The UTeach Secondary STEM Teacher Preparation Model and Current Standards Reform Initiatives

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Executive Summary

This paper has been prepared by the UTeach Institute, the organization working with universities across the country to implement and improve the UTeach model for secondary science, technology, engineering, and mathematics (STEM) teacher preparation. In partnership with a variety of funders, the UTeach Institute currently works with 35 universities to implement UTeach programs.[1] While Texas, home to the founding UTeach program and seven others, has not adopted the Common Core State Standards, 26 UTeach programs operate in states that have. Thus, alignment of the UTeach program model to the CCSS and other standards reform initiatives is a priority for the national UTeach network. The UTeach Institute is working closely with all partner programs to ensure that UTeach graduates are prepared to implement current national STEM standards.

UTeach, established in 1997 at The University of Texas at Austin, is well aligned with current standards reform initiatives, including the Common Core State Standards (CCSS) and the Next Generation Science Standards (NGSS). In fact, current standards initiatives appear to be converging on many of the principles that have been cornerstones of UTeach since its inception. UTeach was created to attract a wide range of bright science and mathematics majors into secondary teaching careers, to prepare them through an advanced field-intensive curriculum, and to promote professional retention through induction support and ongoing professional development.

The UTeach instructional program was initially developed at UT Austin by a collaborative team made up of clinical and research-active faculty from the colleges of education, science, and liberal arts. Research-active faculty with expertise in STEM, STEM teaching and learning, and the history of science and mathematics worked alongside master teacher[2] practitioners (clinical faculty) to design a program emphasizing deep understanding of STEM content, practices and pedagogy, and strong connections between theory and practice. It was designed to align with the National Council of Teachers of Mathematics, National Science Education Standards, and the American Association for the Advancement of Science Project 2061 Benchmark standards and has been continually revised to address new research and demonstrated best practices in student learning of science and mathematics.

The current CCSS and NGSS reform initiatives place an increased emphasis on developing depth of discipline-specific content knowledge and conceptual understanding; building skills in fundamental science, mathematical, and engineering practices; and applying science and mathematics to solve authentic problems. This in turn necessitates the preparation of teachers with deep content knowledge who have experience designing, carrying out, analyzing, and presenting independent scientific inquiries; constructing and defending logic-based mathematical arguments; applying mathematical tools and practices to solve complex problems and model scientific phenomena; and designing problem- and project-based learning environments for all learners.

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[1] The UTeach Institute partners with the National Math and Science Initiative and the states of Texas, Tennessee, Georgia, Massachusetts, Florida, Maryland, and Arkansas to replicate UTeach at universities across the country. A complete list of strategic partners is available at http://uteach-institute.org/about/detail/partners/.

[2] Master teachers in the UTeach program are former secondary math or science teachers with a minimum of three years teaching experience, a master's degree, and demonstrated teaching excellence and leadership qualities who are hired by the university as clinical faculty.

The UTeach instructional program[3] is designed to do the following:

- Develop deep conceptual understanding and mastery of subject-area content
- Make explicit the underlying connections between mathematics and science
- Develop proficiency in core mathematics and scientific practices
- Develop research and information analysis skills
- Integrate content and pedagogy
- Build strong connections between educational theory and practice
- Emphasize inquiry- and project-based instructional approaches
- Integrate themes of assessment, equity, literacy, and technology
- Cultivate reflective practice

In this paper, we outline some of the challenges that the new standards present for the preparation of secondary STEM teachers in general and discuss the design strengths offered by the UTeach instructional model. We also suggest areas for focus and further development of the UTeach model in order to more completely address the array of expectations outlined by current standards reform initiatives.

The Common Core State Standards and Next Generation Science Standards: Implications for STEM Teacher Preparation

For the majority of states, the Common Core State Standards for Mathematics demand more rigor than their state standards and more emphasis on problem-solving and mathematical thinking. There is also a greater focus on the application of conceptual understanding in authentic contexts.[4] Likewise, the Next Generation Science Standards are calling for science instruction that more closely reflects the real work of scientists and engineers. They emphasize depth of conceptual understanding of core ideas over breadth of content coverage and the integration of science knowledge and ability with the practices needed to engage in scientific inquiry and engineering design.[5]

There is widespread agreement in the education community that most teacher preparation programs are likely to require at least some redesign in order to adequately prepare teachers for the new standards.[6] Professional societies and accreditation agencies have recently begun to provide recommendations and standards for the preparation of STEM teachers based on these new standards.

The Council for the Accreditation of Educator Preparation (CAEP) in their 2013 draft recommendations[7] emphasizes the link between instruction and content, calling for teacher preparation programs to develop candidates' content knowledge and pedagogical knowledge so that "candidates demonstrate an understanding of the critical concepts and principles in their discipline, including college and career-readiness expectations, and of the pedagogical content knowledge necessary to engage students' learning of concepts and principles in the discipline" (p. 16).

