

# An Innovative STEM Education Framework for a Changing Educational Landscape

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## Abstract

This article describes features of NAU Teach, a secondary mathematics teacher preparation program that is modeled on the U Teach program at the University of Texas-Austin. NAU Teach is a research-based STEM program that develops the next generation of mathematics and science teachers by engaging them in rigorous content and methodology coursework specifically developed to provide a broad, cross-curricular framework of innovative instruction. NAU Teach has been specifically designed to serve the needs of preservice mathematics and science teachers as they embark on teaching a new generation of students in an ever changing world. The NAU Teach program focuses on the development of inquiry-based instructional methods, reflective practice, and peer collaboration through a carefully sequenced series of courses that consistently promote early and frequent field work and a learner-centered focus of teaching and learning. Though the NAU Teach program is a blended mathematics and science teacher preparation program, this article will focus on the preparation of secondary mathematics teachers by describing the cross-curricular (mathematics & science) methodological sequence of courses, along with the mathematics-specific pedagogical courses, that preservice mathematics teacher candidates take as part of this program. Connections between the NAU Teach program and guidelines for the content and pedagogical preparation of teachers will be made with specific attention paid to the development of reflective, innovative, flexible, and reform-oriented mathematics teachers.

**Keywords:** mathematics education, STEM education, preservice teachers, teacher education programs

## 1. Introduction

In 2007, Northern Arizona University (NAU) was selected as part of a large-scale initiative to replicate the highly successful U Teach program (U Teach Institute, 2015) out of the University of Texas-Austin. The U Teach program is a secondary STEM teacher preparation program that encourages partnerships between colleges of science and education at replication sites in order to strengthen the production of high-quality science and mathematics teachers. President Obama recognized the U Teach replication program as a model for preparing a new generation of highly qualified mathematics and science teachers at a special event at the White House on January 6, 2010 (UTNews, 2010). The U Teach model has been shown to dramatically increase student recruitment into mathematics and science teaching, while increasing the retention rate of graduates to 84% after four years, compared to 60% nationally (U Teach Institute, 2015). Graduates from U Teach and U Teach replication sites are “highly sought after by schools and districts for their strong content knowledge and experience with inquiry- and project-based instructional methods” (U Teach Institute, 2015). Key elements of the U Teach program and U Teach replication programs are development of deep content knowledge in the chosen STEM discipline, proficiency in core scientific and mathematical practices, and the ability to “apply appropriate STEM pedagogical strategies to promote student mastery of core concepts, principles, and practices in mathematics and science,” (U Teach Institute, 2015).

As part of its adoption of the U Teach model, NAU embraced the core tenets of the U Teach program while also maintaining its focus on strong content-based pedagogy for its mathematics preservice teacher candidates. This article summarizes foundational elements of NAU Teach, NAU’s adapted version of U Teach, and connects programmatic emphases on inquiry-based instructional methods, reflective practice, and peer collaboration with preparation of teachers ready to serve the ever changing needs of a new generation of students.

### 1.1 The NAU Teach Program

NAU Teach is a research-based STEM teacher preparation program that develops the next generation of mathematics and science teachers by engaging them in rigorous content and methodological coursework specifically designed to provide a broad, cross-curricular framework of innovative instruction. Undergraduate pre-service teacher candidates in the NAU Teach program complete the equivalent of a full content major, along with a full sequence of content-based methodology courses, as part of their undergraduate studies. Best practices for STEM teaching and learning are incorporated into and modeled as part of each methodological course throughout the program, as outlined by the *Mathematics Education of Teachers 2* (CBMS, 2012) recommendations and the *Standards for Preparing Teachers of Mathematics* (AMTE, 2017). Teacher candidates actively experience and reflect upon research-based best practice in a carefully sequenced program of study and are expected to utilize these practices in the context of their own teaching during practicum field experiences and student teaching.

