**University of Kentucky**
**Department of Science, Technology, Engineering, and Mathematics Education**
**Master of Science in Science, Technology, Engineering, and Mathematics (STEM) Education**
***STEM PLUS$^{+}$: Producing Teacher Leaders for Urban/Rural Schools***

# Program Conceptual Framework

## Conceptual Framework for the Professional Education Unit at the UK

The conceptual framework for the professional education unit at the University of Kentucky (UK) is guided by the theme, *Research and Reflection for Learning and Leading.* This theme is aligned closely with both the institutional vision and mission of UK and the vision and mission of the professional education unit. The theme reflects and guides how we approach preparation of professional educators within the context of a research extensive, land grant university.

*Research* is a valued activity and tool within UK's educator preparation programs. Faculty and candidates generate scientific research using a wide range of research methodologies and contribute to the professional literature. Programs use practitioner inquiry and data-based instructional models in applied settings to enhance student learning and professional development. Research findings from the entire field of education inform design of courses, selection of interventions, and features of professional education programs.

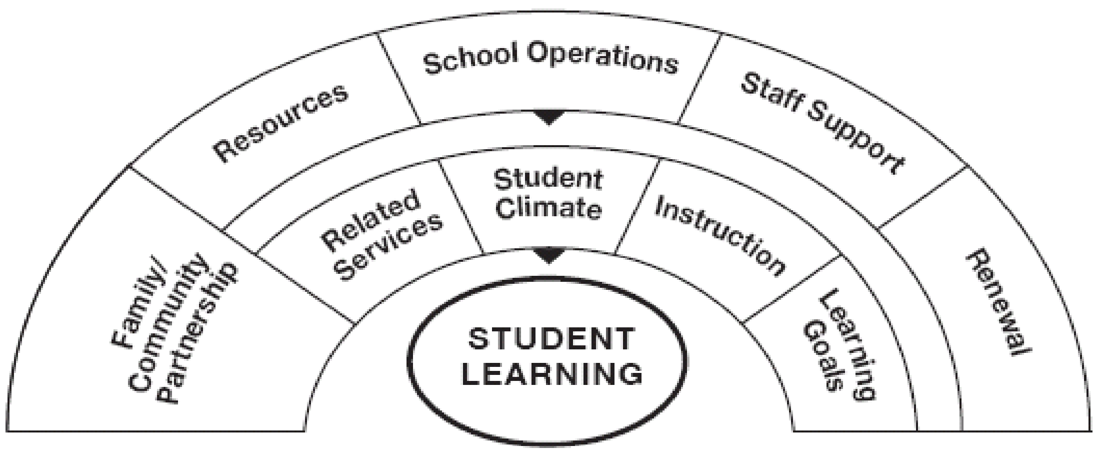
*Reflection* is a long-standing aspect of UK's educator preparation programs and is, in our view, a hallmark of professional practice. Reflective assessment of performance, outcomes, and approaches to problems is a dynamic process appropriate for faculty, experienced educators, and candidates in initial stages of their careers. Candidates are expected to complete numerous reflective activities as they work to meet standards; the goal is to prepare educators who are capable of analysis and problem-solving that will result in improving educational practices and outcomes.

*Learning* is included as a component within our conceptual framework to underscore our commitment to the many facets of learning and to highlight the ways in which our programs conceptualize, promote, and accomplish learning. As a unit, we do not share a single theoretical view of learning. Faculty and candidates conceptualize learning using a wide range of perspectives including behavioral, constructivist, and social. We believe that our diversity of thought enriches and strengthens our unit. The reference to learning in our conceptual framework encompasses learning among all those who participate in our educator preparation programs and those who are affected by the educational efforts of our faculty and candidates.

*Leading* is an expectation that faculty hold for ourselves and an outcome that we promote among our candidates. As members of the educational community at Kentucky's flagship university, we believe it is our obligation and privilege to provide leadership in educational policies and practices across levels and dimensions of universities, schools, and agencies. We believe that as leaders and followers work together to improve student learning among diverse student populations, we can obtain positive results that improve education in Kentucky and beyond.