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[3] For more information on the design of the UTeach secondary STEM teacher preparation program, see *The UTeach Elements of Success* and *The UTeach Instructional Program*, available at http://uteach-institute.org/publications.
[4] National Governors Association Center for Best Practices, Council of Chief State School Officers. (2010). *Common Core State Standards for Mathematics.* Washington, DC: Author.
[5] National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: The National Academies Press.
[6] Association of Public and Land-grant Universities/Science and Math Teacher Imperative. (2012). *Preparing future secondary science teachers for the Next Generation Science Standards.* Washington DC: Association of Public and Land-grant Universities. SMTI/TLC Working Group on CCSS. (2011). *The Common Core State Standards and teacher preparation: The role for higher education.* Washington, DC: Association of Public and Land-grant Universities.
[7] CAEP Commission on Standards and Performance Reporting. (2013). *Draft recommendations for the CAEP Board.* Washington DC: Council For the Accreditation of Educator Preparation.

This "deeper learning" called for by the CCSS and CAEP is exemplified by these attributes:

- An understanding of the meaning and relevance of ideas to concrete problems
- An ability to apply core concepts and modes of inquiry to complex real-world tasks
- A capacity to transfer knowledge and skills to new situations, to build on and use them
- Abilities to communicate ideas and to collaborate in problem solving
- An ongoing ability to learn to learn (p. 17)

Likewise, the InTASC Model Core Teaching Standards[8] were updated in 2011 in part by "the new imperative that every student can and must achieve to high standards" (p. 3). They call for a stronger focus on application of knowledge and skills so that teachers can have a "deep and flexible understanding of their content areas and be able to draw upon content knowledge as they work with learners to access information, apply knowledge in real world settings, and address meaningful issues to assure learner mastery of content" (p. 8). Content Standards 4 and 5 are of particular importance:

- Standard #4: Content Knowledge. The teacher understands the central concepts, tools of inquiry, and structures of the discipline(s) he or she teachers and creates a learning experiences that make the discipline accessible and meaningful for learners to assure mastery of the content. (p. 24)
- Standard #5: Application of Content. The teacher understands how to connect concepts and use differing perspectives to engage learners in critical thinking, creativity, and collaborative problem solving related to authentic local and global issues. (p. 27)

Mathematics Teacher Preparation

In a recent report, updated to address the CCSS, the Conference Board of Mathematical Sciences (CBMS) outlines recommendations for the preparation of mathematics teachers.[9] The Conference Board recommends a minimum preparation requirement for middle school teachers of 24 semester hours of mathematics courses at a level of pre-calculus and higher, including courses that address essential ideas underlying secondary mathematics. For high school teachers, an additional 18 hours of advanced mathematics courses is recommended, along with a three-course calculus sequence, statistics, and courses focused on high school mathematics from an advanced standpoint. A research experience "that includes performing experiments and grappling with problems, building abstractions as a result of reflection on the experiments, and developing theories that bring coherence to the abstractions" (p. 65) is also recommended. Additional specific recommendations for the mathematics that teachers need to know include the following:

- Coursework for prospective teachers should be designed to examine the fundamental principles that underlie the mathematics *they will teach* in depth, from a teacher's perspective. (p. 17)
- Coursework for prospective teachers should allow time to engage in reasoning, explaining, and making sense of the mathematics that they will teach. Course recommendations include the history of mathematics and statistics-probability courses that focus on data collection, analysis, and interpretation. Courses for prospective high school teachers of mathematics should be equivalent to an undergraduate major in the subject, including courses that explore and elaborate on the topics of the high school curriculum at an advanced level. (p. 18)

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[8] Council of Chief State School Officers. (2013). Interstate Teacher Assessment and Support Consortium *InTASC model core teaching standards and learning progressions for teachers 1.0: A resource for ongoing teacher development*. Washington, DC: Author.
[9] Conference Board of the Mathematical Sciences. (2012). *The mathematical education of teachers II*. Providence, RI and Washington, DC: American Mathematical Society and Mathematical Association of America.

- Coursework for prospective teachers should develop the habits of mind of a mathematical thinker and problem-solver, such as reasoning and explaining, modeling, seeing structure, and generalizing. (p. 19)

The CBMS report also emphasizes "that teacher education must be recognized as an important part of a mathematics department's mission and should be undertaken in collaboration with mathematics education faculty. In short, mathematics faculty must become deeply engaged with and involved in both pre-service and in-service mathematics teacher professional development" (p. 19).

