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Introduction to the 2019 AAAS ARISE Commissioned Paper Series

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1. Bell, C., Gitomer, D., Savage, C., & Mckenna, A. H. (2019). *A Synthesis of Research on and Measurement of STEM Teacher Preparation*. American Association for the Advancement of Science.

2. Fuller, E. J., & Pendola, A. (2019). *Teacher Preparation and Teacher Retention: Examining the Relationship for Beginning STEM Teachers*. American Association for the Advancement of Science.

3. Youngs, P., Bieda, K., & Kim, J. (2019). *Teacher Induction Programs Associated with Retention in the STEM Teaching Workforce*. American Association for the Advancement of Science.

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Introduction

Improving STEM education has been a rallying cry among U.S. policymakers, industry, and educators since at least the Sputnik Era, and especially since the turn of the 21st century. The argument is that in today's society, all citizens need to be literate in mathematics and science, with an increasing emphasis on engineering and technology as well (e.g., Carnegie Commission on Mathematics and Science Teaching, 2009). The argument continues: thus, K-12 schools need to prepare both the educated citizenry and prepare those students who wish to pursue careers in STEM fields with the necessary knowledge and skill to succeed in college and careers. However, making good on this goal requires a prepared educator workforce, which presents particularly thorny problems as science and mathematics have been fields that have historically and recently been characterized by teacher shortages, especially in high poverty schools (e.g., Cowan, Goldhaber, Hayes, & Theobald, 2016). Moreover, elementary teachers have been underprepared and under-supported in teaching these subjects and – with the exception of mathematics – elementary students have had limited opportunities to engage in science, engineering, and technology in sustained ways.

This is a complex problem, which entails policies and practices about what subject matters are taught (and when), what materials are available, how schools are held accountable for demonstrating student learning, how new teachers are prepared, how practicing teachers are supported in expanding their relevant professional knowledge, and how their leaders are prepared to both support and evaluate them. Millions of dollars and thousands of projects have been devoted to some aspect of this problem: curriculum development, professional development for teachers and leaders, master teacher programs, assessment development, and research to inform all of those efforts and others. The U.S. Department of Education has sponsored myriad programs with a primary STEM emphasis, among them Math-Science Partnerships, a STEM

Teacher Incentive Fund, a STEM Master Teacher Corps, a Minority Science and Engineering Improvement Program, and Hispanic Serving Institutions STEM and Articulation Programs. 100K in 10, a national network of diverse organizations dedicated to STEM education has promised to add 100,000 STEM teachers to America's classrooms by 2021 (https://100kin10.org/about). Cultural institutions have joined forces with K-12 schools to build programs for teachers and students alike. Professional associations – the National Science Teachers Association, the National Council for Teachers of Mathematics, the American Society for Engineering Education just to name a few – have partnered with other organizations to sponsor professional development, create networks, invest in the development of materials, and author standards to provide guidance, support and resources. Private and federal foundations have invested in similar efforts. Industry has convened round tables, invested in projects, provided human and material resources to schools as partners in these efforts.

Central to many of these efforts has been concentrated attention on the teacher workforce, including both initial teacher preparation and on-going professional development. Here too the problem is complex, including attention to recruiting teachers into development programs; retaining them once they are in the programs; offering powerful opportunities to learn about students, subject matter, and pedagogy; crafting high quality clinical experiences and which teachers practice and learn from new approaches to teaching and learning; and assessing teacher and program effectiveness. The enthusiasm for these projects is considerable.

But these ideas are not new, and we have an obligation as educators, scholars, leaders, and activists to consider what we have learned from previous research on these topics. The papers in this volume provide crucial background information on the existing research literature concerning

STEM teacher preparation, focusing on teacher induction, teacher attrition, and documenting the kinds of research on and measurement of STEM teacher preparation currently underway. Here we define STEM teacher preparation ambitiously, as including the prospective teachers, teacher educators, programs, and institutions involved in initial K-12 STEM teacher preparation, which include the K-12 schools and partners in teacher preparation like cultural institutions and industry. The authors of the papers in this volume were charged with both attending to the existing broader literature on these topics, while paying particular attention to the STEM-specific literature. Because the research base is uneven, they were also asked to consider the most pressing topics for future research that can readily inform on-going efforts to improve STEM teacher preparation.

Peter Youngs, Jihyun Kim, and Kristen Bieda summarize the extant research on teacher induction as it relates to the retention of STEM teachers. Research has consistently shown the teachers who persist through the early years of their careers become more effective over time (Papay & Kraft, 2015; National Academy of Education, 2009; Wilson, Floden, & Ferrini-Mundy, 2001). This is especially important in light of research that has shown that teachers are more likely to leave schools that serve low-income and/or ethically and culturally diverse students (e.g., Ingersoll & May, 2007; Lankford, Loeb, & Wyckoff, 2002). Thus, insights into how to retain new teachers long enough to help them become confident and good is essential. Early career programs, often referred to as induction, have been seen as an important lever in increasing early career teacher retention.