Leadership, and specifically Teacher Leadership, within our framework of *Research and Reflection for Learning and Leading*, is informed by the "Framework for School Leadership Accomplishments" (Bellamy, Fulmer, Murphy, & Muth, 2007, p. 34). In this framework, ***student learning*** is the central objective and it is accomplished through nine interactive, collaborative efforts by diverse stakeholders (see Figure 1 below). Permission to use this model was granted by Bellamy and his colleagues.

***Figure 1. Framework for School Leadership Accomplishments***




This framework for teacher leadership was also informed by emerging descriptions of roles and responsibilities teachers and other educational practitioners assume in schools (e.g., Crowther, 2009; Crowther, Kaagan, Ferguson, & Hann, 2002; Katzenmeyer & Moller, 2009; Merideth, 2007; Murphy, 2005) and by strategies recommended for developing teachers for supporting school leadership (O'Hair & O'Dell, 1995; Stone & Cuper, 2006; Zepeda, Mayers, & Benson, 2003). The intent is to provide diverse opportunities for veteran and novice teachers in their preparation for assuming needed academic leadership responsibilities in their fields (Blase & Blase, 2006; Harrison & Killion, 2007).

This framework is designed to help actualize the theme, *Research and Reflection for Learning and Leading*, and thus prepare a skilled and influential group of leaders who will work as members of learning communities focused on the essential goal of schools: student learning.

## Mission Statement for the Department of STEM Education

The mission of the Department of Science, Technology, Engineering, and Mathematics Education (STEM Education) at the University of Kentucky (UK) is to promote scholarship, engagement, and teaching that is innovative and contributes to improving the quality of P20 education, especially in science, technology, engineering, and mathematics, in the Commonwealth, the nation, and the world. Thus, the STEM Education faculty work collaboratively together and across our content areas to achieve excellence in teacher education development and practice. Our efforts are guided by the following goals:

- Increase and retain Commonwealth and national participation of individuals in the STEM pipeline pre-K through their time in the workforce.
- Substantially increase the number and diversity of high-quality STEM teachers we prepare.
- Build strong partnerships among universities, community colleges, school systems, state governments, businesses and other stake holders, especially those within the Commonwealth.
- Prepare students, undergraduate and graduate, to innovatively think and plan for roles in schools, departments of education, professional agencies and associations, and colleges and universities.
- Develop the human and physical resources of STEM Education to facilitate the achievement of its mission, vision, and goals.
- Promote diversity and inclusion across our scholarship, engagement, and practice activities.
- Promote the design, implementation, and use of research by our faculty and students, undergraduate and graduate, that addresses current education dilemmas and improves transdisciplinary and innovative science, technology, engineering, and mathematics educational policy and practice especially in P20 settings.

The Department of STEM Education is grounded in our college-wide framework of *Research and Reflection for Learning and Leading* and related to national accreditation standards through NCATE (National Council of Accreditation of Teacher Education). Our department-specific framework is guided by standards and recommendations from the following:

- National Research Council,
- American Association for the Advancement of Science,
- National Academy of Engineering and the American Society for Engineering Education,
- International Society for Technology in Education, and
- National Council of Teachers of Mathematics.

All six organizations stress an understanding of central discipline specific concepts as well as those that unite the disciplines, such as, the tools of inquiry, the importance of professional values/ethics, skills in the use of technology, and a commitment to multicultural competence and awareness.

The STEM Education mission and goals also guided faculty as they designed and developed the new Master of Science in STEM Education Program presented in this document. The program reflects over 24 months of brainstorming and research, innovative thinking and writing, and collaborative development and critical reviews of course syllabi by a host of individuals and faculty-governance bodies, including our Mathematics Education and Science Education Program Faculties containing faculty content experts, classroom teachers, and teacher leaders. The STEM PLUS$^+$ Program was approved by the UK College of Education, Graduate School, and Faculty Senate during the spring of 2010.

