PREPARING TEACHERS TO TEACH THE STEM DISCIPLINES IN AMERICA'S URBAN SCHOOLS

Cheryl J. Craig, Paige K. Evans
and Donna W. Stokes

ADVANCES IN RESEARCH
ON TEACHING

VOLUME 35

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ADVANCES IN RESEARCH ON TEACHING, VOLUME 35

PREPARING TEACHERS TO TEACH THE STEM DISCIPLINES IN AMERICA'S URBAN SCHOOLS

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FOREWORD

*teach*HOUSTON: Interdisciplinary, Experiential STEM Reform

F. Michael Connelly

What is one to make of a book with the title *Preparing Secondary STEM Teachers to Teach in America's Urban Schools* with what appears in the Abstract to have the subtitle *teach*HOUSTON? One part is rather grand and universal and the other more specific and local. I tend to think of subtitles, stated or implied, as reliable content descriptors. But my expectations faded as page after page and chapter after chapter unfolded. To be sure, *teach*HOUSTON names a concrete geographically limited program. The book assesses the status of teaching and learning in the STEM fields and describes a specific program to address the worrying picture that emerges. The program has direct consequences and possibilities for the Houston area. But the book as a whole and its account of this program addresses critical educational issues worldwide and demonstrates a kind of interdisciplinary action research rarely seen. Both the program and its practical demonstration of interdisciplinary action provide models useful in other jurisdictions and for other interdisciplinary sets. Unlike some, perhaps most, reform-oriented books, this one does not move inexorably step by step from problem to program to solution. Instead, different entry points and perspectives come in and out of focus in different chapters. Late in the book, in Final Words section, it is observed that the volume might be thought of as a mélange. Readers accustomed to step-by-step reform accounts might benefit by jumping from the opening overview chapters to Final Words section to better prepare them for the rich, original work found throughout. This book has insights and learnings for, and beyond, the STEM fields. Readers with different interests will find the book filled with suggestion and insight. Some of these possible readings follow.

The book describes a curriculum reform program in more or less standard educational change terms. The text begins with a thoughtful account of the educational learning problem, a description of the reform initiative to address the problem, and short-term demonstrations of evidence suggesting the problem is on its way to being solved. There is much to be learned about the status of STEM education and what might be done about it in the book's pages. As a Canadian reader, I would have welcomed a slightly expanded global picture but the language used to address the problem is readily applicable to a larger landscape. But what grips my attention and makes this book special in the literature of STEM

education and educational reform is that suffusing a more or less traditional educational reform structure are two initiatives that warrant two follow-up monographs: interdisciplinary collaboration and the link between reform experience and content. It is well known that educational reforms rarely outlast the input of reform support and, when they do, they fade and become invisible over time. I am struck by the thought that this book describes two qualities that have a chance to defy these reform "facts."

Joe Schwab (1960) who is featured throughout this book showed how scientists within disciplines adhere to particular forms of thought. Both he and the philosopher Kuhn (1970) pointed out that changing these formal ways of thinking constituted revolution within fields of inquiry. School education and the education of teachers are cross-disciplinary. The purpose is to educate persons, not advance inquiry in a discipline. It is reasonably well known that any curricular reform must be done in the context of all the other school subjects and disciplines. Add some science to the school day, subtract some geography. Thus, the STEM disciplines are inherently in conflict with one another in traditional educational reform. The reform brilliance of STEM is that it puts the disciplines on the same side. This, however, is where Schwab and Kuhn's insight into forms of disciplinary thinking comes into play. If it is revolutionary for a scientist within a discipline to confront new ways of thinking about his or her discipline, consider the problem of STEM with different disciplines at work, each with their own traditions of thought. Moreover, educational scholars rarely fit easily among those in the traditional disciplines, thereby immensely confounding the interdisciplinary mix. Add to the interdisciplinary mix the voice and action of school teachers and teacher educators whose ends in view are the education of persons in contrast to the advancement of a discipline. The resulting logical interdisciplinary stew is immensely complex. This frames the work of the complex *teach*HOUSTON STEM Project. There is a telling study by Seymour Fox (1972), one of Schwab's students, who sets up a curriculum deliberation study involving school-based educators and subject area academics. He found that the educators deferred to the academics such that this dimension of interdisciplinary planning was missing. But throughout this book remarkable things are described. Two academic university departments joined hands. Academic educators and school people joined in. Chapter by chapter, the reader is led through what I consider to be remarkable settings…mathematicians talking to scientists, professors learning from school teachers, teacher educators and curriculum specialists providing ideas, literature, and experiential research methods shaping the mix.

