%.[8]

As shown in **Table 1**, teachers who responded to the STEM Survey varied from the non-respondent teachers in terms of their personal characteristics and of the characteristics of the classrooms and schools in which they taught. Responding teachers (column 2) had higher licensure test scores (WEST-B) than nonrespondents (column 3), but they had lower average years of teaching experience. There are also notable geographic differences between respondents and nonrespondents. For example, teacher candidates who completed their teaching preparation at an institution west of the Cascades were less likely to respond than those who attended an institution east of the Cascades. Panel B of Table 2 focuses on the classroom and school characteristics of STEM Survey respondents compared with nonrespondents. Here, the only significant differences between respondents and nonrespondents was school level: Teachers who taught at a middle or high school were more likely to respond than those in elementary schools, as well as teachers who teach a math class being less likely to respond to the survey.

For the purposes of this paper, we focused on the subset of questions in the STEM Survey that ask STEM teachers about their perceptions of their student teaching experiences, which we summarize in **Figure 1.**[9] Respondents were asked to respond to each question on a Likert scale, with responses ranging from "Strongly Disagree" to "Strongly Agree." Figure 1

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[7] Many of the included questions were derived from The Teacher Pathways Project Surveys (Boyd et al., 2006). See Appendix A for a full timeline for survey administration and see Appendix B for information about the entire WSTS.
[8] See Appendix C for more information and context about this response rate.
[9] See Appendix D for the distribution of these survey responses and other questions about preparation that were included in the survey but were not considered in this analysis.

shows the distribution of responses for each question. One pattern is that early career STEM teachers tend to feel more positive about the extent to which their student teaching experiences prepared them for managing the classroom, supporting ELL students, accelerating the learning for high-performing students, and facilitating group work than they did about how well their student teaching experiences prepared them to use a variety of instructional methods, support students with disabilities, teach in high-poverty settings, and address the needs of struggling students. The finding about preparation to serve ELL students differs from the finding by Boyd et al. (2008), who find that graduates had less opportunity to develop strategies to teach ELL students as part of their preparation than any other experience.

3.3 Analytic Sample and Sample Statistics

Table 2 summarizes statistics for the variables of interest described in Section 3.1 and that were used as predictors in the models outlined in the next section.[10] We considered five observable measures for the cooperating teacher of each STEM teacher: (1) teaching experience (CT Experience); (2) whether the cooperating teacher has a master's degree (CT Master's Degree) and three measures of homophily; (3) whether the cooperating and STEM teachers graduated from the same TEP (CT Same TEP); (4) whether the cooperating and STEM teachers have the same teaching endorsement (CT Same Endorsement); and (5) whether the cooperating and STEM teachers are the same gender (CT Same Gender). As shown in Table 2, the average teaching experience of cooperating teachers in the sample is more than 14 years, about 75% of cooperating teachers had a master's degree, about 20% worked with a student teacher from the same TEP, more than 90% worked with a student teacher in the same endorsement area, and

[10] Table 2 presents the means for the 926 teachers from the 2,302 collected survey responses who: a) completed the entire survey, b) could be matched to their cooperating teacher, and c) could be matched to their student teaching school. This information is necessary to link both to the cooperating teacher and student teaching classroom information.

slightly more than 50% worked with a student teacher of the same gender. These trends are consistent with prior summary statistics reported from a different sample of cooperating teachers in Washington State (Krieg et al., 2020b), with the notable exception that the proportion of cooperating teachers working with a student teacher of the same gender was much lower in this sample.

We also considered five characteristics of each STEM teacher's student teaching classroom: (1) the percentage of EDS (ST Class %EDS); (2) the percentage of students receiving SPED services (ST Class %SWD); (3) the percentage of ELL students (ST Class %ELL); (4) whether the STEM teacher was hired into the same school (ST Same School); and (5) the school level (ST Same Level) (e.g., elementary or middle school) in which they student taught. Again, these results are similar to summary statistics reported in prior work with a different student teaching dataset in Washington State (e.g., Krieg et al., 2020b).

4. Analytic Approach

Our basic analytic approach to each of the three research questions (RQs) outlined in Section 1 is the same. Let y_{it} be the survey response to one of the questions summarized in Figure 1 for teacher *i* in year *t* (2018–19 for all teachers). We used these responses to create a linear variable for which a one-unit increase corresponded to one level higher on the Likert scale in Figure 1. We then estimated a series of linear regression models of the following form:

$$y_{it} = \alpha_1 P_{it} + \alpha_2 S_{it} + \alpha_3 C_{it} + \alpha_4 ST_i + \alpha_5 CT_i + \varepsilon_{it} \qquad (1)$$

In the model in equation 1, P_{it} *are personal characteristics of teacher i* in year *t* that include whether the respondent attended a Washington TEP, had a master's degree or higher, and their STEM endorsement category. S_{it} are current school characteristics that include if the respondent taught STEM at a middle school, high school, or other, and if they taught in Western or Eastern Washington. C_{it} are current classroom characteristics that include the percentage of EDS students in their current classroom, the percentage of SPED students, and the percentage of bilingual students. ST_i are student teaching classroom characteristics for teacher *i* that include the percentage of EDS students in their student teaching classroom, the percentage of SPED students, and the percentage of bilingual students. Finally, CT_i are cooperating teacher characteristics for teacher *i* that include the cooperating teacher's number of years of experience, if the cooperating teacher had a master's degree or higher, if the cooperating teacher attended the same TEP as the respondent, if the cooperating teacher and respondent had the same endorsement, and if the cooperating teacher and respondent were the same gender. All the coefficients in Model 1 can be interpreted as the expected change in a teacher's survey response (on the Likert point scale) to a given question associated with a one-unit increase in each of these variables, all else equal.

