TENNESSEE CONSORTIUM ON RESEARCH, EVALUATION & DEVELOPMENT

THEC STEM Professional Development Program:

ROUND ONE EVALUATION REPORT

NOVEMBER 2013

CARLA J. JOHNSON

VANDERBILT PEABODY COLLEGE

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TABLE OF CONTENTS

Content……...i
Figures……iii
Tables……...iv
Executive Summary……v

SECTION ONE
Introduction…… 1
Background……1

SECTION TWO
Research Methods……... 3
Research Questions……3
Core Conceptual Framework……..3
Data Collection and Analysis…….. 4
Teacher Observation Data……..4
Classroom Observation Instrument……4
Response Rate - Teacher Observation Data…… 6
Analysis of Teacher Observation Data……... 6
Teacher Survey Data……...7
Teacher Survey Instruments……...7
Response Rate - Teacher Survey……7
Analysis of Teacher Survey Data……...8
Teacher Content Assessments……8
Content Assessment Instrument……8
Limitations……9

SECTION THREE
Findings Overall for THEC STEM PD Investment – Research Question 1……10
Classroom Observation Findings……..10
Design Lesson…….. 10
Implementation of Lesson……12
Classroom Culture……14
Mathematics/Science Content Domain…… 16
Content Knowledge Assessment Findings……18

SECTION FOUR

Findings Overall for THEC STEM PD Investment – Research Question 2……....20
Teacher Survey Findings……...20
Teacher Opinions Related to STEM Teaching……..20
Teacher Perceived Importance Related to STEM Teaching…….. 20
Instructional Influences……21
Teacher Preparedness……... 22
Frequency of Use of Effective Pedagogy…….. 22
Student Activities……..22
Parental Support……... 23
Principal Support……..23
Professional Development Experiences……24

SECTION FIVE

Concluding Observations……..25
Improved Pedagogical Skills……25
Improved Content Knowledge……25
Improved Opinions……..25
Programs Considered Best Practice……...26
Summary……...26

References……...27

Appendix……28
Austin Peay State University (APSU)–Assad and Wells, PIs……..29
East Tennessee State University (ETSU)–Rhoton and Zhao, PIs……..37
East Tennessee State University (ETSU)–Tai and Ho, PIs……44
Lipscomb University–Hutchinson and Boyd, PIs……..52
Middle Tennessee State University (MTSU)–Winters and Kimmins, PIs……...60
Tennessee Technological University (TTU)–Anthony and Smith, PIs……...68
Tennessee Technological University (TTU)–Baker and Fromke, PIs…… 76
Tennessee Technological University (TTU)–Gore and Hunter, PIs……...83
Tennessee Technological University (TTU)–Ramey and Rust, PIs……....91
University of Tennessee-Chattanooga (UTC)–McAllister and Ebiefung, PIs……99
University of Tennessee-Chattanooga (UTC)–Wigal and Cowan, PIs……..106

List of Figures

Figure 1. Design Average Score Over Time for Round One Programs……11
Figure 2. Design Average Score Over Time by Program Classification for Round One Programs……... 12
Figure 3. Implementation Average Score Over Time for Round One Programs……... 13
Figure 4. Implementation Average Score Over Time by Type for Round One Programs……..14
Figure 5. Classroom Culture Average Score Over Time for Round One Programs……... 15
Figure 6. Classroom Culture Average Score Over Time by Program Classification for Round One Programs……... 16
Figure 7. Mathematics/Science Content Average Score Over Time for Round One Programs….17
Figure 8. Mathematics/Science Content Average Score Over Time by Program Classification for Round One Programs…….. 18