The picture that emerges is rich and borders on the edge of believability. I would love to see a follow-up manuscript that made the remarkable interdisciplinary qualities described herein the subject of inquiry. What does it take among the disciplines, and among educators and practitioners, to carry off a successful interdisciplinary collaboration? What difficulties were encountered? How were they conceptualized and solved? Is there any evidence that Schwab and Kuhn might have overdramatized forms of thought or, perhaps, that there are cultural

shifts toward more organic ways of thinking? Were there, one wonders, members of the *teach*HOUSTON team who were influenced by Chinese or Asian thought, which might have influenced the willingness to work across disciplinary lines of thought?

The second standout quality of this book is what I earlier called the link between reform experience and content. The massive international curriculum reforms of the last century, broadly falling under the heading of post Sputnik mobilization, led to an educational industry of reform and reform study. One of the mostly unchallenged insights from that industry is that telling school people what to do does not work. Yet it is clear that people with ideas about the practical value of their disciplines or their work look for ways to implement their ideas. People with good ideas about teaching and learning are perennially trapped in the logistic web of the wise and knowledgeable teaching the unwise and unknowledgeable. Returning to Schwab and Kuhn, and speaking rather broadly, the form of thought is one that the philosopher McKeon (1952) called logistic. Work out good ideas, and figure out how to train people to use them. The general failure of this form of thought about school change led to elaborate, often quite sensitive and responsive, ways of implementing ideas. Turned upside down, School-Based Reform took hold. *teach*HOUSTON stands in between and has it both ways. On the one hand, the best disciplinary ideas are at play. On the other hand, advanced notions of experience and their role in learning and in research method are at work. I know of no other major educational reform program that utilizes experiential method and theory in the context of an ongoing disciplines-based reform. The idea that the disciplines can bring insight and make a difference to schooling while, at the same time, learning from participating school practitioners is a rare quality in the study of educational reform. The fact that these processes are sufficiently recognized by *teach*HOUSTON participants at all levels to warrant specific research methodology built on the uncontrolled quality of experience is special. As with everything described in these pages, this quality requires intellectual strength and leadership along with collaborative interdisciplinary spirit and action. Again, I urge the authors/participants to consider a follow-up manuscript in their intended three-book series to unpack this "secret sauce" quality so vital to understanding *teach*HOUSTON and the interdisciplinary practices and research embedded in it.

My final thought is that in reflecting on my remarks about this book I have not been altogether transparent about my knowledge of the intellectual and practical dynamics at play. I was a student of Schwab and spent much time thinking about many of the issues discussed in this book. Moreover, I have followed Professor Craig's work for many years and am aware of her international reputation in experiential school-oriented thought. I do not know with certainty that her Asian studies influenced the holistic interdisciplinary thinking evident in this book (Craig et al., 2018). But the shape of the *teach*HOUSTON project and of the book built around it is consistent with the philosophical and practical trajectory of Craig's work. There must be something special about the Houston educational environment that brought so many diverse participants together in this atypical interdisciplinary, experiential, collaborative journey.

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OVERVIEW OF THE BOOK

Cheryl J. Craig, Paige K. Evans and Donna W. Stokes

ABSTRACT

This chapter outlines the contents of Preparing Secondary STEM Teachers to Teach in America's Urban Schools*. The volume begins with an overview of the teach*HOUSTON *STEM teacher education program in Chapter 2 and is followed by an account of the collaboration that took place between a Physics professor and a teach*HOUSTON *Physics teacher educator and its impact on STEM teacher preparation in Chapters 3-4. Chapters 5 and 6 include discussions about formal and informal learning opportunities and include a narrative of a student's experience on how the Noyce Internship Institute contributed to their STEM teacher learning. In Chapters 7–9, readers learn about the influence of parents, teachers, and professors on students' entry into and decision to work in the STEM and/or STEM education field, with an emphasis on those in STEM teacher education. Chapter 10 highlights the value of scholarship grants; Chapter 11 addresses the growth and development of teach*HOUSTON*, the impact of the scholarships awarded to many of its students and traces where its graduates currently are teaching in order to demonstrate that teach*HOUSTON *has fulfilled its mission. The final chapter of the book reflects on teach*HOUSTON *as a secondary urban teacher education program and summarizes significant points that have led to its success.*

Keywords: STEM teacher preparation; secondary teacher education; urban teacher education; physics teacher preparation; National Science Foundation; *teach*HOUSTON

This book shines a spotlight on *teach*HOUSTON, a secondary education program that grew from a mere seed of an idea to a fully fledged science, technology, engineering, and mathematics (STEM) teacher education program with a faculty and staff all on its own. This first chapter, Chapter 1, which is authored by Cheryl

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J. Craig, Paige K. Evans, and Donna W. Stokes, sketches the different coauthored contributions to this volume and elucidates how each chapter builds on the others to offer a prismatic view of *teach*HOUSTON. Throughout this volume, readers will learn of *teach*HOUSTON's challenges and successes as a leading STEM teacher education program, in producing secondary teachers for America's urban schools.