## STEM PLUS$^+$ Program Overview

STEM PLUS$^+$, *Producing +eacher Leaders for rUral Schools in STEM Education*, seeks to increase the number of teacher leaders in STEM Education, especially mathematics and science, for Kentucky's impoverished and chronically low performing rural schools. Created and implemented by a partnership consisting of the University of Kentucky's (UK) Colleges of Education, Engineering, and Arts and Sciences, the Partnership Institute for Mathematics and Science Education Reform (PIMSER), and the UK Field Network, STEM PLUS$^+$ will replace the UK's Master of Science in Secondary Education – Math/Science existing advanced certification Rank II program with a model STEM Education program that targets teachers in their rural or urban school districts, engages them in a redesigned, innovative Master's Degree Program, and provides them with meaningful support during the program.

The core of STEM PLUS$^+$ is an innovative, multi- and transdisciplinary Master of Science in Education/Rank II program through which current mathematics and science teachers will earn a STEM Education major with concentration, and Rank II certification, in their current specific STEM teaching discipline(s). The overarching goal of this program is to prepare teachers to assume diverse and innovative leadership responsibilities and roles that assure continuous improvement and student achievement. Teacher leadership, project-based instruction, literacy across the curriculum, curriculum and mentoring leadership, effective use of technology, and teaching diverse learners are issues that will unite the STEM education courses of the major.

In STEM PLUS$^+$, candidates will engage in coursework tailored to their needs as teacher leaders. They will experience coursework in STEM Education, STEM content, and leadership. Candidates will get an overview of STEM Education, what STEM is, how to implement STEM curriculum and instruction into mathematics and science classrooms effectively, content specific coursework to further their depth of content knowledge, and develop overall their STEM knowledge for teaching in addition to deepening their pedagogical content knowledge.

STEM PLUS$^+$ responds to the needs of its teachers and their high need urban or rural schools by creating unique programs for each future teacher leader tailored to their goals in their Professional Growth Plan and the needs of their districts. In addition, STEM PLUS$^+$ will help its future teacher leaders:

1. Connect theory and practice through reflection, teaching, scholarship, and STEM educational research.
2. Design authentic, project-based learning experiences that consider students of diverse backgrounds and perspectives.
3. Explore uses of appropriate assessments and technological tools to enhance STEM teaching and learning.
4. Develop communication skills through multiple forms of discourse and written, oral, and on-line narratives.
5. Explore and implement innovative and engaging curricula, especially around the Kentucky Core Academic Standards and College and Career Readiness.

In addition to the Unit's theoretical framework and the mission of the Department of STEM Education, the STEM PLUS$^+$ Program was guided by the following frameworks.

## STEM Education Conceptual Framework

Since the launch of Sputnik and the passing of the National Defense Education Act of 1958 in its wake (Carney, Chubin, & Malcom, 2008), the U.S. government and non-government organizations have continued to increase their funding of endeavors meant to improve K-20 STEM education, mostly with the ultimate goal of swelling the pipeline of individuals that will, eventually, grow the national STEM workforce (Carney et al., 2008; Kuenzi, 2008). More recent reports such as *A Nation At Risk* (National Commission on Excellence in Education, 1983) and *Rising Above the Gathering Storm* (Committee on Science, Engineering, and Public Policy, 2006) have kept the concern for STEM education reform paramount in the nation's psyche. *STEM*, the grouping of science, technology, engineering, and mathematics, is more than just a convenient acronym and the wide call for educators prepared to find commonalities while respecting disciplinary differences as they talk and teach across them is loud indeed.

All endeavors will be framed with a transdisciplinary design. We define *transdisciplinary* as engagement, investigation, innovation, and praxis addressing present-day issues and problems in a way that explicitly highlights discipline commonalities while respecting disciplinary expertise and practice within and across STEM (Thompson Klein et al., 2001; Nicolescu, 2002).