NAU Teach pedagogical courses have been designed to incorporate early and frequent field-based teaching experiences, collaborative inquiry, and self-reflection as driving forces that promote candidates' growth as STEM educators. Teacher candidates begin a carefully planned sequence of intensive teaching opportunities from the first two recruitment courses in the program and then continue with increasingly intensive field experiences throughout the program. Classroom-based teaching experiences, or "teaches," are enacted by all candidates within the first course of their first semester in the program. With the exception of one learning theory course and one research methods course, each subsequent class contains a field-based element where candidates plan and implement standards-based mathematics lessons in elementary, middle, and high school classrooms. Prior to student teaching, teacher candidates log at least 54 practicum hours in K-12 classrooms. Partnerships with regional school districts and teachers within those districts enable NAU Teach to create diverse, supportive classroom environments for field experiences in the K-12 school settings. Mentor teachers work with the teacher candidates in the schools and provide valuable feedback and coaching to teacher candidates throughout the program by reviewing lesson plans, providing oral and written feedback, and supporting valuable field experiences. Upon completion of each instructional experience, teacher candidates reflect on their lesson and its impact on the student learning experience. Focused reflections promote connections and insights related to practice, discourse, decision making, and student engagement and learning.

As part of the planning process, candidates often work in teams of two to three to investigate the content area in which they will be teaching, to gather instructional resources, to obtain feedback from course instructors on their ideas and activities, and to collaboratively plan inquiry-based lessons. Through scaffolded coursework and structured field-based practicum experiences, candidates engage in progressively challenging teaching events that promote more independence (in terms of planning and instruction) and more rigorous content development in the context of authentic classroom teaching experiences (see Table 1 for complete course descriptions). At the start of the program, teacher candidates engage in two exploratory one-credit courses (*Step One, Inquiry Approaches to Teaching* and *Step Two, Inquiry-Based Lesson Design*) where they work in small teams to plan and implement pre-designed lessons in order to "try out teaching" in upper elementary and middle school classrooms. Either concurrently or shortly after taking these early *Step* courses, teacher candidates also take a three-credit learning theory course (*Knowing & Learning Mathematics*) to better understand how students learn and how instructional design and curricular decisions align with various learning theories. Explicit connections between early field experiences and learning theories as part of the *Knowing and Learning* class are intended to reinforce the instructional decision making and classroom structures that candidates are encouraged to integrate into their planning and implementation of lessons during their early field-based experiences.

Following this early sequence of courses, teacher candidates engage in advanced pedagogical studies related to technology, equity, and discourse as part of *Classroom Interactions*. This course further promotes active teaching experiences through its field-based practicum sequence where students work in teams to develop and implement original two-day instructional lesson sequences that focus on specific content standards in middle school classrooms. *Research Methods* does not involve a fieldwork component, but provides candidates with multiple, iteratively focused opportunities to connect school mathematics to real-world phenomena. By first experiencing investigative tasks themselves as learners and then planning these kinds of inquiries for students, candidates come to deeply understand the practices involved with implementing lessons that utilize technology and modeling to support learning. *Project-Based Instruction*, the program capstone and final field-based class prior to student teaching, further explores general pedagogical skills and knowledge related to assessment and curriculum while having teacher candidates collaboratively plan and implement a one- to two-week standards-based instructional unit centered around a driving question and focused on the development of a unit-based project or product.