Chapter 2, *Overview of the teach*HOUSTON *Program*, highlights the need for highly qualified STEM teachers in Texas, most especially in Houston, the fourth largest city in the United States. The strength of this chapter, authored by Paige K. Evans, Cheryl J. Craig, Donna W. Stokes, and Jeffrey Morgan, is that all the requisite pieces – the backbone of the program, so to speak – are painstakingly accounted for, which makes *teach*HOUSTON's key features visible and accessible to those who want to know more about it. Readers are also introduced to inquiry-based learning, student-centered instruction, and culturally responsive pedagogy. Additionally, the improvements made to the program over time are recounted. Most importantly, the collaboration between representatives of the Physics Department and the *teach*HOUSTON faculty is made known. This is especially informative because *teach*HOUSTON is housed in the Mathematics Department and has its offices located in the College of Education, which means the program's roots are truly cross-disciplinary.

Chapter 2 naturally leads to Chapter 3, *Collaboration Between a Physics Professor and a Physics Teacher/Teacher Educator*, which is coauthored by Donna W. Stokes, Paige K. Evans, and Cheryl J. Craig. Reduced to the essence, this chapter chronicles how a "deep collaboration" took shape between a Physics professor and a Physics teacher educator. While issues having to do with the cross-listing of courses for Physics and Physics Education students most certainly arose, the collaborators spoke in one voice to ensure that the rigor of the Physics and Physics teacher education coursework was never challenged again. This reinforced how both professors needed to work hand-in-hand at the forefront, otherwise *teach*HOUSTON and *teach*HOUSTON's scholarship students would risk being perceived as inferior – as opposed to being different – from pure Physics majors.

Authored by Paige K. Evans, Donna W. Stokes, and Cheryl J. Craig, Chapter 4, *A Narrative Inquiry Into Teaching Physics as Inquiry: One Teacher's Journey*, shares the lived experiences of undergraduate student whose pseudonym is Jason. The authors follow Jason through *teach*HOUSTON program and his subsequent school placements. The chapter fittingly ends with Jason becoming a cooperating teacher and mentor for other *teach*HOUSTON preservice teacher candidates. Here, the reader will see how the leadership of *teach*HOUSTON sustains the program through robust alumni participation, which also will be touched on in some of the chapters that follow. Also included in this chapter is the Physics as Inquiry course that Paige Evans developed and enacted. A critical underpinning of *teach*HOUSTON's curriculum, the new Physics course engages secondary preservice teachers in interactive, inquiry-based teaching pedagogies for Physics. The chapter not only shows how the course was designed to meet the needs of students of color but also how it fulfills content requirements in terms of credit

hours for different STEM certification purposes. Physics majors and minors can obtain 7-12 Math/Physics certification, which allows teachers to teach both math and science; 7–12 Physical Science certification, which allows them to teach both Physics and Chemistry; and 7-12 Composite Science certification, which allows teachers to teach any Science.

In Chapter 5, readers learn about related activities of *teach*HOUSTON. Written by Donna W. Stokes and Paige K. Evans, the chapter, *Enhancing Preservice Teacher Preparation Through Formal and Informal Learning Experiences*, tells how *teach*HOUSTON's preservice teachers are afforded experiences to enhance their content development and teaching skills such as workshops, discipline specific courses, conferences, professional development opportunities, and paid internships. For example, interns become inducted as counselors and teaching assistants for a summer STEM camp for underserved middle school students for training in both formal and informal settings. Readers will also learn how topics varying from Bullying to the Growth Mindset are given front-stage attention through interactive experiences. Engagement in formal and informal activities, taught by both Physics and *teach*HOUSTON faculty and staff, allows students to be exposed to science as inquiry and project-based learning.

Chapter 6, *Examining the Impact of Informal Experiences on Preservice Teachers' Self-efficacy*, is one of several multiauthored chapters that follow. The chapter's first author is Paige K. Evans and her coauthors are Leah McAlister-Shields, Mariam Manuel, Donna W. Stokes, Cheryl J. Craig, and Ha Nguyen. The work highlights the impact of informal learning experiences for students pursuing STEM teaching careers at a time when considerable shortages of appropriately certified teachers exist in America's urban schools.