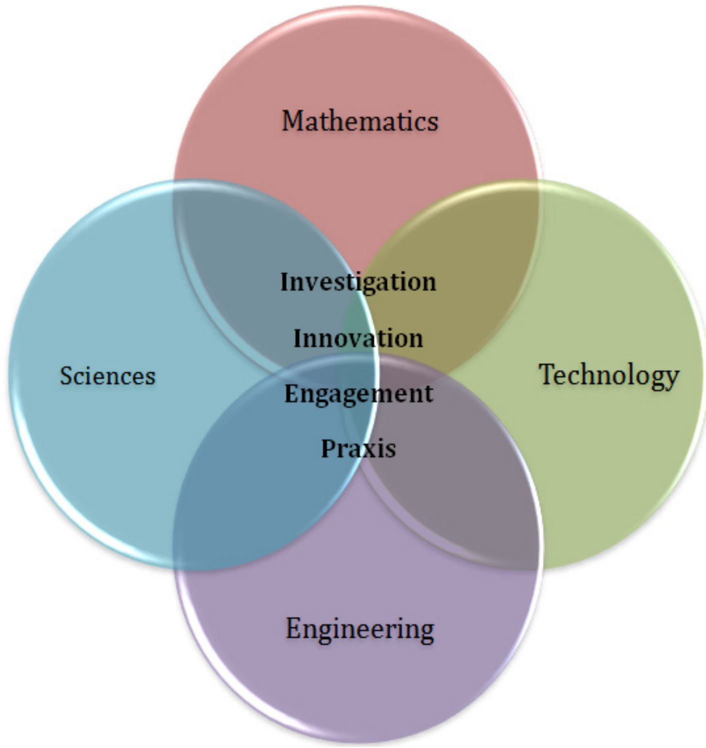



*Figure 2:* Transdisciplinary approach uniting UK STEM Education Department endeavors

Transdisciplinary and interdisciplinary work, such as that fostered by those within our master's degree program in STEM education, is of great promise in a world ever more "flat." Recognizing the need to prepare students for their "modern interdisciplinary futures" (Holley, 2009), interdisciplinary programs of study are being offered at most institutions of higher education[1] and have moved beyond a simply economic model regarding student benefits. They also allow for greater learner-centered pedagogy, both with respect to educator as learner and educators' future K-12 student learners; this occurs by engaging learners in practices and knowledge that unite disciplines and in meeting learners natural interests in their education pursuits, allowing for more well-rounded, practical, education applicable in an ever-changing world (Haynes, 2002; Holley, 2009).

The *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics [NCTM], 2000), *Benchmarks for Science Literacy* (American Association for the Advancement of Science [AAAS], 1993), and the *National Science Education Standards* [NSES] (National Research Council, [NRC], 1996) advocate curricula emphasizing the integration of the STEM disciplines. Much of science is grounded in mathematics; mathematics provides the

[1] More universities, including University of Kentucky's benchmarks, now encourage students' pursuit of interdisciplinary majors. These include the Program In Individualized Studies at the University of Washington, the Gallatin School of Individualized Studies at New York University, the University of Alabama's New College, and the Interdisciplinary Studies Program at Michigan State.

machinery for making sense of the world in an analytical and quantitative fashion. Science and engineering, on the other hand, provide a plethora of applications to which the theoretical underpinnings of math can be applied. Too often instruction under develops these important relationships. Strengthening the relationship among the STEM disciplines in both the educational and research venues will result in stronger, more cohesive learning and exploration in K-12 educational settings.