LIST OF TABLES

Table ES1. LSC Overall Rating……vii
Table ES2. Classroom Observation Findings – Round One Programs……..vii
Table ES3. Teacher Survey Findings: Teacher Opinions……..viii
Table ES4. Teacher Survey Findings: Teacher Perceived Importance…… ix
Table ES5. Teacher Survey Findings: Instructional Influences – Encourages Effective Instruction…….. x
Table ES6. Teacher Survey Findings: Teacher Preparedness……..xi
Table ES7. Teacher Survey Findings: Frequency of Use of Effective Pedagogy…… xii
Table ES8. Teacher Survey Findings: Student Activities……...xiii
Table ES9. Teacher Survey Findings: Parental Support……xiv
Table ES10. Teacher Survey Findings: Principal Support……xiv
Table ES11. Teacher Survey Findings: Professional Development Experiences……xv
Table 1. Round One THEC STEM Professional Development Funded Programs……2
Table 2. LSC Domains……... 5
Table 3. LSC Overall Rating……... 5
Table 4. Pre- and Post-Average Percent Correct by Program Classification……...19

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EXECUTIVE SUMMARY

In 2010, as part of Tennessee's Race to the Top grant, The Tennessee Higher Education Commission (THEC) received funding for the implementation of STEM (science, technology, engineering, and mathematics) Professional Development (STEM PD) across the state of Tennessee. A request for proposals (RFP) was released in April 2011. This RFP focused on delivery of professional development designed to promote innovative practices in STEM education, and participating programs were expected to emphasize the improvement of STEM teacher pedagogical skills and content knowledge. Round One (2011-12) funding was distributed across 11 programs, and 18 programs were funded in the second round (2012-13). This report addresses programs participating in Round One. The research questions guiding this evaluation include:

1. What impact, if any, do THEC STEM professional development programs have on teachers' pedagogical skills and STEM content knowledge?
2. What impact, if any, do THEC STEM professional development programs have on teachers' opinions regarding the teaching of STEM?
3. Which funded STEM professional development programs demonstrate significant growth in Teacher Quality (pedagogical skills and content) and should be considered for inclusion as best practice for Tennessee?

Round One of the THEC STEM PD program included three high school Chemistry focused programs (Tennessee Tech University, Lipscomb University, and East Tennessee State University), two elementary science programs (Tennessee Tech University, East Tennessee State University), four primary/elementary school level mathematics programs (Tennessee Tech University, Austin Peay University, Middle Tennessee State University, and University of Tennessee-Chattanooga), and two middle school level mathematics programs (Tennessee Tech University, University of Tennessee-Chattanooga).

CORE CONCEPTUAL FRAMEWORK

THEC STEM PD programs were required to organize the delivery of their programs around the Core Conceptual Framework for Effective Professional Development (Desmione, 2009) as the organizing framework. The five components of the framework include: content knowledge focus, active learning experiences, coherence with state/district goals and standards, extended duration of program, and collective participation of teams of teachers from individual schools. Round One funded programs described within their proposals how they would address each of the five components of the framework within the context of their STEM PD.

Study Methods

This evaluation used both qualitative and quantitative data to determine the impact of the Round One THEC STEM PD programs. Data collection included teacher classroom observations (video-recorded), two teacher surveys, and program developed pre/post assessments of mathematics or science content knowledge.

Classroom Observations

Each teacher was required to submit three recordings of their teaching: one prior to participation in the THEC STEM PD program, one mid-way through the program, and the final video at the end of the program. Each video was scored using the Local Systemic Change Classroom Observation Protocol (LSC), which was developed by Horizon Research for use with the National Science Foundation's (NSF) funded State Systemic Initiatives (SSI) as a measure of reform-based instructional practices in science and mathematics. The instrument examines design of lesson, implementation of lesson, culture of instruction, and content knowledge delivered.

Teacher Surveys

Participants also completed two surveys in a pre/post manner for the THEC STEM PD programs. The first survey was the Local Systemic Change Teacher Questionnaire (LSCTQ) appropriate to their content and grade level (e.g., science or mathematics, K-6 or 7-12). The LSCTQ was also designed for use with NSF's SSI programs. The Survey of Enacted Curriculum (SEC) was the second survey used for the THEC STEM PD programs. The SEC survey was developed by the SEC Collaborative and used extensively to evaluate STEM teaching quality and alignment of instruction to academic standards.

Program-Developed Pre/Post Content Assessments

Each program was required to develop their own 25-item pre/post content knowledge assessment for participating teachers to complete. Programs provided copies of their assessments, keys, and spreadsheets of teacher individual item responses for the evaluation.