In some specifications, we also added interactions that capture the similarity between the current and student teaching classroom placements of each teacher:

$$y_{it} = \beta_1 P_{it} + \beta_2 S_{it} + \beta_3 C_{it} + \beta_4 ST_i + \beta_5 CT_i + \beta_6 C_{it} * ST_i + \varepsilon_{it} \quad (2)$$

The interaction coefficients in this model in β_6 can be interpreted as the expected change in the relationship between each student teaching classroom variable and teachers' survey responses as a function of changes in the corresponding current classroom variable.

We used the models above to address all three RQs. To investigate what types of preservice and current experiences are predictive of STEM teachers' perceptions of how well their field experiences prepared them for teaching, we simply tested whether each *group* of variables in Equations 1 and 2 was jointly predictive of STEM teachers' survey responses. This allowed us to estimate a more parsimonious version of the models in Equations 1 and 2 to address RQ2 (What specific characteristics of student teaching classrooms are predictive of these perceptions?) and explore the extent to which specific characteristics of teachers' student teaching placements are predictive of STEM teachers' survey responses. Finally, we specifically considered the interaction terms in Equation 2 to investigate whether these relationships varied depending on the characteristics of the teacher's current classroom (RQ3).

The analytic approach described was designed to disentangle the contributions of STEM teachers' classroom placements to their perceptions of their preparation from other confounders (e.g., teaching experience) or mediators (e.g., their current classroom placements) in these relationships. But there are also several limitations that are important to acknowledge. First and foremost, our analyses are based on a survey that, while distributed to every early career STEM teacher in the state, received a response from about only 50% of these teachers, and only a subset of whom provided the necessary information to connect survey responses to cooperating teacher and student teaching information. It is possible that the teachers who provided this information in their survey responses were not representative of all STEM teachers in the state; indeed, some comparisons we present suggest that more qualified teachers (as measured by licensure test scores) were more likely to respond, which raises questions about generalizability across the state. Another important caveat is that the findings are based on a single state (Washington) and may not generalize to other states with different preparation and K–12 environments.

5. Results

5.1 What types of preservice and current experiences are predictive of STEM teachers' perceptions of how well their field experiences prepared them for teaching?

Table 3 reports the results of a series of f-tests of whether each group of variables described in Equations 1 and 2 are jointly predictive of STEM teachers' responses to different questions about their preparation. Columns in Table 3 correspond with the specific questions summarized in Figure 1 that serve as the dependent variable in these regressions. The significance tests reported in Table 3 can be interpreted as tests of the null hypothesis that the relationships between the variables within each category and the survey responses are all zero.

We draw several conclusions from Table 3. First, there is little evidence that the personal characteristics of STEM teachers themselves (e.g., their degree level and endorsements) or the cooperating teachers' characteristics (e.g., their experience or degree level) explain any variation in STEM teachers' survey responses. On the other hand, teachers' current school characteristics (e.g., their school level) and current classroom characteristics (e.g., the percentage of EDS or ELL students in their current classroom) appear to explain some variation in their perceptions of their abilities to manage their classroom. This is important, as it suggests that these are potentially important control variables to include in our investigation of RQ2.

Perhaps more important, STEM teachers' student teaching classroom characteristics are jointly predictive of their perceptions of their preparation to teach ELL and high-poverty students, and measures of the alignment between their current and student teaching classroom are jointly predictive of their perceptions of their preparation to teach ELL students and low-performing students. These measures will become the variables of interest in our subsequent models, while for parsimony, we do not consider characteristics cooperating teachers in subsequent models, because there is little evidence that such characteristics explain much variation in STEM teachers' survey responses.

5.2 What specific characteristics of student teaching classrooms are predictive of these perceptions?

Table 4 summarizes the estimates from the model in Equation 1, where the outcomes are survey responses about how well teachers' student teaching experiences prepared them for specific aspects of their current job. As with Table 3, the column names are abbreviations that refer to specific questions in Table 1. Motivated by the trends in Table 3, we focused on three groups of variables (the percentage of EDS, SWD, and ELL in student teaching and current classrooms) and controlled for some personal and current school characteristics. The odd columns in Table 4 address the extent to which these variables in the teacher's student teaching classroom ("ST Class") or current classroom ("Current Class") are predictive of survey responses. As discussed in Section 4, these coefficients can be interpreted as the expected increase in STEM teachers' survey responses associated with a one standard deviation increase in each of these variables.

Focusing first on the current classroom characteristics, there is some clear evidence that STEM teachers in higher-poverty classrooms feel less prepared to manage their classrooms, support ELL students, and support low-performing students. Arguably, the more interesting relationships are for the student teaching variables in this table. One key finding is that in controlling for current classroom placements, the percentage of EDS students in the teacher's *student teaching* classroom is positively and significantly predictive of their perceptions of their preparation to manage their classroom, support ELL students, and teach in high-poverty settings. Some of the coefficient magnitudes are striking. For example, a one standard-deviation increase in the percentage of EDS students in a STEM teacher's student teaching classroom is predictive of nearly a 0.8 increase in their predicted response to the question about the extent to which their student teaching placement prepared them to teach in high-poverty settings. However, perhaps not surprisingly, being in a higher-poverty classroom as a student teacher is significantly and negatively predictive of their perceptions of their abilities to differentiate instruction for high-performing students.

There are also some sensible relationships for the other measures of the student teaching classroom. For example, the percentage of students with disabilities in the student teaching classroom is positively predictive (in the interaction specification) of STEM teachers' perceptions of how well their student teaching placement prepared them to teach students with individualized education plans (IEPs). Likewise, the percent of ELL students in the student teaching classroom is positively predictive of STEM teachers' perceptions of how well their student teaching placement prepared them to teach ELL students, but it is negatively predictive of their perceptions of their preparation to teach high-performing students. To our knowledge, this is the first empirical evidence that the characteristics of student teaching classrooms (as measured by administrative data about these student teaching placements) are predictive of teachers' perceptions of their preparation to teach specific populations of students.