Similar recommendations have been in place for a decade or more. In 2004, the Committee on the Undergraduate Program in Mathematics (CUPM) of the Mathematical Association of America offered recommendations for mathematics majors preparing to teach secondary mathematics that were informed by the 2001 version of *The Mathematical Education of Teachers* by CBMS. The CUPM Curriculum Guide[10] provides the following recommendations for majors preparing to teach secondary mathematics:

- Learn to make appropriate connections between the advanced mathematics they are learning and the secondary mathematics they will be teaching. They should be helped to reach this understanding in courses throughout the curriculum and through a senior-level experience that makes these connections explicit.
- Fulfill the requirements for a mathematics major by including topics from abstract algebra and number theory, analysis (advanced calculus or real analysis), discrete mathematics, geometry, and statistics and probability with an emphasis on data analysis.
- Learn about the history of mathematics and its applications, including recent work.
- Experience many forms of mathematical modeling and a variety of technological tools, including graphing calculators and geometry software. (p. 54)

Science Teacher Preparation

According to the National Academy of Sciences,[11] the implications of the Next Generation Science Standards for teacher preparation include:

- Developing prospective teachers' deep and accurate knowledge of the cross-cutting concepts, disciplinary core ideas, and scientific and engineering practices, including the knowledge of and ability to collaborate as scientists do to "develop new theories, models and explanations of natural phenomena." (p. 257)
- Developing in prospective teachers the ability to engage students in these crosscutting concepts, disciplinary core ideas, and scientific and engineering practices, including an explicit focus on modeling through a wide array of research-based instructional practices. (p. 257)
- Developing expertise in prospective teachers at recognizing and using appropriate pedagogical strategies to uncover and address student's preconceived scientific ideas, models or misconceptions. (p. 257)
- Providing experiences with and developing prospective teachers in reviewing, analyzing and modifying curricular materials to meet emerging new standards and current research in the learning sciences. (p. 258)
- Introducing prospective teachers to a range of scientific investigations, including simple classroom investigations, field studies outside the classroom, formal laboratory experiments, and student-designed investigations. (p. 258)

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[10] Committee on the Undergraduate Program in Mathematics (CUPM). (2004). *Undergraduate programs and courses in the mathematical sciences: CUPM curriculum guide 2004*. Washington, DC: Mathematical Association of America.
[11] National Research Council, *A framework for K-12 science education*.

- Developing in prospective teachers the knowledge and practices to support these investigations, including how to prepare, organize, and maintain materials; implement safety protocols; organize student groups; and guide students as they collect, represent, analyze, discuss data, argue from evidence, and draw conclusions. (p. 258)
- Providing prospective teachers with opportunities to acquire and learn the practices that ensure their students know how to obtain, represent, communicate, and present information; in essence, to develop STEM literacy in their students. (p. 258)

Professional associations representing various science disciplines have also published recent recommendations for strengthening teacher preparation that are aligned with NGSS expectations. The Task Force on Teacher Education in Physics produced a 2012 report[12] calling for improvements in the preparation of physics teachers. Recommendations include strengthening commitments by university physics and education departments to develop excellent physics teachers through rigorous content preparation, including physics courses that are necessary and appropriate and "extensive physics-specific pedagogical training and physics-specific clinical experiences" (p. 25).

Distinguishing Features of the UTeach Instructional Program

The UTeach secondary STEM teacher preparation program has been preparing math and science teachers to design and implement inquiry- and project-based instruction that emphasizes application of mathematics and science concepts and practices since 1997. The new standards are in fact calling for the essential approaches to teaching and learning on which the UTeach instructional program was founded.

UTeach Program Design

The UTeach pre-service instructional program is characterized by 1) a rigorous content major paired with 2) a streamlined, field-intensive UTeach curriculum[13] that is firmly situated within the STEM domains. The UTeach curriculum, pictured in Figure 1, includes the following groups of courses:

- UTeach Recruitment Courses (colored orange in the figure) are one-hour courses taught by UTeach master teachers and designed to encourage STEM majors to "try out teaching" through a series of authentic teaching experiences in local classrooms.
- UTeach STEM Education Courses (blue) are based on current research in teaching and learning specifically within the STEM domains and are taught by science and mathematics education faculty. UTeach master teachers assist with field teaching components associated with these courses.
- UTeach STEM Content Courses (green) are generally taken concurrently with STEM education courses and are designed to emphasize content and develop scientific and mathematical practices of particular importance to secondary math and science teachers.
- Apprentice Teaching (purple) consists of a semester-long teaching experience and seminar that provides a culminating opportunity for students to demonstrate proficiencies required for certification.
- Portfolio (gray). Students provide evidence through a portfolio that they are proficient across a number of criteria ranging from subject-matter knowledge to effective instructional design and classroom management. Along with proficiencies required during the final Apprentice Teaching experience, this collection of evidence must satisfy minimum criteria in order for students to be recommended for certification.

