# STEM CONTENT AND PEDAGOGY ARE NOT INTEGRATED

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## 01 CONTEXT AND TRENDS

**Improvements in teacher preparation** to better focus on the unique characteristics of 21st-century teaching and learning have been frequently discussed over the past two decades, and numerous qualities that contribute to successful preservice programs have been noted (Darling-Hammond, 2010). One of these qualities addresses the importance of integrating strong content preparation with subject-specific pedagogy (Darling-Hammond, 2006). This is particularly important in science, technology, engineering, and mathematics (STEM) teacher preparation (De Miranda, 2008; Niess, 2005; Windschitl, 2009).

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Several studies have shown that teacher content knowledge can positively contribute to student achievement in science and mathematics, especially at the secondary level (Harris & Sass, 2011; Monk, 1994; Wayne & Youngs, 2003). Similarly, increased exposure to inquiry-based STEM pedagogical practices during teacher preparation (specifically, instruction in pedagogical content knowledge, which includes methods and best practices specific to a particular subject area) has been linked to increased student achievement (Monk, 1994). Yet teacher preparation programs rarely connect content instruction with pedagogical methods. Rather, pedagogy and content are often taught in isolation in STEM teacher preparation programs, leaving much to be desired by way of instructing future teachers with how to appropriately and successfully engage students with STEM content toward mastery learning (Ball, Thames, & Phelps, 2008).

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## DISCUSSION

**Content preparation,** in conjunction with content-specific pedagogy instruction, has been linked to both increased teacher confidence and increased student achievement in many STEM areas (Bleicher, 2006; Darling-Hammond, 2000; Smith, 1999). However, content-specific departments and education departments rarely collaborate on teacher training practices (Feiman-Nemser, 2001). This is particularly true in areas of STEM teacher preparation. For example, as Otero, Finklestein, McCray, and Pollock (2006) explain, "[T]eacher preparation is not solely the responsibility of schools of education. Content knowledge is one of the main factors positively correlated with teacher quality (U.S. Department of Education, 2002), yet the science faculty members directly responsible for teaching undergraduate science are rarely involved in teacher recruitment and preparation" (p. 445).

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At the same time, teacher candidates often lack adequate preparation and exposure to active learning practices—classroom instruction that moves beyond traditional lecture and engages students in activities, discussion, and processes that promote higher-order thinking and collaboration—in both their STEM content courses and their pedagogy-focused courses within their teacher preparation programs (Freeman et al., 2014; Niemi, 2002). Despite growing recommendations advocating for greater faculty engagement with and use of more active learning and inquiry-based approaches to enhance STEM learning, professors and instructors in teacher preparation programs typically do not use these instructional strategies (Anderson et al., 2011). Even in cases where pedagogical methods coursework is grounded in progressive, inquiry-based STEM approaches, preservice teachers' STEM content preparation is still largely delivered through traditional "stand and deliver" instruction (Bajak, 2014; Freeman et al., 2014). This inconsistency in how one is taught and how one is being taught to teach can impact teacher candidates' overall learning success in the content area and send mixed pedagogical messages about what constitutes good teaching practice.

Indeed, unless a teacher candidate is majoring in a STEM-related field, STEM content preparation in preservice programs tends to be weak. This is particularly true for elementary teacher candidates (Hibpshman, 2007; Jeffery, McCollough, & Moore, 2015): Many elementary teachers express an uneasiness with teaching STEM in their classrooms due to factors such as inadequate content knowledge, low self-confidence in the field, and lack of understanding and proficiency with effective STEM teaching methods (Bursal & Paznokas, 2006; Murphy & Mancini-Samuelson, 2012).

03
## BRIGHT SPOTS

**In response to this apparent disconnect** in STEM teacher candidate preparation and what is known about best practices for teaching and learning in these disciplines, some universities have answered the call. These institutions have developed innovative teacher preparation programs that focus on producing teacher candidates with both deep content understanding and effective STEM pedagogical knowledge (American Association of Colleges for Teacher Education, 2007; Ferber, 2011).

One example, the UTeach Program developed by the University of Texas at Austin in 1997, is a replicable, sustainable teacher preparation program solely focused on the development of secondary STEM teachers (UTeach Institute, 2016). Lauded by the U.S. Department of Education (2014) as a program "demonstrating vital leadership in improving teacher preparation" (para. 7), the UTeach program "prepares teachers with deep content knowledge and proficiency with pedagogical strategies that promote student mastery of [STEM] principles and concepts" (UTeach, 2015, p. 1). As it looks to celebrate its 20th year in 2017, the UTeach network has grown to include 44 replication sites at universities across the nation, totaling a combined annual enrollment of more than 6,200 STEM teacher candidates and 2,600 graduates (UTeach Institute, 2016).

Additionally, recognizing a need for increased content and STEM pedagogical acquisition for elementary teachers, the elementary education program at North Carolina State University (NCSU) "creates teacher-leaders with deep content knowledge in all elementary disciplines, with a special emphasis on science, technology, engineering, and mathematics for a strong STEM-focused instruction" (NCSU, 2016). In addition to rigorous STEM content courses, teacher candidates take multiple science, mathematics, and engineering-specific pedagogy and methods courses. The Accomplished Teachers of Mathematics and Science (ATOMS) research project, initiated in 2011, tracks preservice teachers' progress through the program and into their own classrooms. It has found positive outcomes associated with "strong domain knowledge, pedagogical content knowledge, and positive attitudes towards teaching science and mathematics" (McIntyre et al., 2013).

Each of these programs provides robust teacher preparation through STEM-specific programs designed around the integration of content and pedagogy, collaboration between STEM content and teacher preparation faculty, and early and frequent classroom experiences with quality mentor teachers.

## 04 CONCLUSION

**Given the shortage of highly qualified STEM teachers in the U.S.,** coupled with areas of growing demand for a skilled STEM workforce (U.S. Department of Education, 2015; Xue & Larson, 2015), teacher preparation must continue to rise to the challenge of growing and developing strong, passionate future STEM teachers. To do so, programs should ensure their curriculum includes instructional continuity between content and teacher preparation faculty, rigorous content preparation, and STEM-specific pedagogical instruction that can be used in field-based experiences. Doing so will allow teacher candidates to practice and grow in confidence in their STEM instructional know-how.

## ABOUT THE GRAND CHALLENGES WHITE PAPERS

In 2017, 100Kin10 released an unprecedented representation of the big, systemic challenges to preparing and supporting STEM teachers following over two years of extensive research alongside more than 1,500 STEM teachers and hundreds of other education experts. As a part of this work, 100Kin10 commissioned a series of short white papers from well-versed thinkers and practice-oriented researchers to synthesize the most relevant research around the specific challenge areas. Together, they compose a thoughtful and well-rounded examination of the systemic challenges currently facing STEM teaching.

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