5.3 Do these relationships vary depending on the characteristics of the teacher's current classroom?

An important question that arises from the results discussed for RQ2 is whether these relationships vary for teachers in different *current* teaching assignments. Therefore, we present estimates from the interaction models (Equation 2 in Section 4) in the even columns of Table 4. The most notable interaction is between the percentage of EDS in the student teaching classroom and the current classroom, which is positively predictive of STEM teachers' perceptions of their abilities to manage their classrooms. In other words, STEM teachers feel better prepared to manage their classrooms if they student taught in a higher-poverty classroom, but particularly if they are currently teaching in a higher-poverty classroom.

We illustrate this relationship further in the contour plot in **Figure 2,** which plots the predicted response to teachers' responses to the question "How well did your student teaching experience prepare you to handle a range of classroom management or discipline situations?" as a function of the percentage of EDS in their student teaching (x axis) and current (y axis) classrooms.[11] The shading represents the predicted value of the teacher's response (see the legend on the right-hand side of the graph, centered so the mean response is zero): The regions denoted by "+" indicate regions where the predicted response is significantly greater than zero, and the regions denoted by "-" indicate regions where the predicted response is significantly less than zero.

Focusing on these statistically significant regions, teachers tend to feel better prepared to manage their current classroom (i.e., have a predicted response that is greater than the average teacher) when the percentage of EDS in their current classroom is similar to the percentage of EDS in their student teaching classroom (i.e., regions close to the y = x line in Figure 2). On the other hand, teachers tend to feel less prepared to manage their current classroom (i.e., have a predicted response that is lower than the average teacher) when the percentage of EDS in their current classroom is considerably greater than the percentage of EDS in their student teaching classroom (i.e., the upper left region of Figure 2). This is consistent with prior evidence (e.g.,

[11] These contour plots are generated from a more flexible specification of the model in column 2 of Table 4 that includes a cubic of student teaching classroom %EDS and interactions between this cubic and the current classroom %EDS. See Goldhaber et al. (2017) for the details of this specification.

Goldhaber et al., 2017; Krieg et al., 2020b) that the alignment between teachers' current and student teaching classrooms matters, in this case for teachers' perceptions of their preparation to manage their current classrooms. In fact, we interpret the patterns in Figure 2 as one potential and plausible mechanism for the relationships found in these earlier papers; in other words, that the importance of alignment for teacher effectiveness found in prior papers may, in part, be due to teachers who experience alignment feeling better prepared to manage their classrooms, particularly in high-poverty settings.

6. Discussion and Conclusions

This is the first large-scale study, to our knowledge, that connects administrative data on student teaching placements of STEM teachers with their perceptions of their preparation. This analysis provides the first empirical evidence that the characteristics of STEM teachers' student teaching classrooms, as measured by administrative data about these placements, are predictive of their perceptions about teaching specific populations of students. The findings generally align with the commonsense notion that gaining more experience with particular types of students as a student teacher helps teachers prepare for teaching positions with those same types of students. Moreover, these findings support research showing that the alignment between student teaching and first teaching jobs predict in-service teacher performance (Goldhaber et al., 2017; Krieg et al., 2020b) and retention (Goldhaber et al., 2020c). Specifically, the results, which are based on survey data in this study, highlight several potential mechanisms for prior findings that teachers are more effective and more likely to stay in the profession when they teach in a school or classroom with similar student demographics as their student teaching classroom.

There are several implications of our findings, but we are cautious about overinterpretation because the evidence linking feelings of preparedness to in-service teacher performance is limited and mixed (e.g., Ronfeldt et al., 2020a,b).[12] That said, the findings connecting student teaching classroom demographics to STEM teachers' perceptions of their abilities to teach specific populations of students build on a growing evidence base suggesting that student teaching schools and classrooms matter for candidate development (e.g., Ronfeldt et al., 2012, 2015). These findings, along with the finding that STEM teachers in high-poverty classrooms feel better prepared to manage their classrooms if they also student taught in a high-poverty classroom, also add to a body of research (e.g., Boyd et al., 2009; Goldhaber et al., 2017; Krieg et al., 2020) suggesting that student teachers should be placed in settings to begin their careers that look like the classrooms in which they student taught. This suggests that policymakers and practitioners should strive to do a better job aligning the experiences of student teaching and early career in-service responsibilities of early career STEM teachers.

It is important to acknowledge that this task is difficult because student teaching has historically occurred in the disproportionately advantaged classrooms near TEPs (Krieg et al., 2016), and there may be benefits (both logistical and otherwise) to placements nearby to TEPs. But the task is certainly not insurmountable. For example, new remote supervision technologies necessitated by the COVID-19 pandemic, may facilitate future placements in classrooms further from TEPs that may be more representative of the types of classrooms candidates will face in their first year of teaching (Goldhaber et al., 2021b).

One important null finding is that we did not find evidence that cooperating teacher characteristics were predictive of feelings of preparedness. This finding is somewhat surprising

[12] As we discussed above, the 50% response rate on the survey raises concerns about the representativeness of the responses.

given the growing evidence about the importance of this mentoring relationship for teacher candidate development and in-service teacher performance (e.g., Goldhaber et al., 2020a,b,c; Ronfeldt et al., 2018). That said, these findings on STEM teachers are consistent with earlier work on a more general sample of teachers (Matsko et al., 2020) that finds relatively weak relationships between candidates' perceptions of their cooperating teacher and other observable data about these teachers.

Teachers report that the mentoring they receive in student teaching is vital to their future success in the classroom (e.g., Ganser, 2002). This, combined with the aforementioned empirical evidence on the importance of mentoring, suggests that more work is necessary to identify what identifiable qualities in potential cooperating teachers, or the training they receive, might help to ensure a productive mentoring experience for student teachers. Although we argue for the alignment of preservice student teaching and in-service classroom responsibilities, mentors could also play an even stronger role in training student teachers to work with different types of students through purposeful mentoring practices (Windschitl et al., 2020). Thus, a potentially fruitful line of future research could investigate the nature of the training that cooperating teachers receive for mentoring student teachers and whether this training predicts the same types of perceptions of preparation considered in this study.