Chapters 7, 8, and 9 are a trilogy. Each deals with a particular influence on STEM students' decision to enter into and stay in STEM fields, including STEM teacher education. They illustrate how students' pursuing the STEM disciplines are shaped not only by their own experiences but also by those around them. Chapter 7 focuses on the influence of parents, Chapter 8 tells about the influence of teachers, and Chapter 9 is all about the influence of professors. These chapters also bring to the forefront the great diversity Houston has to offer. Although the book thus far has focused mainly on *teach*HOUSTON and teacher education, these chapters include who/why students pursue STEM teaching as well as other STEM fields such as Computer Science. This is important because computer science and technology are the next STEM content areas to be interwoven into the *teach*HOUSTON program through a recently awarded National Science Foundation (NSF) grant in 2020 to Principal Investigator, Paige Evans.

Chapter 7, *The Influence of Parents on Undergraduate and Graduate Students' Entering the STEM Disciplines and STEM Careers*, is used with the permission of the *European Journal of Education*. Authored by Cheryl J. Craig, Rakesh Verma (cybertechnology, cybersecurity), Donna W. Stokes, Paige K. Evans, and Bobby Abrol, it tells of the circumstantial and planned curriculum making that *teach*HOUSTON and computer science students experienced with their parents during their preschool and public school years. In this chapter, the home STEM

experiences of three students, Katrina Roderick, Ryan Archer, and Sam Bernard (pseudonyms), are spotlighted.

Chapter 8, *A Tribute to "Unsung Teachers": Teachers' Influences on Students Enrolling in STEM Programs With the Intent of Entering STEM Careers* whose authors are Cheryl J. Craig, Paige K. Evans, Rakesh Verma, Donna W. Stokes, and Jing Li, published and used with the permission of the *European Journal of Teacher Education*, centers around teachers who left lasting imprints on the *teach*HOUSTON and computer science scholarship students. This chapter highlights three higher education students from very diverse backgrounds, pseudonyms being Joyce Harding (white female high poverty), Omid Kassem (immigrant to the United States), and Leon Mitchell (member of a historically underserved Black community second in size to Harlem).

The third paper of the trilogy is Chapter 9 of this volume, *The Influence of Professors on Students Enrolled in the STEM Programs with the Intent of Embarking on STEM Careers*. Authored by Jing Li, Paige K. Evans, Cheryl J. Craig, Donna W. Stokes, Rakesh Verma, and Gang Zhu, this chapter spotlights what the STEM students organically shared about learning from particular professors. The positive stories they told are ones that naturally spilled out because the STEM students needed to tell them, not because they were coaxed by the authors to reveal these storied nuggets. This makes it entirely fitting that this chapter is first-authored by Jing Li who herself was a student (albeit a doctoral one) at the time, as was Gang Zhu, another author of this multiauthored work.

Next in the lineup of chapters is *The Value of STEM Scholarship Grants to Undergraduate and Graduate Students Intending to Study the STEM Disciplines and Pursue STEM Careers*, which is Chapter 10. Jing Li is the first author with her coauthors being Cheryl J. Craig, Tenesha Gale, Michele Norton, Gang Zhu, Paige K. Evans, Donna W. Stokes, and Rakesh Verma. Seven stories of the impact that the NSF-funded scholarships had on the *teach*HOUSTON and computer science students are presented. The pseudonyms for the students are Omid Kassen, Anton Ivanov, Joyce Harding, Duong Pham, Sanjay Ritzvi, Kadeem Bello, and Tonya Goodson. This array of false names we chose also signals Houston's wide diversity as well as the diversity evident in *teach*-HOUSTON and in the computer science programs at the University of Houston. Each of the seven students identified a different way that the STEM scholarship grants helped them. The experiences shared in this chapter are truly eye-opening and profound. Every STEM educator should read this chapter. Also, every philanthropist should think and make funding decisions, keeping individual student narratives such as the ones featured in this work in mind.

Our second to last chapter, Chapter 11, has to do with *Where Are the teach*HOUSTON *Preservice Teacher Candidates Now? Are They Still in the Urban Teacher Force*?, which is coauthored by Paige K. Evans, Mariam Manuel, Ha Nguyen, Donna W. Stokes, Cheryl J. Craig, Xiao Han, and Jeffrey Morgan (*teach*HOUSTON's codirector). This chapter explores a different kind of impact question: the quantitative query concerning how many students were impacted and where *teach*HOUSTON alumni are currently working. The chapter asks: Did *teach*HOUSTON produce more physics teachers than the Houston region

previously had in the 10 years before the program began? Did those benefiting from *teach*HOUSTON mostly stay in the region and/or urban schools? Do those teachers continue to be reflective of Greater Houston's shifting diversity?