KEY FINDINGS

Overall Findings

Classroom Observations

Overall, the THEC STEM PD programs significantly improved in all four domains (design, implementation, culture, and content) from baseline to end of program. Design of lesson includes the planning, organization, resources, attention to equity, level of collaboration, flow of lesson, assessments, and sense making that take place during the delivery of lesson. Implementation of lesson consists of the level of investigative mathematics/science included, quality of management of classroom, pace of lesson, modifications made, questioning strategies, and formative assessments

included in the delivery of the lesson. Classroom culture refers to the amount of active participation of all students and level of collaborative learning, including having students explore their own ideas, questions, conjectures, and propositions or to challenge the ideas of others. Finally, the mathematics/science content knowledge domain focuses on the accuracy of content knowledge delivered by the teacher, as well as the alignment of content to appropriate grade and student levels of understanding.

Each item within each domain ranges is scored on a scale of 0 to 5, with 0 being used when there is no evidence of a component within a domain, and a score of 5 awarded when a component is used "to a great extent". Each domain has multiple questions that are scored individually, and an overall rating (i.e., mean score) for each domain is generated (see Table ES1).

Table ES1. LSC Overall Rating

Score	Title
0-1.9	Ineffective Instruction
2-2.9	Elements of Effective Instruction
3-3.9	Beginning of Effective Instruction
4-4.9	Accomplished, Effective Instruction
5	Exemplary Instruction

Table ES2. Classroom Observation Findings – Round One Programs

Domain	Baseline Rating	End Rating	Classification
Design	2.26	2.49	Elements of Effective Instruction
Implementation	2.48	2.96	Elements of Effective Instruction
Classroom Culture	2.57	3.10	Elements of Effective Instruction
Content Knowledge	2.70	3.26	Elements of Effective Instruction

Teacher Surveys

Teacher surveys included the constructs of: teacher opinions, teacher perceived importance, instructional influences, teacher preparedness, frequency of use of effective pedagogy, student activities, parental support, principal support, and professional development experiences. An analysis of data for the Round One Programs indicated participants overall experienced significant growth in all of these areas. Findings for each of these constructs are presented in Tables ES2-ES10 below.

Table ES3. Teacher Survey Findings: Teacher Opinions

Construct	Baseline % Agreement	End % Agreement
Students generally learn science/math best in classes with students of similar abilities.	54%	49%
I feel supported by colleagues to try out new ideas in teaching science/math.	82%	86%
Science/math teachers in this school have a shared vision of effective science/math instruction.	68%	70%
Science/math teachers in this school regularly share ideas and materials related to science/math.	68%	74%
Science/math teachers in this school are well supplied with materials for investigative science/math instruction.	43%	46%
I have time during the regular school week to work with my peers on science/ math curriculum and instruction.	38%	38%
I have adequate access to computers for teaching science/math.	48%	48%
I enjoy teaching science/math.	93%	96%
The science/math program in this school is strongly supported by local organizations, institutions, and/or business.	23%	35%

Table ES4. Teacher Survey Findings: Teacher Perceived Importance

Construct	Baseline % Agreement	End % Agreement
Provide concrete experiences before abstract concepts.	67%	75%
Develop students' conceptual understanding of science/math.	83%	87%
Take students' prior understanding into account when planning curriculum and instruction.	80%	83%
Make connections between science/math and other disciplines.	72%	78%
Have students work in cooperative learning groups.	65%	69%
Have students participate in appropriate hands-on activities.	82%	86%
Engage students in inquiry-oriented activities.	70%	80%
Have students prepare project/ laboratory/research reports.	26%	36%
Use computers.	36%	49%
Engage students in application of science/math in a variety of contexts.	65%	69%
Use performance-based assessment.	48%	57%
Use portfolios.	18%	22%
Use informal questioning to assess student understanding.	67%	77%

Table ES5. Teacher Survey Findings: Instructional Influences – Encourages Effective Instruction