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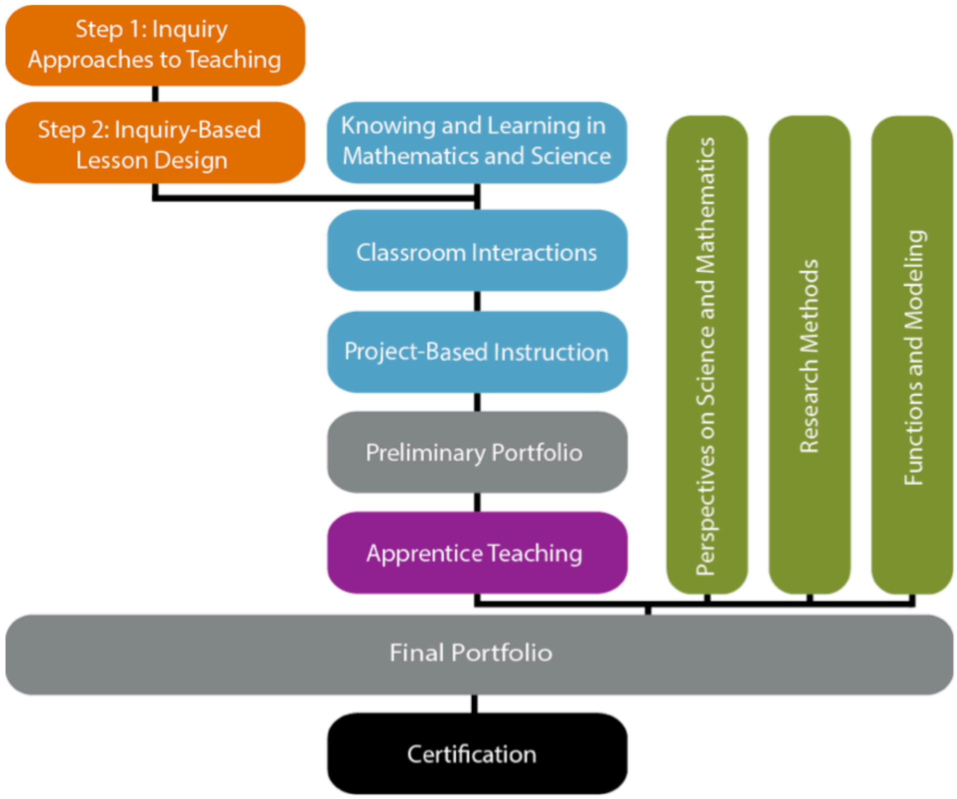
[12] Meltzer, D. E., Plisch, M., & Vokos, S. (2012). *Transforming the preparation of physics teachers: A call to action: A report by the Task Force on Teacher Education in Physics (T-TEP).* College Park, MD: American Physical Society.

[13] UTeach courses at UT Austin comprise between 24 (for science majors) and 27 (for math majors) semester credit hours of degree plans that range from 120–128 total semester credit hours.

Figure 1. UTeach Curriculum Snapshot



The UTeach instructional program is designed with several core intentions:

Develop deep conceptual understanding and mastery of subject-area content. UTeach courses provide rigorous instruction based on current research and emphasize the development of deep-level understanding of both subject material and pedagogy. UTeach students take all the coursework required to obtain a rigorous STEM major along with their teaching certification. At the University of Texas at Austin, mathematics majors take a minimum of 27 credit hours of upper-division mathematics and science. Science majors take a minimum of 22–30 credit hours of upper-division science and mathematics.[14] Computer Science majors take a minimum of 40 credit hours of upper-division computer science, mathematics, and science. Content knowledge is assessed by enforcing a cumulative minimum GPA across STEM major and UTeach pedagogy courses. Content knowledge is also a component of UTeach classroom observation protocols and must be demonstrated through evidence submitted in a required exit portfolio.

Make explicit the underlying connections between mathematics and science. UTeach courses help students explore the relationships within and between the disciplines of mathematics and science and how that content is learned by novices and experts. Mathematics and science students take most of their UTeach courses together, creating ongoing opportunities for collaboration and discussions of the commonalities and differences in how each discipline is learned and taught. All students design and carry out a series of independent scientific inquiries that necessitate the application of mathematics for data analysis and modeling. All students receive instruction on the historical and philosophical development of mathematics and science disciplines.

[14] The minimum required credit hours among science major degree plans include 22 for Geoscience majors, 25 for Chemistry majors, 30 for Physics majors, and 30 for Biology majors.

Develop proficiency in core mathematics and scientific practices. Students are required to take UTeach courses specifically designed to develop their skills in applying mathematics and science practices to solve authentic problems and conduct research. Math majors take the *Functions and Modeling* course, where they are required to demonstrate their ability to collaborate in groups, make conjectures and defend results/proofs related to important mathematical content, and critique the justifications and arguments of their peers. Making connections between mathematics concepts fundamental to the secondary mathematics curriculum is also stressed. All students, including mathematics majors, take the *Research Methods* course.[15]

Develop research and information analysis skills. Students are required to take UTeach courses that include an explicit focus on data and information analysis and synthesis. The *Perspectives on Science and Mathematics* course is a history course designed to develop sophisticated research and information analysis skills through the study of the published literature and primary sources, building their understanding of the historical development of the kinds of questions scientists and mathematicians have tried to answer and why. In the *Research Methods* course, developing the habits of mind and practices of scientists and mathematicians, students conduct statistical analysis of investigation data, apply scientific arguments in matters of social importance, write scientific papers, and give oral presentations of scientific work.