From Chapter 11, we shift seamlessly to the Final Word, which is Chapter 12. In Chapter 12, authors Cheryl J. Craig, Paige K. Evans, and Donna W. Stokes reflect backward on *teach*HOUSTON and address key points that led to its creation and its sustenance. The authors additionally discuss their personal development and share how their job responsibilities have changed in response to *teach*HOUSTON's growth and change.

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OVERVIEW OF THE *teach*HOUSTON PROGRAM*

Paige K. Evans, Cheryl J. Craig, Donna W. Stokes and Jeffrey Morgan

ABSTRACT

*teach*HOUSTON *is a university-based secondary STEM teacher preparation program that addresses the critical need for highly qualified STEM teachers in Texas and across the country. STEM teachers are prepared through early and ongoing field-based teaching experiences and rigorous research-based instruction that integrates content and pedagogy provided by faculty members who have extensive teaching experience in public schools.* teach*HOUSTON serves the fourth largest city in the United States, along with its satellite communities and has many noteworthy features which are mapped in this chapter. Particular attention is paid to inquiry-based learning, student-centered instruction, and culturally responsive pedagogy as well as the improvements in the program based on the collaboration between physics and* teach*HOUSTON faculty.*

Keywords: Teacher education model; urban teacher education; science as inquiry; secondary STEM teacher preparation; culturally responsive pedagogy; *teach*HOUSTON

Providing a solid foundation in STEM is important in the education of future physicists, engineers, computer scientists, chemists, and medical doctors who can

*An earlier version of this updated chapter is: Craig, C., Evans, P., Stokes, D. & Bott, S. (2017). Attracting, preparing and retaining teachers in high need areas: A science as inquiry model of teacher education. In M. Peters, B. Cowie & I. Mentor (Eds.), *A companion to research in teacher education*. New York, NY: Springer Publishing.

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contribute to scientific discoveries. Indeed, as the economy of the United States shifts, having a strong STEM trained workforce is essential for the country to remain globally competitive. Over the next decade, our nation will need approximately one million new STEM professionals which can be met by increasing the number of students trained in STEM fields (Xue & Larson, 2015). Nevertheless, this will require STEM teachers who have the necessary content area knowledge and pedagogy to foster success and excitement in STEM at a time when there is a severe shortage of STEM teachers. According to the US Department of Education (2016), a persistent shortage of STEM teachers exists in the United States and the overall US production of STEM teachers fell 20% between 2009 and 2014. It is problematic that the United States is losing jobs to the global workforce because local students have been inadequately prepared for careers that require strong mathematics and science skills. Additionally, our public school system has not shown progress, especially in mathematics and science education (Chen, 2009).

Addressing content area knowledge and problems of pedagogy is particularly daunting in Texas, which has approximately five million students. It is difficult to believe that greater than 30% of middle school mathematics and science teachers are teaching out of their field and 13.3% and 28.7% of high school teachers are teaching out of their fields in mathematics and science, respectively (Texas Education Agency, 2017). This means these teachers instructed STEM classes without receiving adequate training and preparation. This is even more evident in the secondary schools in underserved areas of Houston which tend to employ the least qualified teachers and have the greatest shortages. This contributes to the achievement gap that Darling-Hammond (2011) termed an "opportunity gap." Nelson, Palonsky, and McCarthy (2009) suggest that underserved students are twice as likely to have uncertified teachers in comparison to their white peers. Figs. 1 and 2 illustrate the percentages of high school full-time equivalent school science and mathematics teachers in Texas who are assigned positions out of field in relation to the percentages of youths living in poverty.

Attracting highly qualified teachers to teach in high-poverty schools is problematic due to lack of funding, support, and resources. Also, good teachers according to American law are prepared in the content areas they are teaching. It has been shown that low-income students have only a 10% chance of having a good teacher in their K-12 education (Chenowith, 2010). Students from middle class homes have a support network which enables them to persist if taught by one or two weak teachers whereas high poverty students are less likely to recover. According to Villegas and Clewell (1998), these risks may be lessened by increasing the number of minority teachers as they may provide desperately needed role models for minority youth as they develop their own racial identities within an educational context. Students from low socioeconomic backgrounds may also benefit from the presence of minority teachers as they may foster successful academic outcomes in part to the contributions of minority teachers serving as role models for students of color (Dee, 2005; Pitts, 2007).

The urgent problem of preparing a sufficient number of qualified STEM teachers is matched only by the equally important need to retain STEM teachers