**Table 1.** NAU Teach Course Overview and Descriptions

Course/Credits	General course and field-based experience descriptions
<i>Step One - Inquiry Approaches to Teaching</i> (1 credit)	<i>Step One</i> is a lab course that allows teacher candidates to explore the teaching profession through site-based observations, in-class inquiry into teaching and learning, and the collaborative development and implementation of two to three team-taught single-day mathematics or science lessons in elementary classrooms. Teacher candidates who successfully complete this course receive a \$100 stipend to offset the cost of enrollment and encourage STEM majors who would otherwise not consider teaching as a career to try teaching as a possible profession. In the first “teach” teacher candidates work in cross-content teams to implement a pre-planned and prepared lesson. During the second and third “teaches,” teacher candidates are provided with instructional materials but must write the lessons that address indicated content and instructional intent. Following each “teach,” whole class discussions promote reflection on the effectiveness of the lessons and each teacher candidate is responsible for a small written reflection on their own instruction. As part of this class, teacher candidates engage in 6 hours of field-based practicum experiences consisting of 3 hours of observation and 3 hours of teaching.
<i>Step Two - Inquiry-Based Lesson Design</i> (1 credit)	<i>Step Two</i> is similar to <i>Step One</i> in that it is a lab-based course where teacher candidates explore the teaching profession through observations and the development and implementation of three team-taught single-day lessons. So that content-based planning and instruction can be more heavily emphasized, students work in content-based pairs to plan and teach. Teacher candidates collaborate directly with their assigned mentor teacher to discuss content standards, instructional ideas, and plans for their three-lesson progression, with one lesson taught during each of three consecutive weeks. Lessons are implemented in a middle school classroom so that teacher candidates can connect their planning and instruction to learning theory, questioning, management, and content development for higher grades. The final project includes an in-depth lesson analysis that focuses on the impact of inquiry-based teaching on the student learning experience. As part of this class, teacher candidates engage in 5 hours of field-based practicum experiences consisting of 2 hours of observation and 3 hours of teaching.
Knowing & Learning Mathematics (3 credits)	Though it has recently switched to a content-specific format for mathematics and science candidates, <i>Knowing and Learning Mathematics</i> has traditionally been a cross-disciplinary perspective course that examines what it means to learn and know mathematics and science. More recent content-based offerings focus on how various theories and aspects of knowing and learning mathematics inform instructional decisions and student learning. This course on educational learning theory emphasizes social constructivist ideologies within the context of cognitive science and how students learn. Ten hours of practicum field work explores the one-on-one nature of teaching and learning through content-based tutoring at local middle and high schools.
Classroom Interactions (3 credits)	<i>Classroom Interactions</i> explores the role of content, pedagogy, curriculum, and technology as they promote learning and impact equity. Teacher candidates, working in content-based teams, develop and implement one one-day lesson and one two-day lesson that highlight attention to equity, curriculum, technology, and assessment. Teacher candidates plan and write lesson plans that mirror the content being currently taught in their placement classrooms. Upon completion of each teaching experience, teacher candidates complete an analysis that focuses on what was successful in their lesson, what improvements they need to make, and how their lesson and instruction impacted student learning. Included in the reflection is a detailed analysis of student work. As part of this class, teacher candidates engage in 15 hours of field-based practicum experiences consisting of 12 hours of observation and 3 hours of teaching.

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Research Methods (3 credits)	UTeach, NAU Teach, and state and national content standards posit that mathematics and science education should more authentically align with actual mathematics and science practice. This applied course engages candidates in designing, conducting, and presenting four inquiries into real-world phenomena using statistical and mathematical analytical tools. <i>Research Methods</i> integrates mathematical practices and scientific inquiry processes to allow teacher candidates to collaboratively develop, implement, analyze, and reflect on research-based projects that use 21 <sup>st</sup> century skills to bring learning alive and actively engage learners in constructing and applying content understandings.
Project-Based Instruction (3 credits)	As part of <i>Project-Based Instruction</i> teacher candidates collaborate to design and implement a multi-day unit focused on exploring authentic, important, and meaningful questions of real concern to students. The scope and sequence of the instructional unit are determined by the entire class through an iterative, collaborative process, and individual lessons are planned and implemented by teacher candidates in instructional pairs. An emphasis on research-based effective assessment practices to inform instruction guides planning and lesson implementation. Collaboration and communication play an integral role in providing continuity from day-to-day in the midst of instruction. Reflection on individual lessons and the unit as a whole help teacher candidates connect their practice to research-based best practice, as discussed in various classes and developed throughout the entire NAU Teach program, and to better inform their own growth and understanding of the many factors that influence effective instruction. As part of this class, teacher candidates engage in 20 hours of field-based practicum experiences consisting of 15 hours of observation and 5 hours of teaching.
Apprentice Teaching & Seminar (12 credits and 1 credit, respectively)	<i>Apprentice Teaching</i> and the associated <i>Seminar</i> serve as the capstone experience for teacher candidates in the NAU Teach program. Candidates engage in a semester-long placement as a student teacher in a middle or secondary mathematics classroom. The seminar is used to support students throughout their student teaching experience while providing the avenue to engage in reflective practice, continue their growth in understanding their own impact on students based on their practice, and examine critical issues in education that arise in the context of student teaching. Teacher candidates begin observing their mentor teacher at the start of the semester, slowly take over instructional duties for some classes as the semester progresses, and then assume full instructional responsibility for all classes for a 2-3 week period toward the end of the semester. During the semester, teacher candidates prepare a Candidate Work Sample (CWS) that demonstrates each candidate's use and implementation of inquiry-based lessons, different learning strategies, and formative and summative assessment during a 2 week period of instruction in one class. Analysis of student work, modification of instruction based assessment findings, integration of university faculty and mentor teacher feedback, and reflection on teaching and learning are emphasized throughout the CWS.