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Figure 1. Distribution of Student Teaching Responses (*Rate how well your student teaching experience prepared you to:*)

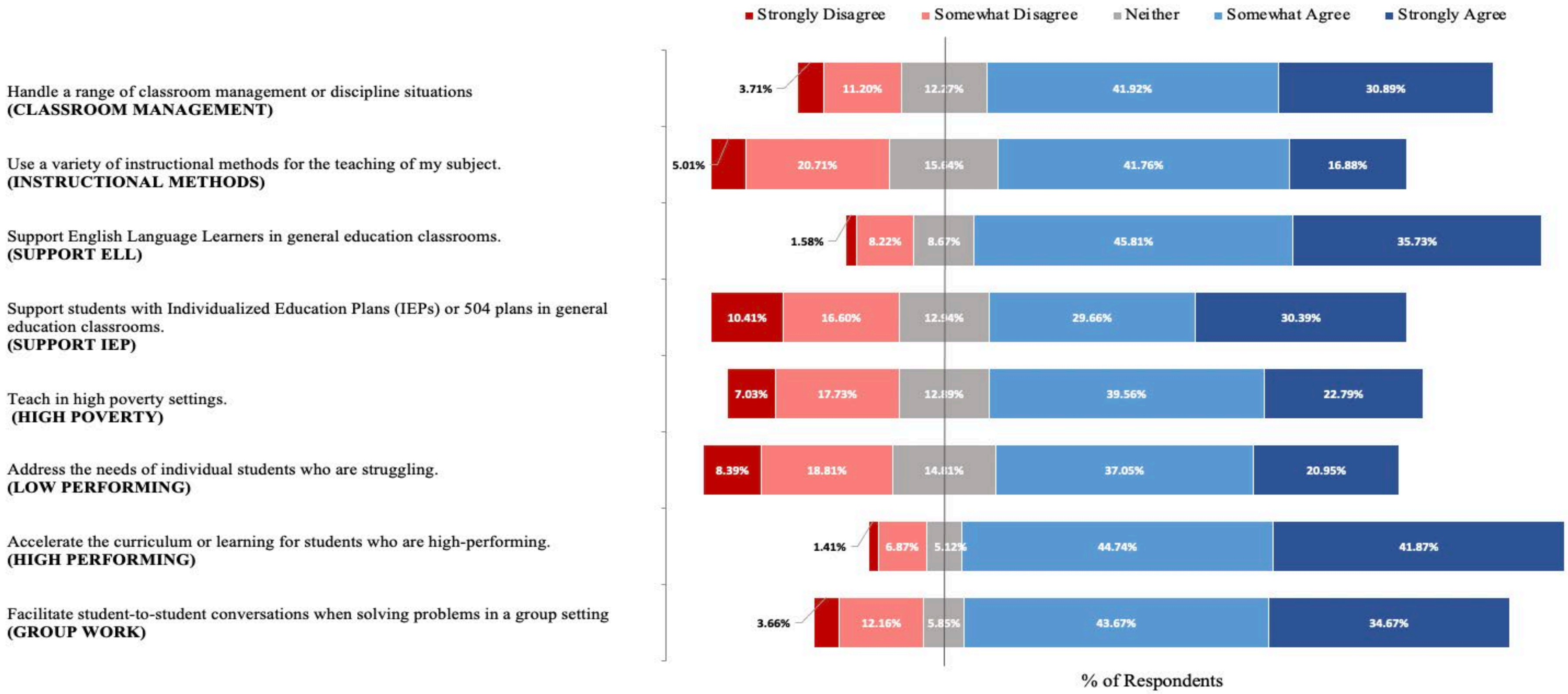
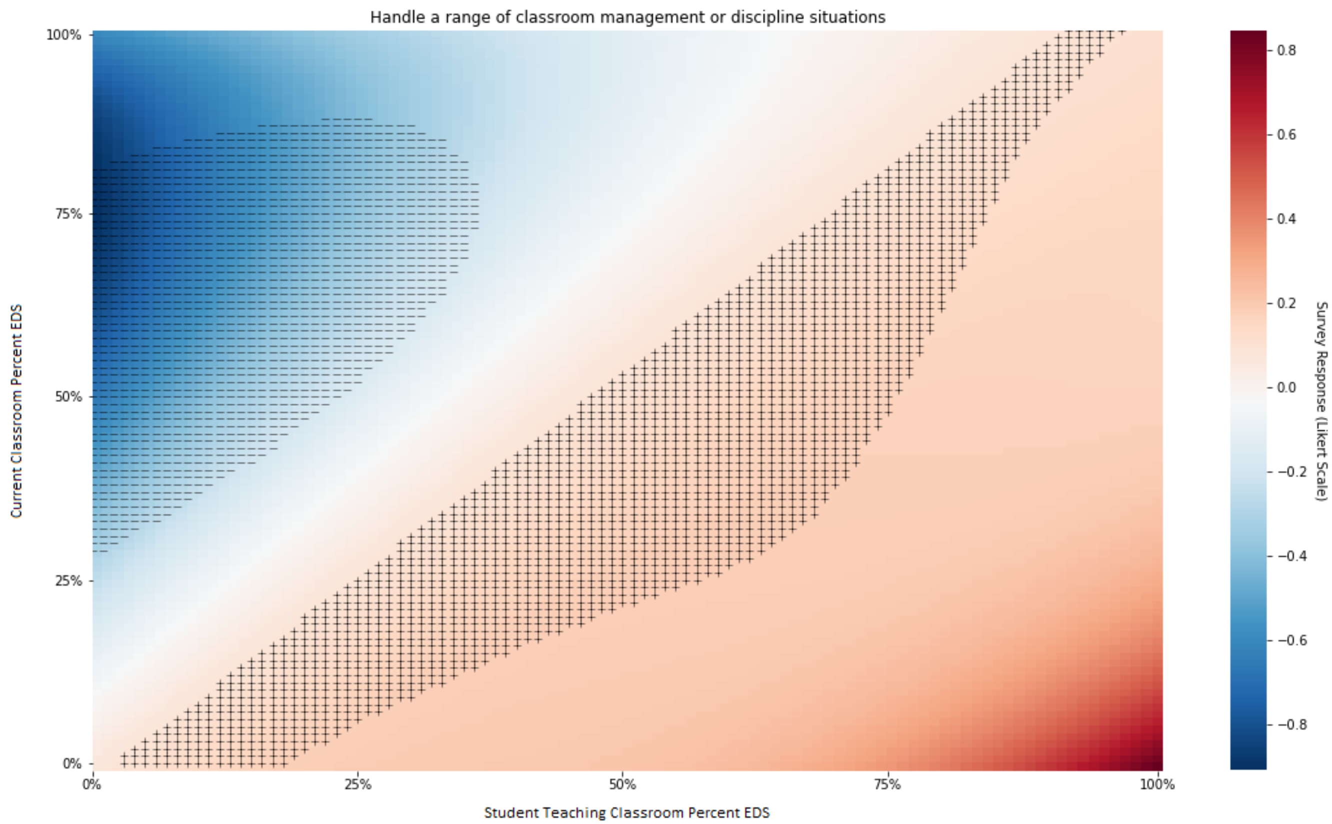