Integrate content and pedagogy. There are no generic education courses in the UTeach course sequence. Rather, UTeach education courses are specifically designed to meet the needs of future secondary teachers of science, mathematics, computer science, and engineering and are domain specific. Discipline-focused content courses such as *Research Methods*, *Functions and Modeling*, and *Perspectives on Science and Mathematics* provide content knowledge of particular importance for teachers and also count toward a STEM degree major. For example, students in *Research Methods* not only carry out their own independent investigations but review and critique the work of their peers to gain experience providing feedback and guidance that can be applied in their future secondary classrooms.

Build strong connections between educational theory and practice. The design of the UTeach program field components provides students with early and ongoing opportunities to implement and reflect on the instructional strategies applied in grades 4–12 classrooms about which they are learning in their university pedagogy courses. All practice teaching experiences are tightly coupled with the content and concepts presented in the five required field-based courses—*Step 1: Inquiry Approaches to Teaching, Step 2: Inquiry-Based Lesson Design, Classroom Interactions, Project-Based Instruction*, and *Apprentice Teaching*. Course assignments and projects involve detailed analysis of student field experiences and significant class time is devoted to preparing for, practicing, debriefing, and reflecting on those teaching experiences.

Emphasize inquiry-, problem- and project-based instructional approaches. Students begin the program designing, implementing, and reflecting on a series of inquiry-based lessons utilizing the BSCS 5E Instructional Model,[16] focusing initially on the development of effective questioning strategies. This emphasis continues throughout the program as a variety of research-based instructional strategies are introduced, explored, and analyzed for effectiveness in secondary school settings. As a culminating experience, UTeach includes an entire field-based course devoted to project-based instruction (PBI). Student proficiency in this area is a component of UTeach classroom

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[15] Three UTeach courses—*Project-Based Instruction, Functions and Modeling*, and *Research Methods*—are described in more detail later in this paper.

[16] Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J.C., Westbrook, A., & Landes, N. (2006). *The BSCS Instructional Model: Origins and effectiveness: A report prepared for the National Institutes of Health, Office of Science Education*. Colorado Springs, CO. BSCS.

observation protocols and must be demonstrated through video evidence submitted in the required exit portfolio.

Integrate themes of assessment, equity, literacy, and technology. Rather than have stand-alone generic courses on each of these topics, the UTeach curriculum integrates these important themes into all courses, developing students' competency as they progress through the program. Clinical faculty (master teachers) assess UTeach student competency developmentally in each of these areas through the use of an observation protocol during all clinical teaching experiences, and students are required to reflect on and analyze their own growth by repeatedly providing evidence of effective use of assessment strategies, integration of technology, and lesson design that promotes learning for all students. Student proficiency in this area is a component of UTeach classroom observation protocols and must be demonstrated through evidence submitted in a required exit portfolio.

Cultivate reflective practice. UTeach students are observed and provided feedback by clinical faculty (master teachers), course instructors, and classroom mentor teachers a minimum of 10 times prior to the *Apprentice Teaching* semester and 10 times during that final *Apprentice Teaching* practicum. Students prepare formal, written reflections each time they teach in the five field-based courses. Peer feedback is another explicit component of all UTeach courses and ranges from collaborative lesson plan development to feedback on practice teaching to review of the published literature to writings and oral presentations of scientific or mathematical concepts. Students are required to modify lessons based on evidence of student learning and provide written rationales for the changes made, based on assessment of student data. In-depth student video and written analyses of their own teaching are major components of the *Classroom Interactions* and *Project-Based Instruction* courses. Evidence of reflective practice is a component of a required exit portfolio as well.

Developing Proficiency in Mathematical, Scientific, and Engineering Practices

One of the greatest strengths of the UTeach instructional model is the emphasis placed on developing teachers' abilities to 1) apply core scientific and mathematical practices to authentic, complex problems and 2) design instructional learning environments to engage K-12 learners in these same practices. The UTeach curriculum explicitly develops candidates' proficiency in the eight Mathematical Practices called for by the CCSS-M and the eight Scientific and Engineering Practices called for by the NGSS.

An underlying UTeach design principle, the integration of math and science, creates a rich learning environment in all UTeach courses, where mathematics students are continually exposed to scientific applications and science students develop facility in the use of mathematical tools.

Inquiry- and project-based instructional design are introduced early in the UTeach program and emphasized throughout. Students are introduced to the BSCS 5E Instructional Model during the very first UTeach course, where they utilize nationally recognized and research-based science and mathematics curriculum materials: FOSS and GEMS materials, both developed by the Lawrence Hall of Science at the University of California, Berkeley. Students gain experience with standards-based lesson and unit design throughout the program and are continually challenged to critically review and modify published curricula to ensure alignment with the newest and most applicable standards they are expected to meet—either at the district, state, or national level.

There are a few UTeach courses in particular that stand out with regard to the emphasis on teaching practices highlighted in the CCSS-M and the NGSS.