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As shown in Table 1, students enrolled in the NAU Teach program complete a series of mixed-methods mathematics and science pedagogical courses that structure learning experiences and classroom teaching events to promote reflection, innovation, flexibility, and form-oriented instruction.

The cumulative effect of iterative experiences in learning, teaching, and reflecting make NAU Teach graduates especially prepared to be innovate, flexible, and responsive to various educational settings and situations. The ability to experience live teaching within the first few weeks of starting this program, to continue those field based experiences throughout every course in the program, and to culminate in the development of a project-based unit as part of the program capstone, enable NAU Teach teacher candidates to engage as teachers in the art of teaching throughout every facet of the program. These regular classroom-based experiences promote development of crucial skills and

dispositions over the course of the program and embed reflective practice into candidates' development as new teachers.

In addition to taking the blended mathematics and science methodology classes described above, teacher candidates pursuing degrees in mathematics education also take three additional mathematics-specific methodology course to further develop pedagogical content knowledge (*Functions, Applications, and Explorations* and *Methods of Teaching Secondary Mathematics I and II*). These courses provide teacher candidates with valuable content-specific learning experiences that rigorously examine post-primary mathematics content in depth and model instructional approaches that promote student-centered problem solving, reasoning, exploration, and collaboration (see Table 2 for complete course descriptions). These classes are typically taken while candidates are concurrently enrolled in *Knowing and Learning Mathematics*, *Classroom Interactions*, and *Project-Based Instruction*, respectively. It has been the experience of the instructors that mathematics students are often better prepared than their science counterparts, who have traditionally lacked content-specific methodology coursework, to write individual lessons as part of their *Classroom Interactions* and *Project-Based Instruction* practicum teaching experiences because of the focused content-based pedagogical lessons and direct learning experiences in which candidates engage as part of these mathematics methods courses. Experiencing and debriefing mathematics-specific lessons and activities, engaging in mathematics-specific pedagogical discussions, and reflecting on content and practice standards in the context of mathematics instruction allows mathematics teacher candidates to integrate deep conceptual knowledge and effective instructional decision making into their planning and instruction throughout the program.

**Table 2.** Mathematics Education Course Overviews and Descriptions

Course/Credits	General course description
Functions, Applications, and Explorations (3 credits)	The first of three mathematics-specific methodology courses, <i>Functions, Applications, and Explorations</i> provides mathematics teacher candidates with an in-depth study of topics in secondary mathematics related to functions and algebra. The focus of this class includes algebraic meanings and representations, mathematical modeling of various families of functions, and discrete versus continuous models. Rigorous content connections related to applications and deep understanding of functions and multiple representations of algebraic concepts are made.
Methods of Teaching Secondary Mathematics I (3 credits)	The second mathematics methodology course examines content, pedagogical, and technological trends and issues related to the teaching of numbers/operations and geometry in the 7-12 mathematics classroom. Students participate as learners and as developing teachers in activities and assignments that aim to increase pedagogical content knowledge of the specified content areas. Students develop an understanding of the connections between the conceptual and procedural approaches to these mathematical topics and corresponding curricular and pedagogical decisions that support effective instruction related to these areas.
Methods of Teaching Secondary Mathematics II (3 credits)	The final mathematics-specific methodology course, <i>Mathematics Methods II</i> examines content, pedagogical, and technological trends and issues related to the teaching of probability, statistics, precalculus, and calculus. As with <i>Methods I</i> , this class provides mathematics preservice candidates with the opportunity to focus on the specific content and pedagogical context of teaching and learning probability, statistics, precalculus, and calculus.

As shown in Table 2, mathematics teacher candidates enrolled in the NAU Teach program complete a series of mathematics-specific pedagogical coursework that promotes in depth conceptual understanding and rigorous application of post-primary content and methodology.