Figure 2. Predicted response to classroom management question as a function of current and student teaching classroom %EDS



Notes: + = Significantly greater than mean; - = Significantly less than mean; EDS = Economically disadvantaged students.

Table 1. Characteristics of the Washington STEM Teacher Survey (WSTS) sample, respondents, and non-respondents

	WSTS Sample	WSTS Respondents	WSTS Non-Respondents
	N = 4,594	N = 2,303	N = 2,291
Panel A: Teacher Characteristics			
In-State Graduate	0.766	0.765	0.767
Masters Degree	2.388	2.461	2.324**
WEST-B Math	278.186 (16.976)	279.524 (16.841)	277.057*** (17.013)
WEST-B Reading	270.052 (15.668)	271.217 (15.343)	269.079*** (15.874)
WEST-B Writing	261.945 (18.338)	263.375 (18.069)	260.725*** (18.482)
Teaching experience	1.798 (0.877)	1.723 (0.892)	1.865*** (0.857)
Panel B: Classroom & School Characteristics			
Elementary School	0.678	0.639	0.713***
Middle School	0.149	0.162	0.136*
High School	0.156	0.177	0.138***
Other school level	0.017	0.021	0.013*
West of the Cascades	0.775	0.788	0.763
Science Course	0.297	0.295	0.299
Math Course	0.907	0.890	0.920*
School % SPED	13.867 (5.283)	14.006 (5.562)	13.744 (5.024)
School % EDS	47.909 (27.385)	47.985 (27.105)	47.841 (27.635)

Notes: We define WSTS Respondents in Table 1 as any survey that was returned by a respondent and had at least the first question answered, "Are you currently teaching science, technology, engineering, or math to students in grades K-12 in Washington state?". This number drops considerably in Table 3 where we define Survey Respondents as any respondent that a) completed the survey, b) could be matched to their cooperating teacher, and c) could be matched to their student teaching school.
P-values from two-sided t-test: *p<.05; **p<.01; ***p<.001.

Table 2. Summary statistics of student teaching variables (analytic sample only)

	Analytic Sample
	N = 926
CT Experience	14.44 (8.39)
CT Masters Degree	0.75
CT Same TEP	0.19
CT Same Endorsement	0.93
CT Same Gender	0.54
ST Class %EDS	49.03 (25.89)
ST Class %SWD	10.28 (15.55)
ST Class %ELL	13.26 (16.4)

Notes: Analytic sample includes any respondent from the 2,302 collected survey responses that: a) completed the entire survey, b) could be matched to their cooperating teacher, and c) could be matched to their student teaching school. CT = cooperating teacher; EDS = economically disadvantaged student; ELL = English Language Learner; SWD = student with disabilities; TEP = teacher education program

Table 3. F tests of categories of predictors of early career STEM teacher survey responses

	CLASSROOM MANAGEMENT		INSTRUCTIONAL METHODS		SUPPORT ELL		SUPPORT IEP		HIGH POVERTY		LOW PERFORMING		HIGH PERFORMING		GROUP WORK	
	F-stat	p-value	F-stat	p-value	F-stat	p-value	F-stat	p-value	F-stat	p-value	F-stat	p-value	F-stat	p-value	F-stat	p-value
Personal characteristics	1.49	0.192	1.25	0.283	1.03	0.397	0.73	0.598	0.57	0.72	1.42	0.215	1.06	0.381	1.83	0.104
Current school characteristics	2.46	0.044	1.17	0.324	0.06	0.994	0.51	0.725	1.11	0.353	1.35	0.25	0.33	0.855	1.19	0.312
Current classroom characteristics	5.29	0.001**	0.24	0.866	1.02	0.384	1.69	0.167	0.53	0.665	2.43	0.064	1.70	0.166	0.12	0.95
Student teaching classroom characteristics	1.29	0.277	1.31	0.271	11.24	0.000**	1.51	0.21	29.36	0.000**	2.08	0.102+	1.44	0.231	0.34	0.8
Cooperating teacher characteristics	0.96	0.442	1.16	0.329	0.25	0.938	0.88	0.492	1.54	0.175	1.16	0.327	2.27	0.046*	0.55	0.74
Current & student teaching classroom / school alignment	1.66	0.142	1.45	0.204	3.33	0.005*	2.04	0.071	1.58	0.164	2.32	0.041*	0.51	0.767	1.15	0.334