Project-Based Instruction. The UTeach instructional sequence includes an entire course devoted to project-based instruction. A major focus of this course is on developing an approach to designing, implementing, and evaluating problem- and project-based curricula and processes by employing approaches that have emerged from collaborations between teachers and researchers. Skills in integrating the STEM disciplines and STEM-specific pedagogical content knowledge are developed as UTeach students work toward the design of project-based units. Competency is continually built as students read about and discuss the principles of PBI; reflect on observations of project-based learning environments in high school settings; and incorporate what they are learning into the design of problem-based lessons, and ultimately, an entire project-based unit. An intensive field component includes observation of well-implemented project-based instruction in local schools as well as implementation of problem-based lessons with area high school students in an out-of-classroom field setting. See Figures 2 and 3 for detailed alignment of PBI course objectives to the CCSS-M Mathematical Practices and the NGSS Scientific and Engineering Practices.

In this course, students . . .

- discuss and critique the merits of project-based instruction in terms of students' cognitive development, equity, and motivation.
- reflect on applications of educational theory as it relates to classroom practice in the area of project-based instruction.
- distinguish between project-based instruction and other instructional approaches and decide which approach best fits instructional goals based on the benefits and limitations of each.
- evaluate the usefulness of technology in achieving learning objectives and select appropriate resources for student use based on the relationship of salient features of the technology to learning objectives.
- use inquiry methods with secondary students in a problem-based setting.
- describe examples of project-based instruction in math or science and analyze those examples in terms of several well-studied, field-tested models for PBI.
- demonstrate skill in setting up and managing lab and field project-based environments.
- use PBI design principles to develop an interdisciplinary, three- to four-week project-based unit for secondary math and/or science courses.
- develop alternative assessments appropriate for project-based instruction.
- discuss lab safety and liability issues related to project based instruction and wet-lab or field environments (OSHA regulations, how to read material safety data sheets, safe disposal of chemicals, etc.).
- use relevant technology to develop projects (e.g., concept mapping software, video editing software, etc.).
- integrate relevant technology into curricular units (e.g., Internet, simulations, data analysis packages, modeling software, etc.).
- plan instruction that promotes equitable and diverse participation so that all students have an opportunity to learn.

Research Methods. All students, including mathematics majors, take the *Research Methods* course where students learn how to design and carry out independent investigations to answer new questions. Students design experiments to answer scientific questions and to reduce systematic and random errors. They incorporate statistics to interpret experimental results and deal with sampling errors, and do mathematical modeling of scientific phenomena. They also present their scientific work orally. Thus, the course content is organized into five units that correspond to the development of their inquiries and a presentation on a scientific topic of choice: Curiosity and Scientific Inquiry, Experimental Design and Analysis, Statistics, Scientific Information, and Modeling. See Figures 2 and 3 for detailed alignment of *Research Methods* course objectives to the CCSS-M Mathematical Practices and the NGSS Scientific and Engineering Practices.

In this course, students . . .

- create their own experiments to answer scientific questions.
- design experiments to reduce systematic and random errors and use statistics to interpret the results.

- use probes and computers to gather and analyze data.
- use statistics to interpret experimental results and deal with sampling errors.
- treat human subjects in an ethical fashion.
- apply safe laboratory procedures.
- find and read articles in the scientific literature.
- create mathematical models of scientific phenomena.
- apply scientific arguments in matters of social importance.
- write scientific papers.
- give oral presentations of scientific work.

Functions and Modeling. In addition to their major course requirements, mathematics majors take the UTeach course *Functions and Modeling*, designed to engage future math teachers in challenging, non-routine problem solving, problem-based learning, and applications of mathematics. In this course, students collaborate to collect data and explore a variety of situations that can be modeled using linear, exponential, polynomial, and trigonometric functions. Topics involving function properties and patterns, complex numbers, parametric equations, polar equations, vectors, and exponential growth and decay are investigated. Explorations involve the use of multiple representations, transformations, data analysis techniques (such as curve fitting), and interconnections among topics in algebra, analytic geometry, statistics, trigonometry, and calculus. The lab investigations include use of various technologies, including computers, calculators, and computer graphing software. See Figure 2 for detailed alignment of *Functions and Modeling* course objectives to the CCSS-M Mathematical Practices.

In the course, students . . .

- demonstrate a depth of content knowledge with regard to important secondary mathematics topics such as parametric relations, polar relations, matrices, exponential and logarithmic functions, vectors, and complex numbers.
- generate and work with relevant lab or exploration data and use regression, matrix, function pattern, and systems methods to produce a model of the data.
- present mathematical ideas and topics in a knowledgeable, precise, and effective manner.
- demonstrate proficiency in the use of technology in the mathematics classroom.
- identify mathematics content connections between the various levels of secondary mathematics curriculum and between secondary and university level curriculum.

Figure 2. This matrix depicts how each of the UTeach courses *Project-Based Instruction*, *Functions and Modeling*, and *Research Methods* address the eight mathematical practices outlined in the CCSS-M.