The NAU Teach program concludes with a semester-long student teaching placement and instructional seminar as part of the *Apprentice Teaching* class. During student teaching, teacher candidates complete a Candidate Work Sample (or portfolio of their instructional experiences), engage in a teaching seminar with other student teachers that focuses on continued growth and support as novice teachers, and gradually take over instructional duties from their mentor teacher, eventually teaching the full course load for a period of two to three weeks.

## 2. Conceptual Framework for NAU Teach

NAU Teach was developed in such a way that the guiding principles of multiple research-based theoretical and practical frameworks could be enacted. The frameworks that guide the development and continued growth of NAU Teach include an emphasis on (1) content-based preparation, (2) an understanding that knowledge of content must be supported with knowledge of mathematics teaching and knowledge of students, and (3) an integrated understanding of how teachers learn and develop the capacity for standard-based instruction. Each of these frameworks has contributed to the development of this teacher preparation program that fosters reflection, collaborative processes, empowerment, and innovative instruction. Each framework is described below.

### 2.1 Content-Based Teacher Preparation

A primary foundation of the NAU Teach program is what Ball and Bass refer to as “a practiced-based theory of mathematical knowledge for teaching” (2003, p. 5) and “requires a shift from a focus on what teachers know and believe to a greater focus on what teachers do” (Ball and Forzani, 2009, p. 503). This shift involves giving

significant attention not just to the knowledge demands of teaching but to the actual tasks and activities involved in the work. It would not settle for developing teachers’ beliefs and commitments; instead, it would emphasize repeated opportunities for novices to practice carrying out the interactive work of teaching and not just to talk about that work (Ball and Forzani, 2009, p. 503).

It also requires teacher educators to specify what preservice teachers need to learn to do and “requires developing instructional approaches to help teachers learn to do these things for particular purposes *in context*” (our emphasis), (Ball and Forzani, 2009, p. 503).

This practiced-based theory is also related to what is usually called *pedagogical content knowledge* (PCK), a term first coined by Shulman in 1986. Shulman describes PCK as “the particular form of content knowledge that embodies the aspects of content most germane to its teachability” and includes “the ways of representing and formulating the subject that make it comprehensible to others”, “what makes the learning of specific topics easy or difficult”, and “knowledge of strategies most likely to be fruitful in reorganizing the understanding of learners” who might have faulty conceptions and misconceptions (Shulman, 1986, pp. 9-10).

Implicit in these ideas is that it is better to have teacher education programs in which content and pedagogical experiences are intertwined and based in specific content areas rather than the traditional model where content courses are offered by specific disciplines and general pedagogy courses are housed in a college of education. Other statements are more explicit. Steele and Hillen (2012) write

pedagogical knowledge is neither discrete nor conceptually separable from the knowledge of the mathematics content being taught. Knowledge of how to teach a particular slice of mathematics rests on one’s knowledge of the mathematics in question; however, research that has investigated the development of mathematical knowledge for teaching has shown this process to be less additive (e.g., learn the content, then learn to teach it) and more iterative (pp. 53-54).

Darling-Hammond, Hammerness, Grossman, Rust, and Shulman (2005) “acknowledge the importance of content pedagogy” when they write, “Recent research in cognitive psychology suggest that expertise is developed within particular domains rather than generically” (p. 404). Furthermore, they report on recent studies that support teacher education programs that include “a common core curriculum grounded in substantial knowledge of development, learning, and subject matter pedagogy, taught in the context of practice” (p. 406).

Supported by the results cited above, the NAU Teach program was designed as a content-based teacher preparation program. From start to finish, preservice teacher candidates engage in coursework and field experiences that are set in content-based contexts. No general teacher education courses are required, all field experiences occur in mathematics classrooms, and all programmatic courses, classroom discussions, activities, and assignments are STEM-based.