Notes: **Personal characteristics** include if the respondent attended a Washington TEP, had a master's degree or higher, and their STEM endorsement category; **Current school characteristics** include if the respondent taught STEM at a middle school, high school, or other, and if they taught in Western or Eastern Washington, **Current classroom characteristics** include the percentage of EDS students in their current classroom, the percentage of SPED students, and the percentage of bilingual students; **Student teaching classroom characteristics** include the percentage of EDS students in their student teaching classroom, the percentage of SPED students, and the percentage of bilingual students**;** **Cooperating teacher characteristics** include the cooperating teacher's number of years of experience, if the cooperating teacher had a master's degree or higher, if the cooperating teacher attended the same TEP as the respondent, if the cooperating teacher and respondent had the same endorsement, and if the cooperating teacher and respondent were the same gender; **Current and student teaching classroom/school alignment** include if the respondent's current and student teaching school are the same, if they are at the had the same grade level, if they have the same percentage of EDS students, if they have the same percentage of SPED students, and if they have the same percentage of bilingual students. Column headers indicate dependent variables summarized in Figure 1.
P-values from two-sided t-test: *p<.05; **p<.01.

Table 4. Current classroom characteristics, student teaching classroom characteristics, and alignment as predictors of survey responses

	CLASSROOM MANAGEMENT		**INSTRUCTIONAL METHODS**		**SUPPORT ELL**		**SUPPORT IEP**		**HIGH POVERTY**		**LOW PERFORMING**		**HIGH PERFORMING**		**GROUP WORK**	
Current Class %EDS	-0.19*** (0.05)	-0.18*** (0.05)	-0.02 (0.04)	-0.03 (0.04)	-0.11* (0.05)	-0.11* (0.05)	-0.04 (0.05)	-0.03 (0.05)	-0.07 (0.05)	-0.07 (0.05)	-0.07+ (0.04)	-0.07+ (0.04)	0.01 (0.05)	0.01 (0.05)	-0.04 (0.04)	-0.04 (0.04)
ST Class %EDS	0.16*** (0.05)	0.17*** (0.05)	0.03 (0.04)	0.03 (0.04)	0.14** (0.05)	0.15** (0.05)	0.02 (0.05)	0.02 (0.05)	0.78*** (0.05)	0.78*** (0.05)	0.06 (0.04)	0.08+ (0.04)	-0.13** (0.05)	-0.12* (0.05)	-0.05 (0.05)	-0.05 (0.05)
ST EDS * Current EDS		0.07+ (0.04)		0.01 (0.03)		0.07+ (0.04)		0.10** (0.04)		-0.02 (0.04)		0.04 (0.03)		-0.05 (0.04)		0.02 (0.03)
Current Class %SWD	-0.04 (0.06)	-0.04 (0.06)	0.01 (0.05)	0.01 (0.05)	0.05 (0.07)	0.05 (0.07)	0.09 (0.07)	0.11+ (0.07)	0.05 (0.07)	0.04 (0.07)	-0.00 (0.05)	-0.01 (0.05)	-0.07 (0.06)	-0.08 (0.06)	0.02 (0.06)	0.01 (0.06)
ST Class %SWD	-0.02 (0.05)	-0.12 (0.08)	-0.05 (0.04)	-0.10 (0.07)	-0.13** (0.05)	-0.19* (0.09)	0.08 (0.05)	0.23* (0.09)	-0.07 (0.05)	-0.12 (0.09)	-0.03 (0.04)	-0.11 (0.07)	0.01 (0.05)	-0.08 (0.09)	-0.06 (0.04)	-0.14+ (0.08)
ST SWD * Current SWD		0.04 (0.03)		0.02 (0.02)		0.02 (0.03)		-0.06* (0.03)		0.02 (0.028)		0.03 (0.02)		0.03 (0.03)		0.03 (0.03)
Current Class %ELL	0.03 (0.05)	0.01 (0.05)	0.03 (0.04)	0.02 (0.04)	0.01 (0.05)	0.02 (0.05)	-0.03 (0.05)	-0.05 (0.05)	0.07 (0.05)	0.07 (0.05)	0.04 (0.04)	0.01 (0.04)	0.07 (0.05)	0.05 (0.05)	0.03 (0.05)	0.03 (0.05)
ST Class %ELL	-0.06 (0.05)	-0.08+ (0.05)	-0.03 (0.04)	-0.04 (0.04)	0.28*** (0.05)	0.28*** (0.05)	0.01 (0.05)	-0.01 (0.06)	0.03 (0.05)	0.02 (0.05)	0.00 (0.04)	-0.04 (0.04)	-0.12* (0.05)	-0.15** (0.05)	-0.00 (0.05)	-0.01 (0.05)
ST ELL * Current ELL		0.02 (0.03)		0.01 (0.03)		-0.02 (0.03)		0.01 (0.03)		0.01 (0.03)		0.04+ (0.03)		0.04 (0.03)		-0.00 (0.03)
N	926	926	926	926	926	926	926	926	926	926	926	926	926	926	926	926

Notes. Models also control for if the respondent attended a Washington TEP, had a master's degree or higher, their STEM endorsement category, if they currently taught at a middle school, high school, or other, and if they currently taught in Western or Eastern Washington. Column headers indicate dependent variables summarized in Figure 1.
P-values from two-sided t-test: *p<.05; **p<.01; ***p<.001.

Appendix A: WSTS Implementation April-July 2019

The WSTS was first emailed to qualified STEM teachers (as defined above in section 3.1) using the online survey software, "Qualtrics". This first outreach attempt collected thirty-two percent of the total survey responses. The WSTS was sent to qualified teachers at both their school email and the email they had submitted when applying for their teaching certification. The two email lists were later merged and, moving forward, teachers were sent a reminder to complete the WSTS each Monday morning for the remainder of the survey collection period.