## Mathematics Education Conceptual Framework

As the gateway to the professional community, the Mathematics Education Program Faculty are charged with helping their candidates understand the principles guiding not only the professional teacher but the professional mathematician as well. As developed and outlined in the NCTM (2000) *Principles and Standards for School Mathematics*, these principles address (i) Equity, (ii) Curriculum, (iii) Teaching, (iv) Learning, (v) Assessment, and (vi) Technology and mesh well with the Kentucky Teacher Standards. For instance, NCTM's comment about equity, "that reasonable and appropriate accommodations be made as needed to promote access and attainment for all students" (NCTM, 2000, p. 12) fits well with Kentucky's Teacher Standard III "Creating and Maintaining a Learning Climate" and the position undergirding the Kentucky Education Reform Act (1990) and the most recent Senate Bill 1 (2010) legislation that all students can learn. Indeed, research (e.g., Silver and Stein, 1996) reports that when provided access to high-quality instruction, even students who traditionally have not succeeded in school mathematics programs show greater achievement than they otherwise would show. Clearly there is no panacea—this takes a great deal of work on the part of the classroom teacher, and it is fed not by the wafers seen in *Gulliver's Travels* (Swift, 1726), but rather by purposeful doses of reflection on his or her own teaching and that of colleagues. As NCTM (2000) puts it, "To accommodate differences among students effectively and sensitively, teachers also need to understand and confront their own beliefs and biases" (p. 13). Since teaching is influenced by teachers' norms and values, mathematics teachers must confront, acknowledge, and if necessary, change their beliefs in order to establish a positive and productive classroom community that will ensure learning of mathematics by all students.

Mathematics Education at UK extends and enhances the unit's conceptual framework by providing the opportunities and experiences necessary for advanced teachers to reflect on the perspective of the schools and the profession. Indeed, the National Council of Teachers of Mathematics (NCTM), the principal professional organization for our program, has for the past decade promoted teaching that fosters the development of students' abilities to explore, conjecture, and reason logically, as well as the ability to use a variety of mathematical methods to solve non-routine problems (NCTM, 1989; NCTM 1991; NCTM, 2000). In addition, the STEM PLUS$^+$ advanced certification program in STEM Education prepares mathematics candidates to meet Kentucky's Teacher Standards, benchmarks relating to a variety of aspects of pedagogy, collaboration, professional development, and subject matter knowledge. Teaching to meet these goals requires a great deal of reflective decision making, because what candidates teach depends to a large extent on how it has been learned. Consequently, this advanced certification program strives to blend the learning of mathematics with the learning of pedagogy.

Teachers' mathematical knowledge is essential for teaching (CBMS, 2001), and must be considered. Teachers need to have an understanding of school mathematics in order to teach it to a diverse group of students. With this knowledge they will be equipped to develop excitement and enthusiasm about mathematics as they deepen students' understanding of mathematics. Prospective teachers must not only have knowledge of the mathematics of their potential grade certification, but they must have a sense of the mathematics that occurs below and above their certification level. All in all, they must have mathematical proficiency and develop mathematical proficiency in the students they teach. The National Research Council (2001) argues that there are five strands of mathematical proficiency. These interwoven and interdependent strands include: (a) conceptual understanding, (b) procedural fluency, (c) strategic competence, (d) adaptive reasoning, and (e) productive disposition. In Mathematics Education at UK, advanced teachers develop a deeper proficiency in teaching mathematics. In other words, the future teacher leaders understand the mathematics they teach deeply (i.e., they have a deep understanding of the mathematical content-subject matter knowledge), understand how students learn mathematics, and know how to effectively help students in learning.

Curricular issues, likewise, need to be carefully considered. If the curriculum represents the mathematics to which students have access, it also, by nature of its coherence and the importance of the mathematics it addresses, determines what students *do* learn. As Stigler and Hiebert (1999) point out in their analysis of classroom instruction from the Trends in International Mathematics and Science Study (TIMSS), "big ideas," supported by insightful pedagogy, foster higher-level mathematical thinking, thus bridging the gap between the perspective of the mathematics student and the perspective of the mathematician. It is to this central tenet – that the teacher is the primary mediator between a beginner's understanding and the mathematician's sophisticated development, communication, and evaluation of mathematical ideas – that Mathematics Education at UK adheres. Developing a coherent and important curriculum *must* involve a great deal of planning, deep and flexible understanding of the subject matter, and sensitivity to developing a learning climate in which purposeful representation of important mathematics is played out in classroom instruction. The use of a few important ideas with which to engage students from a variety of perspectives can draw upon the strength of addressing different learning styles (see e.g., Davidson, 1990) and different kinds of intelligences (Gardner, 1993). In Mathematics Education at UK, candidates are prepared to examine and critically evaluate the coherence of a curriculum in terms of how it reflects central and important mathematics and to reflect on its articulation across grade levels. Consistency is vital.