Youngs, Kim, and Bieda report that the research base is thin in terms of STEM-specific studies of teacher induction and its effects on retention, and uneven in terms of accumulated evidence for making strong claims about the effects of induction on retention, even when using research that comes from diverse methodological traditions. In general, the preponderance of evidence suggests that early career teachers benefit from working with mentors who are themselves full time teachers and who have extensive knowledge of the early career teachers' teaching assignment and school. It also appears that strong induction programs are more likely to demonstrate evidence of impact on teachers after the first two years of teaching. Noteworthy is the consistent positive effect that principal leadership can have on teacher retention.

Edward Fuller and Andrew Pendola consider the available literature on teacher preparation and teacher attrition (defined as teachers leaving the profession). It makes logical sense that better prepared teachers might experience more satisfaction and enjoyment in their work, which might lead to longer careers (e.g., Johnson, Kraft, & Papay, 2012). Many other factors have the potential to effect attrition: working conditions (e.g., school leadership, teacher professional community), salary, student characteristics (e.g., poverty, ethnicity), and teacher characteristics (e.g., race, gender) among them. Fuller and Pendola examine the literature for empirical evidence that sheds light on this relationship. Their analysis consists of two components: First they review literature on specific components of teacher preparation (e.g., course taking, field experiences) with teacher attrition. They then present the case of Texas and explore differences in teacher attrition across different types of teacher preparation program.

Fuller and Pendola conclude that because the evidentiary base is limited, it is difficult to draw conclusions about the relationship between teacher preparation components or practices and teacher attrition. However, there is evidence that methods courses and clinical experiences matter, and that this might be especially true in the case of STEM teachers and that graduates of alternative certification programs have lower odds of remaining in the teaching profession. The two major differences between graduates of alternative certification routes and university-based routes were the completion of field experiences prior to a clinical experience, and the completion of said clinical experience prior to becoming a teacher. The authors also explore other factors that contribute to the patterns that surfaced in their analysis.

Courtney Bell, Drew Gitomer, Corey Savage, and Anneliese Haines McKenna review the research on and measurement of STEM teacher preparation. Given the sprawling breadth of that topic, the authors chose to focus on three years of research, analyzing the research questions addressed, the methodologies and methods used, and the characteristics of the findings. The authors identified a range of methods used in teacher preparation research, including methodologies that draw on quasi-experimental, self-report (e.g., surveys or interviews), critical, ethnographic, and case study traditions. The authors also paid attention to evidence that the measures used in the research reviewed were accurate, reliable, and developed validity arguments over time.

The authors organize their analysis around seven purposes of such research which involve describing and understanding: (a) STEM prospective teacher learning and development; (b) improving teacher preparation programs; (c) contributing to teacher preparation program accountability; (d) relationships between STEM teacher preparation and other valued outcomes; (e) assessments and measurement of STEM teacher preparation; (f) framing or reframing issues of STEM teacher preparation; and (g) teacher educators and their practices. The majority of the studies that were identified concerned understanding STEM prospective teacher learning and development, and here many of the studies describe how particular curricula or teacher education experiences shape prospective teacher knowledge or skill. These studies did not, however, describe how those more focused experiences fit into broader programs or were tied to programmatic outcomes. In general, the research on STEM teacher preparation is best understood as emergent. In particular, current research only addresses a small proportion of issues that policymakers see as pressing, for example, the improvement of STEM teacher preparation programs. Noteworthy was the absence of research on technology and engineering teacher preparation, as well as the limited research on secondary teacher preparation (especially in science) and on the preparation of STEM teachers of traditionally underserved K-12 students.

Across the papers, the authors collectively paint a comprehensive portrait of needed future research. This includes research on preconditions that shape teacher preparation (e.g., admissions criteria, prospective teacher characteristics), program inputs (e.g., teacher educator characteristics, financial support for prospective teachers), teacher preparation program components, clinical experiences, teaching assignments post-graduation, and measures of teacher effectiveness and retention.

The authors also address significant cross cutting issues, including the importance of clearly identifying a robust set of shared outcomes for teacher preparation; having robust understanding of the chain of evidence necessary to inform research (e.g., collecting data on working conditions that shape teacher learning and effectiveness); the need for common definitions to guide data collection; the need for common measures; and the need for infrastructure that supports systematic sharing of methods and measures, as well as collaborative work.

The authors of these papers were thorough in summarizing both the strengths and weaknesses of the current research landscape. Their analyses echo the conclusions of other syntheses as well (e.g., National Academies of Sciences, Engineering, and Medicine, 2015). The chapters will no doubt be useful to the many scholars interested in the question of how best to prepare future STEM teachers. The analyses make it very clear what we still do not know, and that might leave some readers overwhelmed by how much is still left to know. However, the picture they provide illuminates both how we can build on previous work, the many exciting new opportunities that lay before us, and the pressing need to engage in collective work across our varied contexts and institutions.

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