8 CCSS Mathematical Practices[17]	**Project-Based Instruction** *Students will be able to . . .*	**Functions and Modeling** *Students will be able to . . .*	**Research Methods** *Students will be able to . . .*
MP1 - Make sense of problems and persevere in solving them	Use PBI design principles to develop an interdisciplinary, three- to four-week project-based unit for secondary math and/or science courses. Use inquiry methods with secondary students in a problem-based setting.	Generate and work with relevant lab or exploration data and use regression, matrix, function pattern, and systems methods to produce a model of the data.	Create their own experiments to answer scientific questions.
MP2 - Reason abstractly and quantitatively	Use inquiry methods with secondary students in a problem-based setting.	Generate and work with relevant lab or exploration data and use regression, matrix, function pattern, and systems methods to produce a model of the data. Demonstrate a depth of content knowledge with regard to important secondary mathematics topics such as parametric relations, polar relations, matrices, exponential and logarithmic functions, vectors, and complex numbers.	Use statistics to interpret experimental results and deal with sampling errors.
MP3 - Construct viable arguments and critique the reasoning of others	Use inquiry methods with secondary students in a problem-based setting.	Present mathematical ideas and topics in a knowledgeable, precise and effective manner.	Write scientific papers. Give oral presentations of scientific work
MP4 - Model with mathematics		Generate and work with relevant lab or exploration data and use regression, matrix, function pattern, and systems methods to produce a model of the data.	Create mathematical models of scientific phenomena.
MP5 - Use appropriate tools strategically	Integrate relevant technology into curricular units (e.g., Internet, simulations, data analysis packages, modeling software, etc.).	Demonstrate proficiency in the use of technology in the mathematics classroom.	Use probes and computers to gather and analyze data.
MP6 - Attend to precision		Present mathematical ideas and topics in a knowledgeable, precise, and effective manner. Demonstrate a depth of content knowledge with regard to important secondary mathematics topics such as parametric relations, polar relations, matrices, exponential and logarithmic functions, vectors, and complex numbers.	Design experiments to reduce systematic and random errors and use statistics to interpret the results.
MP7 - Look for and make use of structure		Generate and work with relevant lab or exploration data and use regression, matrix, function pattern, and systems methods to produce a model of the data.	
MP8 - Look for and express regularity in repeated reasoning		Generate and work with relevant lab or exploration data and use regression, matrix, function pattern, and systems methods to produce a model of the data.	

[17] National Governors Association Center for Best Practices, Council of Chief State School Officers, *Common Core State Standards for Mathematics.*

Figure 3. This matrix depicts how each of the UTeach courses *Project-Based Instruction* and *Research Methods* address the eight scientific and engineering practices outlines in the NGSS.

8 NGSS Scientific and Engineering Practices for K-12 Classrooms[18] *Students will be…*	**Project-Based Instruction** *Students will be able to . . .*	**Research Methods** *Students will be able to . . .*
1. Asking questions (for science) and defining problems (for engineering)	Use PBI design principles to develop an interdisciplinary, three- to four-week project-based unit for secondary math and/or science courses.	Pose scientific questions and design experiments to answer scientific questions.
2. Developing and using models		Create mathematical models of scientific phenomena.
3. Planning and carrying out investigations	Use inquiry methods with secondary students in a problem-based setting. Describe examples of project-based instruction in math or science and analyze those examples in terms of several well-studied, field-tested models for PBI. Demonstrate skill in setting up and managing lab and field project-based environments. Discuss lab safety and liability issues related to project-based instruction and wet-lab or field environments Use PBI design principles to develop an interdisciplinary, three- to four-week project-based unit for secondary math and/or science courses.	Design experiments to reduce systematic and random errors and use statistics to interpret the results. Apply safe laboratory procedures. Treat human subjects in an ethical fashion.
4. Analyzing and interpreting data	Integrate relevant technology into curricular units (e.g., Internet, simulations, data analysis packages, modeling software, etc.). Use inquiry methods with secondary students in a problem-based setting. Use PBI design principles to develop an interdisciplinary, three- to four-week project-based unit for secondary math and/or science courses.	Use probes and computers to gather and analyze data. Use statistics to interpret experimental results and deal with sampling errors.
5. Using mathematics and computational thinking		Create mathematical models of scientific phenomena.
6. Constructing explanations (for science) and designing solutions (for engineering)	Use inquiry methods with secondary students in a problem-based setting. Use PBI design principles to develop an interdisciplinary, three- to four-week project-based unit for secondary math and/or science courses.	Write scientific papers. Give oral presentations of scientific work.
7. Engaging in argument from evidence	Use inquiry methods with secondary students in a problem-based setting. Use PBI design principles to develop an interdisciplinary, three- to four-week project-based unit for secondary math and/or science courses.	Apply scientific arguments in matters of social importance. Find and read articles in the scientific literature.
8. Obtaining, evaluating, and communicating information	Use inquiry methods with secondary students in a problem-based setting. Use PBI design principles to develop an interdisciplinary, three- to four-week project-based unit for secondary math and/or science courses.	Find and read articles in the scientific literature. Write scientific papers. Give oral presentations of scientific work.