"Teaching mathematics well is a complex endeavor, and there are no easy recipes for helping all students learn or for helping all teachers become effective" (NCTM, 2000, p. 16). However, most beginning teachers are in danger of being overwhelmed by the tension between being a student themselves and becoming a teacher (Jones, 1995; Loughran, 2007) and are not provided experiences in which they are encouraged and helped to develop the kinds of understanding of mathematics, of students, and of pedagogy that will ensure their effectiveness. In this advanced certification program, substantial attention is given to cultivating the above understandings and helping beginning and advanced teachers learn how to help their students see mathematics as both connected and meaningful. Prospective and advanced teachers develop the habits of mind of a mathematical thinker and demonstrate engaging styles of teaching. *Effective* mathematics teachers cultivate a challenging and supportive classroom environment; *effective* mathematics teachers engage their students in real problem-solving activity; *effective* mathematics teachers ask good mathematical questions and look at problems from multiple points of view*;* effective mathematics teachers learn how to learn mathematics and use this knowledge to efficiently and effectively teach their students*;* *effective* mathematics teachers are reflective when it comes to their teaching and have sufficient – and sufficiently supported – access to professional development (CBMS, 2001; Grouws, Cooney, & Jones, 1988; National Commission on Teaching and America's Future, 1996). These habits of mind that underpin our teacher certification program for mathematics teaching are made clear and explicit to prospective and advanced teachers as they learn about teaching and teaching to learn.

Making sense of mathematics is foundational to both the learning and teaching of mathematics. Brownell (1947), Skemp (1976), Hiebert and Carpenter (1992), and Bransford, Brown, and Cocking (1999) assert that conceptual understanding, factual knowledge, and procedural facility all are important. Attaining a useful balance among these three areas is difficult for teachers (Eisenhart et al., 1993) let alone for high school students. "Understanding breeds confidence and engagement; not understanding leads to disillusionment and disengagement" (Heibert, Carpenter, Fennema, Fuson, Wearne, Murray, Oliver, & Human, 1997; p. 2). Therefore, by pairing instruction in pedagogy with instruction focused on bringing a university perspective to bear on various mathematics topics, this program prepares advanced teachers to make the kinds of decisions that lead to students' willingness to engage in mathematical activity as well as to their achievement.

A crucial part of the teaching and learning of mathematics – from the teacher's perspective *and* the student's perspective – is assessment. "Assessment should support the learning of important mathematics and furnish useful information to both teachers and students" (National Research Council, 2001; NCTM, 2000, p. 22; Wiliam, 2007). Preparing for high-quality assessment relies on the teacher's ability to look deeply at his or her experience with *particular* subject matter and with *particular* students at a *particular* time, and the ability to use the information to which he or she has access in order to make good instructional decisions. Relying on different formats, focusing on different purposes, and drawing on purposefully selected problems and tasks, assessments are key in students' ability to solve problems of a variety of difficulty levels *and* their willingness to engage in mathematical study. In this certification program, teachers will be engaged in:

- Clarifying and sharing learning intentions and criteria for success;
- Engineering effective classroom discussions, questions, and learning tasks that elicit evidence of learning;
- Providing feedback that moves learners forward;
- Activating students as instructional resources for one another; and
- Activating students as owners of their own learning (Wiliam, 2007)

Finally, we see technology as a tool to enhance students' abilities to reason and solve problems, communicate both with and about mathematics, and establish meaningful connections due to the possibilities of representation afforded by technological devices. Yet, as with all issues surrounding the preparation of high quality teachers of mathematics, there is a need – perhaps a greater need – for reflection on one's teaching, for making decisions regarding what constitutes important mathematics, and for carefully planning purposeful instruction. The appropriate use of technology is seen not as a substitute for knowing a body of mathematical knowledge, but rather as an avenue to help students get to the heart of what it means to do mathematics.