## 2.2 CBMS and AMTE Recommendations and Standards for Preparing Teachers Of Mathematics

The CBMS published reports in 2001 and 2012 as “recommendations for the mathematics that teachers should know and how they should come to know that mathematics...to provide students with a mathematics education that ensures high school graduates are college- and career-ready” (p. xi). In 2017, the AMTE published a “set of comprehensive standards describing a national vision for the initial preparation of all teachers ... who teach mathematics” (p. xiv). First and foremost in these documents is a central focus on mathematics content. These recommendations regarding teacher (pedagogical) content knowledge largely mirror those highlighted in Section 2.1 of this paper above. Three more areas of mathematics teacher knowledge further emphasized by CBMS, AMTE, and throughout the NAU Teach program are discussed below.

### 2.2.1 Equity

“Ensuring the success of each and every learner requires a deep, integrated focus on equity in every program that prepares teachers of mathematics” (AMTE, 2017, p. 1). Equity has been a central pillar of the UTeach program since its inception and is emphasized early and often in NAU Teach. As candidates in NAU Teach learn about and practice planning how to be effective mathematics teachers, they are continually required to reflect on including and supporting all learners. Students in NAU Teach gain knowledge, practice, and understanding regarding equity throughout the program, particularly in Classroom Interactions and Apprentice Teaching. The NAU Teach program supports the idea that “well-prepared beginning teachers of mathematics at the high school level understand the importance of providing each and every high school student with opportunities to learn mathematics that will enable him or her to think analytically and creatively in preparation for workforce, college, citizenship, and life” (AMTE, 2017, p. 127).

### 2.2.2 Technology

According to content guidelines for teacher preparation (e.g. CBMS, 2012), teacher candidates must have the opportunity to engage in using technology in a variety of ways for both teaching and learning mathematics. These tools include technology for learning mathematics with depth as well as technology for teaching mathematics in meaningful ways (CBMS, 2012). “Teachers need to develop the ability to critically evaluate the affordances and limitations of a given (technological) tool, both for their own learning and to support the learning of their students” (CBMS, 2012, p. 34). As described above and highlighted during a recent Council for the Accreditation of Educator Preparation (CAEP) visit, the NAU Teach program incorporates authentic technology-based teaching and learning experiences throughout the program, but perhaps most notably in *Math Methods I and II*, *Research Methods*, and *Apprentice Teaching*. Candidates in these courses have many opportunities to engage in content based explorations as learners and are provided opportunities to plan and reflect on effective use of technology to support teaching and learning mathematics in conceptually rich ways. Experiences in spreadsheets, dynamic geometry and statistics software, computer algebra systems, and other mathematical action technologies (Dick & Hollebrands, 2011) allow our graduates to leave our program “...proficient with tools and technology designed to support mathematical reasoning and sense making, both in doing mathematics themselves and in supporting student learning of mathematics,” (AMTE, 2017, p. 125).

### 2.2.3 Assessment

“Assessment is a cornerstone for all educational endeavors, the means by which those striving to support learning come to know the knowledge, skills, and dispositions of those whose learning they are supporting” (AMTE, 2017, p. 147). Appropriate use of formative and summative assessment tools and techniques is introduced early and employed often throughout the NAU Teach program. Teacher candidates plan, gather, analyze, and reflect on curriculum and instruction using pre and post data from formative and summative assessments as part of every class teach. Providing their students with opportunities to say, do, write, and create as part of classroom instruction allows our teacher candidates to delve into the nuances of student understanding and explore how their instruction impacts the student learning experience. Allowing students to have multiple ways of experiencing content and demonstrating understanding permits our teacher candidates to experience the inherent connection between appropriate content, effective instructional decision making, and promoting depth of understanding. In short, our candidates experience, first hand, the connections between instruction, assessment, and curricular decisions that emphasize active student involvement and construction of knowledge. Candidates focus on the use of assessment data, gathered both formally and informally, to drive instructional decision making, reflect on their impact on student learning, and analyze the effectiveness of their planning and instruction for promoting meaning. These three uses of assessment mirror early recommendations by the National Council of Teachers of Mathematics that emphasize the use of assessment for diverse purposes (NCTM, 1995).