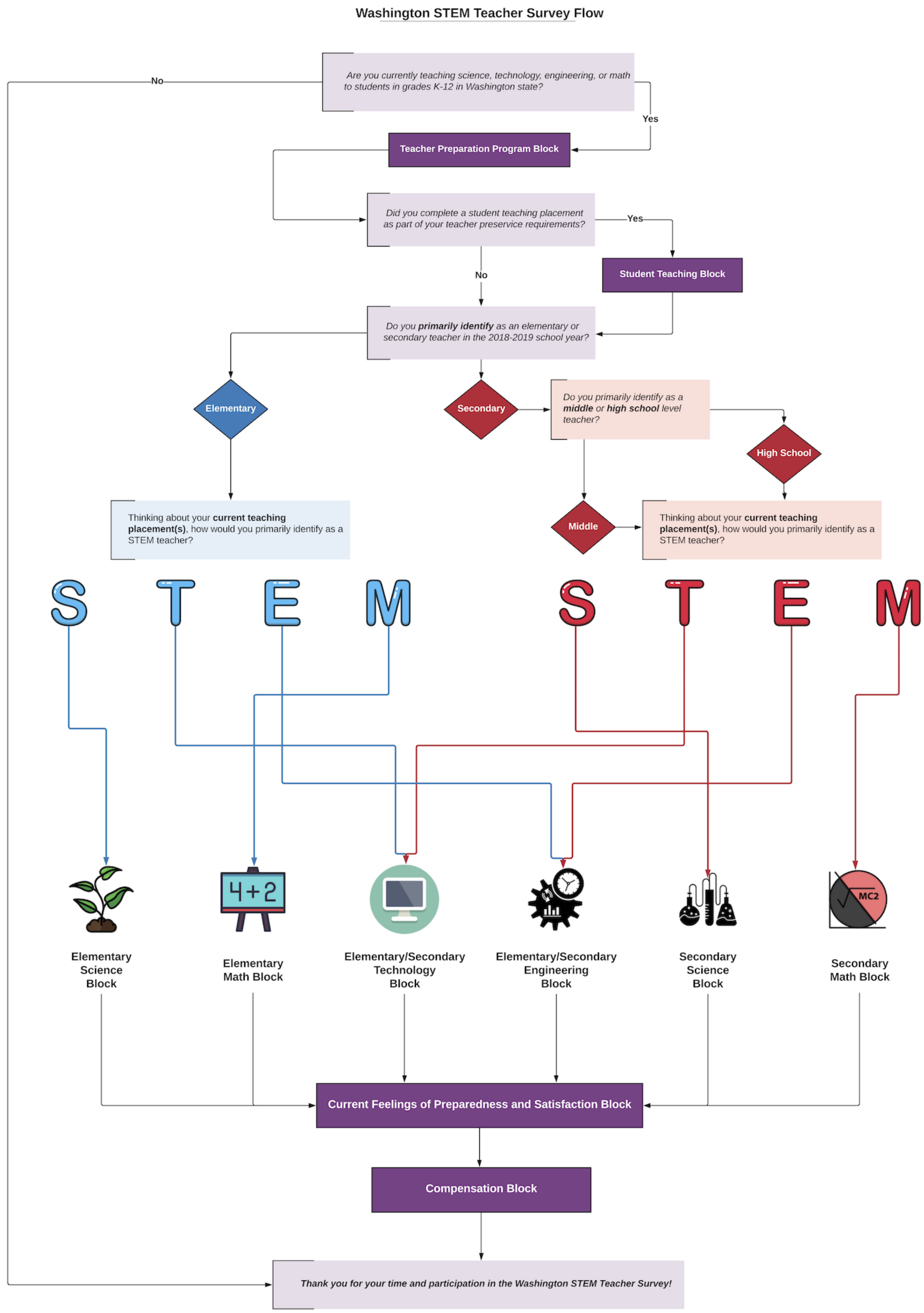
At this time, we contacted the 18 (two per Educational Service District (ESD)) math and science coordinators to discuss their interest in assisting with outreach to their ESD STEM teachers. Of the 18 coordinators, seven agreed to reach out to their teachers on UW's behalf, encouraging teachers to complete the WSTS.

We then sent personalized emails to each of the unfinished survey respondents. After running a preliminary analysis of descriptive statistics on WSTS respondents compared to nonrespondents, we also targeted teachers from the Eastern region of the state, specifically the Spokane and Yakima regions. At this time the educational organizations, WA STEM, Washington Educators Association, and the Washington Association of School Principals, were contacted. These educational organizations reached out to their networks via email, social media, and newsletters.

With the school year wrapping up, we increased our outreach attempts. We made individual phone calls to teacher classrooms after school hours, specifically to districts that listed direct classroom numbers. On average 60-150 phone calls were made each school day for the last two weeks of school. Teachers were offered a lottery of $500 if their school had reached a 60% WSTS response rate (at the end of the survey collection, 445 school had met this requirement). Directors of Communication from twenty-three school districts were also contacted to inquire about outreach involvement in an attempt to increase the WSTS response rate by the end of the school year.

During the last week of school, we pulled the teacher preparation program, student teaching, and current school alignment questions from the original WSTS to create a very brief, two-minute Survey Monkey survey. This SurveyMonkey WSTS was then sent to nonrespondents to solicit responses before the close of the WSTS.

Appendix B. WSTS Flowchart



Appendix C: Details of the WSTS Response Rate

Obtaining a high survey response rate is becoming increasingly difficult (Cull et al., 2005). Response rates for major surveys have consistently declined since their peak in the early 1990's. Unlike administrative data (that can provide information for a full study sample), a survey can only produce data for a sample of the full population. Without achieving a 100% survey response rate, there is always the possibility of nonresponse bias in the response results. Because of this, achieving at least an 80% response rate has long been considered the benchmark to minimize this risk. This benchmark comes from the U.S. Office of Management and Budget (OMB), and their requirement for federally funded research projects (though this benchmark is no longer mandated).