[18] National Research Council, *A framework for K-12 science education*.

Areas for Focus and Further Development of the UTeach Instructional Model

The UTeach secondary STEM teacher preparation instructional model, as a whole, offers a number of design strengths when it comes to addressing the challenges many teacher preparation programs face in preparing candidates to implement a new set of rigorous mathematics and science standards. The current standards reform initiatives have nonetheless raised the bar and do present opportunities to further strengthen the UTeach instructional model. While each of the 35 UTeach programs nationally will need to conduct its own analysis to identify specific opportunities for program improvement, two areas in particular merit further examination by all programs: developing content knowledge through major courses in the discipline and building proficiency in engineering practices.

Developing Science and Mathematics Content Knowledge in UTeach Students

UTeach places a premium on the development of subject matter expertise in teaching candidates, who are required to earn a rigorous degree equivalent to a major in their discipline. While specific content courses have been developed as part of the UTeach course sequence in order to strengthen the content preparation of future teachers, [19] the individual departments within the colleges of science and mathematics continue to have primary responsibility for developing content knowledge among UTeach students. The increased emphasis on rigor and conceptual understanding, the development of core practices in the discipline, and especially the increased focus on examination of the fundamental principles of K–12 school mathematics make it more important than ever that prospective teachers have access to courses offered by STEM departments designed to meet their needs.

UTeach master teachers and faculty in the colleges of science, mathematics, and education will need to work together closely to examine and, in many cases, develop new course offerings and instructional approaches in the STEM degrees that UTeach students earn to ensure adequate preparation in light of new recommendations. For example, the emphasis on earth science core ideas in the NGSS (p. 170) poses a particular challenge for UTeach Austin since no Earth Science certification exists in Texas and Geoscience courses are currently optional for students pursuing Composite Science certification. We expect existing cross-department and cross-college collaborations, central features of the UTeach program, to facilitate a collaborative process to address any deficiencies.

Developing Proficiency in Engineering Practices

UTeach at UT Austin, along with a small number of UTeach programs nationally, has begun to grapple with the role of engineering education in the UTeach program. UT Austin is currently in the fifth year of the UTeachEngineering project, funded by the National Science Foundation, to develop pre-college engineering education and teacher education infrastructure. This initiative has resulted in a year-long high school engineering course, an engineering pathway within UTeach leading to certification in Mathematics/Physical Science/Engineering, a master's degree program in engineering education, and professional development institutes for in-service teachers.[20]

This work has naturally provoked conversations about the role of engineering practices in the development of science and mathematics teachers. While the UTeach instructional model has always emphasized inquiry-, problem-, and project-based instruction, and in fact has included design challenges, UTeach at the University of Texas at Austin has only recently begun to focus explicitly on the inclusion of engineering design activities into UTeach course curriculum.[21] This is an area of continued focus for UT Austin. As engineering-based activities and student outcomes become established (by UT Austin and

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[19] The UTeach courses *Functions and Modeling*, *Research Methods*, and *Perspectives on Science and Mathematics* fulfill major requirements as content courses, but are designed specifically for future teachers.

[20] Marshall, J.A., & Berland, L. (2012). Developing a vision of engineering education. *Journal of Pre-College Engineering Education, 2*(2), 36-50.

[21] Marshall, J. A., & Edelmon, G. (2012). An optics design challenge tying preservice teachers to physics classrooms. American Association of Physics Teachers Winter Meeting, Ontario, CA.

other UTeach program universities), they will be formally integrated into the current model course curricula and disseminated throughout the national network of UTeach programs.

Summary

Philosophically, the UTeach STEM teacher preparation model incorporates a significant portion of what new national STEM education content and instructional standards are recommending. We remain, however, cognizant that these initiatives are only beginning to be implemented in classrooms across the nation. Our understanding of the implications for secondary STEM teacher preparation will evolve as we see how the standards are translated into specific guidance related to teaching and learning in individual STEM disciplines at all levels. Likewise, as states continue to progress in their adoption of standards and development of the curriculum to address them, and as we see what new assessments are implemented, the UTeach community of STEM and STEM education researchers and practitioners will be better able to recommend specific strategies for strengthening our pre-service preparation.

The professional learning community of more than 400 faculty and master teachers across UTeach programs nationwide offers a significant advantage in that a collaborative infrastructure has been established that fosters sharing of best practices and community problem-solving with the explicit goal of continuous improvement of the UTeach secondary STEM teacher preparation model. In this way, all UTeach programs nationwide benefit from the insights gained by individual programs as they encounter new challenges related to implementation of new standards and assessments. We will use our strong collaborative infrastructure to ensure that UTeach secondary STEM teachers are well prepared to implement challenging content standards and we welcome the opportunity to participate in these national efforts to improve STEM teaching and learning for all students.

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