### 2.3 How Teachers Learn

In addition to a concerted effort to promote various knowledge domains as discussed above, the NAU Teach program is designed to help teacher candidates overcome their preconceived notions of what it means to teach and learn, through a long term approach that challenges them to examine their assumptions about instruction, to clarify the language of teaching, and to provide foundational experiences that demonstrate an alternative way to think about and engage in mathematics teaching and learning. As well-versed students who have many years of experience in educational settings under their belt, teacher candidates often arrive in a teacher training program with assumptions about what teaching and learning mathematics looks and feels like based on their own, sometimes traditional, experiences (Lortie, 1975). These faulty assumptions about how students learn are often based on how they themselves learned and on their own limited observations of teacher practice. Teacher candidates' ideas about how teachers teach and plan provide them with a wealth of preconceptions and assumptions about teaching that are actually based on limited analysis and evaluation of only the visible aspects of teaching (Munby, Russell, & Martin, 2001).

In order to help our teacher candidates acknowledge, overcome, and build from their observed assumptions about teaching and learning, NAU Teach aims to develop professional adaptive expertise through every step of the program. Adaptive expertise, or the ability to manage the complexity of teaching through efficient procedures that incorporate innovation when needed (Schwartz, Bransford, & Sears, 2005), is promoted through early and frequent field based teaching experiences that embed flexibility within well planned instructional opportunities. Simultaneous on-the-spot decision making and multiple ways of knowing and doing are integrated into and a natural outcome of the many field-based teaching experiences integrated throughout this program. These are not easily developed skills and slowly grow through the developmental approach to teaching and reflection embedded in the program (Hammerness, et al., 2005). In their first class, candidates develop single, stand-alone lessons based on resources and sample activities provided to them and modeled in class. As they progress through the field-based components of NAU Teach candidates are provided less structure and fewer directed resources to plan their lessons so that they are taking on more initiative and ownership of lesson planning and implementation. By the end of the program, just before student teaching, the program culminates in a collaboratively developed project-based unit that is planned and developed from scratch using candidate resources, ideas, and research. These structured field-based learning experiences support action, reflection, and ultimately understanding of the many nuances of teaching and learning within the classroom.

Direct experience is a fundamental part of developing identity, efficiency, and expertise. Teacher candidates must reflect on their practice and its impact on the student learning experience in order to promote connections between more theoretical and foundational aspects of teaching as developed through coursework and actual classroom practice (Hammerness, et al., 2005). Furthermore, reflection urges teacher candidates to move beyond a focus on their own practice in early field experiences toward a focus on the impact of their instruction on student learning and engagement. As such, regular reflection plays a fundamental role throughout the NAU Teach program. As candidates complete a teach in any given class, a whole group and/or individual reflection occurs. Candidates reflect orally and individually with their mentor teacher and university instructor highlighting the pros and cons of their teaching, noting the places for improvement, and connecting the theoretical and foundational elements of the program with their own practice. Reflective practice helps teacher candidates develop innovation and flexibility through the cyclical process of teaching, reflecting, understanding, and growing as professional practitioners and learners. The more teacher candidates are able to learn about teaching by doing, the more accurately they can reflect on their practice and ingrain habits of practice related to metacognition into their own teaching approaches. Creating the habit of mind of being a reflective practitioner is a fundamental part of the direct teaching/learning experiences of this program.

The collaborative nature of planning and implementation inherent in most of the field-based teaching experiences throughout the NAU Teach program is an important part of identity development for our teacher candidates. Having the structured support of peers and instructors throughout the planning, implementation, and reflection process helps teacher candidates develop and maintain efficiency and innovation. Knowledge for, in, and of teaching and professional contexts is an important part of helping teacher candidates develop their identities as teachers (Cochran-Smith & Lytle, 1999; Hammerness, et al., 2005). Developing that personal and professional teacher-identity is a fundamental component of the program and helps teacher candidates make the transition from student observer to professional educator. Identity development is based on direct teaching experiences, well-supported learning environments, reflective practice, and active participation in communities of practice (Cochran-Smith & Lytle, 1999). Communities of practice often consist of the teacher candidates working in pairs or small groups, with the mentor teacher and the university instructor. Throughout the planning process, teacher candidates often consult with the teacher in whose class they will be teaching on the content, activities and instructional decision making of their lessons. They also gain tremendous insights by observing the classrooms in which they teach prior to their teaching, so that they



are familiar with students and classroom culture. In addition, teacher candidates often consult with the university instructor on the development of their lesson plan and the alignment of their plans with innovative and inquiry-based instructional research-based best practice. The opportunity to practice their lesson with their peers in the context of their NAU Teach classes often provides important feedback on necessary revisions and shifts in instruction.