However, survey response rates can be misleading when considered the only measure of survey data quality or representativeness of the target population. Fallen survey response rates in past decades means only that the potential for nonresponse bias has increased, not necessarily that nonresponse bias has become more of a problem. Studies show there is very little correlation between nonresponse rate and their measures of bias (Groves & Peytcheva, YEAR). There is no evidence that an 80% or higher response rate is optimum, or that efforts to enhance response will automatically reduce nonresponse bias (Hendra & Hill, 2018; Curtin et al., 2000; Keeter et al., 2000; Groves, 2006). Instead, we examine the degree to which sampled respondents differ from the survey population as a whole.

During the course of the WSTS collection, 21 teachers responded that they did not qualify and were dropped from the sample. There were seven true bounces where the survey could not be delivered to the teacher via either their personal or generated school email. At the end of the survey collection, 2,494 total WSTS responses were collected. Of these 2,494 surveys, 155 were duplicate entries from teachers who had completed the WSTS twice. We used the first survey entry to stay consistent with the teachers who had completed the survey only once. Research staff pilot responses accounted for 37 of the survey responses and were also dropped from the sample. Two-hundred-thirty-seven teachers answered "No" to the first survey question that asked teachers if they were currently teaching science, technology, engineering, or math during the 2018-2019 school year. These teachers were not dropped from the sample, instead they exited the WSTS and their response was marked as complete.

Table C1. WSTS Response Rate

	WSTS Respondents
Overall Survey Response Rate	(2,302/4,566) = 50.1%
Starting Sample	4,594
Total Surveys Returned	2,302

Complete Surveys Responses (100% Complete)	(1,852/2,302) = 80.45% of all surveys returned were complete
Partial Survey Responses (< 50% Complete)	242
Partial Survey Responses (> 50% Complete)	2060

Qualtrics Responses (ALL)	2,324
Survey Pilot (UW Staff)	-30
Duplicate Entries (Drop duplicates)	-152
After Dropping Duplicates & Staff Responses	2,142

Survey Monkey Responses (ALL)	170
Survey Pilot (UW Staff)	-7
Duplicate Entries (Drop duplicates)	-3
After Dropping Duplicates & Staff Responses	160

School District Representation	(205/237) = 86.5% of all sample districts were represented
Districts in the sample	237
Districts Represented	205

Notes: There are 295 school districts in the state of Washington. Fifty-eight districts did not have early career STEM teachers teaching in their district at the time of this study. The American Association For Public Opinion Research (AAPOR) created the Standard Definitions Report to fill the need for more comprehensive and reliable diagnostic tools to understand the components of total survey error. Under the leadership of the AAPOR, the survey research community has focused on four operational definitions of rates of survey participation. Here we focus on response rate, generally defined as the number of completed units divided by the number of eligible units in the sample.

Appendix D. WSTS Question Summary Statistics

	Strongly Agree	Somewhat Agree	Neither	Somewhat Disagree	Strongly Disagree
Panel A: Student Teaching Questions (Rate how well your student teaching experience prepared you to:)					
Handle a range of classroom management or discipline situations **(CLASSROOM MANAGEMENT)**	34.67	43.67	5.85	12.16	3.66
Use a variety of instructional methods for the teaching of my subject. (**INSTRUCTIONAL METHODS)**	41.87	44.74	5.12	6.87	1.41
Support English Language Learners in general education classrooms. **(SUPPORT ELL)**	20.95	37.05	14.81	18.81	8.39
Support students with Individualized Education Plans (IEPs) or 504 plans in general education classrooms. **(SUPPORT IEP)**	22.79	39.56	12.89	17.73	7.03
Teach in high poverty settings. **(HIGH POVERTY)**	30.39	29.66	12.94	16.6	10.41
Address the needs of individual students who are struggling. **(LOW PERFORMING)**	35.73	45.81	8.67	8.22	1.58
Accelerate the curriculum or learning for students who are high performing. **(HIGH PERFORMING)**	16.88	41.76	15.64	20.71	5.01
Facilitate student-to-student conversations when solving problems in a group setting **(GROUP WORK)**	30.89	41.92	12.27	11.2	3.71
Panel B: Cooperating Teacher Questions					
My cooperating teacher was an excellent teacher and worthy teacher role model. **(ROLE MODEL)**	72.26	14.78	5.32	4.55	3.08
When I participated in the classroom during my student teaching placement, my cooperating teacher allowed me to try out strategies and techniques for teaching that I was learning in my pre-service classes. **(STRATEGIES)**	75.04	16.5	3.49	2.84	2.13
My cooperating teacher's instructional style and pedagogical approach was aligned with the instructional techniques I learned in my pre-service program. **(ALIGNMENT)**	51.66	28.88	7.57	7.63	4.26
When I participated in the classroom during my student teaching placement, I was regularly observed by my cooperating teacher. **(OBSERVED)**	76.8	13.85	3.61	3.96	1.78
When I had questions or concerns about teaching, my cooperating teacher was available to talk to me. **(AVAILABILITY)**	81.72	10.47	3.31	2.84	1.66
Panel C: Alignment Questions					
The vision of good teaching in my teacher preparation program was similar to the vision of good teaching in the school in which I did my student teaching. **(TEP/ST ALIGNMENT)**	29.16	38.23	13.69	11.22	4.82
The vision of good teaching in my teacher preparation program was similar to the vision of good teaching in the school in which I am currently employed. **(TEP/CURRENT ALIGNMENT)**	31.73	40.8	11.96	11.06	4.4
The vision of good teaching in the school in which I did my student teaching was similar to the vision of good teaching in the school in which I am currently employed. **(ST/CURRENT ALIGNMENT)**	32.14	36.13	11.8	11.27	5.24