Construct	Baseline % Agreement	End % Agreement
State and/or district curriculum frameworks.	51%	58%
State and/or district testing policies and practices.	37%	36%
Quality of available instructional materials.	44%	58%
Access to computers for science/math instruction.	44%	53%
Funds for purchasing equipment and supplies for science/math.	26%	36%
System of managing instructional resources at the district/school level.	31%	44%
Time available for teachers to plan and prepare lessons.	30%	50%
Time available for teachers to work with other teachers.	31%	45%
Time available for teacher professional development.	43%	60%
Importance that the school places on science/math.	67%	69%
Consistence of science/math reform efforts with other school/district reforms.	41%	52%
Public attitudes toward reform.	19%	33%

Table ES6. Teacher Survey Findings: Teacher Preparedness

Construct	Baseline % Agreement	End % Agreement
Provide concrete experiences before abstract concepts.	67%	91%
Develop students' conceptual understanding of science/math.	69%	94%
Take prior understanding into account when planning curriculum & instruction.	82%	93%
Make connections between science/math and other disciplines.	71%	90%
Use of cooperative learning groups.	80%	92%
Have students participate in appropriate hands-on activities.	77%	96%
Engage students in inquiry-oriented activities.	50%	88%
Have students prepare project/ laboratory/research reports.	26%	64%
Use computers.	60%	84%
Engage students in applications of science/math in a variety of contexts.	56%	90%
Use performance-based assessment.	72%	87%
Use portfolios.		
Use informal questioning to assess student understanding.	81%	90%
Lead a class of students using investigative strategies.	51%	86%
Manage a class of students engaged in hands-on/project-based work.	73%	95%
Help students take responsibility for their own learning.	69%	88%
Recognize and respond to diversity.	70%	88%
Encourage students' interest in sci/math.	79%	95%
Use strategies that specifically encourage participation of females/minorities.	54%	82%

Table ES7. Teacher Survey Findings: Frequency of Use of Effective Pedagogy

Construct	Baseline % Agreement	End % Agreement
Introduce content through formal presentations.	70%	73%
Demonstrate a science/math-related principle or phenomenon.	66%	72%
Teach science/math using real-world context.	88%	85%
Arrange seating to facilitate student discussion.	78%	86%
Use open-ended questions.	79%	89%
Require students to supply evidence to support their claims.	68%	85%
Encourage students to explain concepts to one another.	77%	83%
Encourage students to consider alternative explanations.	64%	80%
Allow students to work at their own pace.	71%	78%
Help students see connections between science/math and other disciplines.	65%	76%
Use assessment to find out what students know before or during a unit.	62%	69%
Embed assessment in regular class activities.	84%	84%
Assign science/math homework.	67%	66%
Read and comment on the reflections students have written in their notebooks or journals.	24%	48%

Table ES8. Teacher Survey Findings: Student Activities

Construct	Baseline % Agreement	End % Agreement
Participate in student-led discussions.	45%	68%
Participate in discussions with the teacher to further science/math understanding.	80%	86%
Work in cooperative learning groups.	86%	88%
Make formal presentations to the class.	15%	27%
Read from a science/math textbook in class.	38%	37%
Read other science/math-related materials in class.	36%	47%
Review homework/worksheet assignments.	78%	70%
Work on solving a real-world problem.	63%	75%
Share ideas or solve problems with each other in small groups.	75%	79%
Engage in hands-on science/math activities.	67%	82%
Follow specific instructions in an activity or investigation.	64%	74%
Design or implement their own investigation.	19%	34%
Work on models or simluations.	21%	36%
Work on extended science/math investigations or projects.	8%	23%
Participate in field work.	3%	14%
Record, represent, and/or analyze data.	25%	43%
Write reflections in a notebook/journal.	32%	52%
Work on portfolios.	8%	18%
Take short-answer tests.	56%	49%
Take tests requiring open-ended responses.	38%	46%

Table ES9. Teacher Survey Findings: Parental Support

Construct	Baseline % Agreement	End % Agreement
Volunteer to assist with class activities.	1%	7%
Donate money or materials for classroom instruction.	6%	11%
Attend parent-teacher conferences.	31%	37%
Attend school activities such as PTA meetings and Family Science/Math nights.	6%	11%
Voice support for the use of an investigative approach to science/math.	4%	10%
Voice support for traditional approaches to science/math instruction.	7%	10%