Regular and repeated planning, reflection, and teaching provide foundational learning experiences for the teacher candidates to develop professional expertise through the context of practice. Candidates are exposed to grounded situations likely to occur in the classroom through organized and structured classroom “teaches” that encourage direct connections between theoretical discussions related to teaching and actual classroom-based experiences. NAU Teach’s frequent and early field placements immediately put teacher candidates in the role of teacher and force them to begin challenging their own assumptions about visible and less visible aspects of teaching. Practical and theoretical discussions about effective instruction, student engagement, and discourse as part of formal class meetings within the program are balanced with authentic teaching experiences that allow students to try out strategies and practices discussed in class in actual classroom settings. Direct, but well-supported, experiences where teacher candidates are allowed to challenge their own assumptions about teaching and learning, along with guided reflections on the impact of their instruction on student learning and engagement, are a regular component of every field-based class as part of the NAU Teach program.

### 3. Discussion

In 2017, AMTE published its *Standards for Preparing Teachers of Mathematics*. Underlying these standards were the following assumptions: (1) ensuring the success of every learner demands a deep, integrated focus on equity in every program that prepares teachers of mathematics, (2) teaching mathematics effectively requires career-long learning about teaching mathematics, (3) learning to teach mathematics requires a central focus on mathematics, multiple stakeholders should be responsible for and invested in preparing teachers of mathematics, and (4) those involved in mathematics teacher preparation must be committed to improving their effectiveness in preparing future mathematics teachers. Based on these assumptions, standards were produced that detailed the importance that beginning teachers of mathematics were well-prepared in (1) mathematical concepts, practices, and curriculum; (2) pedagogical knowledge and practices for teaching mathematics; (3) understanding of students as learners of mathematics; and (4) the social contexts of mathematics teaching and learning.

The design of the NAU Teach program meets the spirit of these standards through its focus on student mastery of mathematical content, the teaching and learning of mathematics, and early and frequent field experiences. Our program emphasizes teachers as change agents and empowers our graduates to think of themselves as different from other teachers in that they are innovators in their field. Through mathematics-specific training in content, learning theory, and pedagogy, teacher candidates develop confidence in their own practice and their understanding of students and their learning environment. They understand the importance of identity as a teacher and graduate the NAU Teach program prepared to lay the groundwork for future leadership roles with positive dispositions toward students, teachers, and the profession. Since the start of the NAU Teach program NAU has more than doubled the annual number of candidates it produces, with over 161 total graduates and 76 mathematics education graduates since 2011. One measure of the program’s success is that, as of 2014, our mathematics education graduates have a 68% retention rate in the teaching profession. NAU Teach candidates are highly sought after throughout the state of Arizona, with 100% placement in the profession for those who seek full time teaching positions in post-primary mathematics teaching. Additionally, a vast majority of our graduates report taking on leadership roles (e.g. departmental chairs, district coordination positions, etc.) within two or three years of entering the profession.

### 4. Conclusion

The UTeach program began 20 years ago at the University of Texas-Austin. The program’s primary goals were to increase the number of students majoring in mathematics and science education, and to change the way secondary mathematics and science teachers were being prepared for their careers with the ultimate goal of producing more secondary mathematics and science teachers who would stay in the profession longer. The program’s success in meeting these goals led to its replication at several different universities. Currently, there are 44 universities in 21 states and the District of Columbia implementing UTeach-style programs (UTeach, 2017).

As NAU Teach approaches its tenth year it has, with some modifications, stayed true to the mission of the UTeach program. As described in these pages, the program’s structure allows for students to develop deep content knowledge in their chosen field, with the ability to apply this knowledge in several different field-based practicum situations. The

program's emphases on inquiry-based learning strategies, reflective practice, and peer collaboration help fully develop a teaching candidate who is reflective, innovative, and flexible in a variety of educational settings and situations. With subject-specific pedagogical courses emphasizing learning theory, equity, technology use, research-based projects, and instructional unit development, teaching candidates emerge from the NAU Teach program well prepared to face the continually changing demands of today's secondary classroom.

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