This framework, informed by both experience and scholarship, is shared as a document with candidates in the program and teachers and administrators in the schools in which our candidates are placed. It also is shared through one-on-one interactions with colleagues in the schools and in our own unit. Further, as a program, we go to substantial lengths to model with our candidates our belief that teachers are reflective decision makers. From advisement to application, from admission to midpoint retention, from instruction in the classroom to supervised instruction in the field, and from early assignments to advanced certification, we strive to embody this framework.

## Science Education Conceptual Framework

The Science Education Program is designed to give candidates the theoretical background and pedagogical skills needed to become effective science practitioners. Candidates are introduced to a wide range of instructional materials and ideas that provide opportunities to make decisions relative to appropriate “hands on” and investigative activities for high school students that integrate real world issues national and state standards. Candidates are encouraged to be creative and reflective in developing, implementing, and evaluating plans for teaching secondary school science concepts and skills. A strong emphasis is placed upon teaching the processes of science as well as the content of science. Candidates are expected to have high expectations of all students and provide effective instruction for diverse student groups. Candidates are encouraged to prepare themselves for leadership roles in the schools in which they will serve.

Three main assumptions guiding the National Science Education Standards for science teaching (National Research Council, 1996) also serve as guiding principles for Science Education at UK. These include, (1) how students are taught greatly influences what they learn, (2) how teachers teach is greatly influenced by their perceptions of science as an enterprise and as subject knowledge to be taught and learned, and (3) students actively construct their understanding through individual and social practices. These principles are grounded in the enterprise of science, which is viewed as a human intellectual endeavor to understand and learn about the natural world, and use the knowledge to develop plausible and reasonable solutions to real world problems as well as to lead to advancements in technology. These principles are directly linked with goals outlined in the National Science Teachers Association (2003) and National Council for Accreditation of Teacher science teaching standards and in the Kentucky Program of Studies for high school science (2006). More specifically, the Kentucky Program of Studies states:

> *The science program in high school should provide opportunities for students to think and work like scientists. Applying factual knowledge in real-world scientific contexts allows students to refine the abilities that are the basis of scientific inquiry. These abilities include: (1) identifying questions and concepts that guide scientific investigations, (2) designing and conducting scientific investigations, (3) using technology and mathematics to improve investigations and communications, (4) formulating and revising scientific explanations and models using logic and evidence, (5) recognizing and analyzing alternative explanations and models and (6) communicating and defending a scientific argument, (p.510).*

Thus, the program emphasizes inquiry and other problem solving approaches (e.g., project based design, engineering design, modeling-based inquiry) as ways for learning about the natural world, and as instructional strategies for learning science. Multiple experiences are included throughout the program for program candidates to review studies on using inquiry in science instruction, conduct inquiries into scientific issues and their own instructional practice. These experiences are consistent with the views shared in the National Educational

Technologies Standards for Students and Teachers ([NETS] International Society for Technology in Education, 2007, 2008), Standards for Technological Literacy (International Technology Education Association (2007), the NSTA Positions on Teacher Preparation (2003), and the National College Association for Teacher Education (NCATE).

Previous research studies have underscored the importance of teachers' content knowledge on determining student achievement (Darling-Hammond, 2000; Perkes, 1967-1968; Sanders & Rivers, 1996; Wright, Horn, & Sanders, 1997). Wright, Horn, and Sanders (1997) found teacher effects had the greatest impact on student achievement in comparison to other factors including class size and group heterogeneity. The program draws heavily on what is known about students' learning science, and effective teaching practices, modeling these practices for candidates as well as providing them opportunities to implement strategies in their own instruction and assess the learning outcomes. Readings and discussions include a wide range of resources including, but not limited to, philosophy and history of education, working with students from diverse backgrounds, effective teaching strategies, achievement gap, ethics of teaching, intelligence and technology, multicultural issues, asking and answering action research questions, development, learning, motivation, and goals and strategies of teaching science.

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