Table ES10. Teacher Survey Findings: Principal Support

Construct	Baseline % Agreement	End % Agreement
Encourages selection of science/math content and instructional strategies to address individual students' learning.	80%	81%
Accepts the noise that comes with an active classroom.	83%	84%
Encourages the implementation of current national standards in science/ math education.	84%	90%
Encourages innovative instructional practices.	86%	90%
Enhances the science/math program by providing me with needed materials and equipment.	56%	60%
Provides time for teachers to meet and share ideas with one another.	53%	57%
Encourages me to observe exemplary science/math teachers.	40%	44%
Encourages me to make connections across disciplines.	68%	79%
Acts as a buffer between teachers and external pressures.	71%	65%

Table ES11. Teacher Survey Findings: Professional Development Experiences

Construct	Baseline % Agreement	End % Agreement
Participating in PD has increased my science/math content knowledge.	21%	41%
Participating in PD has increased my understanding of how children think about and learn science/math.	24%	38%
Participating in PD has increased my ability to implement high-quality science/math instructional materials.	25%	38%

Program-Developed Pre/Post Content Assessments

The analysis of data provided by Round One programs revealed significant growth in STEM content knowledge for THEC PD programs. Participants in the elementary mathematics and science programs demonstrated the most growth, however.

Individual Program-level Findings

In addition to the overall THEC STEM PD Round One collective program analysis, individual program analyses were conducted and narratives for each funded program have been included in the report. Five of the funded programs realized significant growth in all areas (e.g., classroom observations, teacher surveys, teacher content knowledge assessment). The programs that have been determined to represent best practice in STEM PD for the state of TN include: Tennessee Tech University – chemistry program, East Tennessee State University – chemistry program, Tennessee Tech University – elementary science program, East Tennessee State University – elementary science program, and Austin Peay University – elementary mathematics program.

SUMMARY

Overall, the evaluation of the THEC STEM PD Round One programs revealed significant growth in science and mathematics teacher effectiveness and attitudes. At an individual program level, five programs realized significant growth for participants as well. The full report will provide additional detail on the findings highlighted in this Executive Summary and will offer insight into the individual programs in an effort to provide a better understanding of experienced growth.

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I. INTRODUCTION

BACKGROUND

In April 2011 the Tennessee Higher Education Commission (THEC) released a request for proposals (RFP) for the first round of Race to the Top funded STEM Professional Development (PD) programs. Eleven programs were funded across the state of Tennessee in Round One (Table 1). The purpose of the THEC STEM Professional Development program is to promote innovative practices in STEM (science, technology, engineering, and mathematics) education by further developing K-12 STEM teachers' pedagogical skills and content knowledge. In addition, the PD programs funded through this grant program and determined to be highly effective will be shared throughout the STEM Innovation Network. Highly effective programs are defined as those that have significant gains in teacher pedagogical skills and content knowledge.

The primary objectives of the program are:

1. To deliver high quality, research-based STEM professional development to K-12 teachers to improve pedagogical skills and content knowledge.
2. To align with the goals of Tennessee's First to the Top plan, including School readiness, College and Career readiness, Implementing the Common Core Standards, and Postsecondary Access and Success.
3. To create a STEM Professional Development best-practices warehouse for use throughout Tennessee's STEM Innovation Network (TSIN) to ensure sustainability of this PD beyond funding from Race to the Top. Through replication and sustainability, it is intended that those PD programs that are models of good practice will and can be accessed and replicated widely throughout the TSIN in order to foster deeper learning of STEM content knowledge for all students.

This annual evaluation report will focus on the complete analysis of data collected for the Round One STEM PD programs (Table 1). Round Two programs have submitted only baseline data at this point. Consequently, the evaluation of Round Two programs will be completed by June 2014. Furthermore, the Final Report for the THEC STEM PD programs (to be submitted June 2014) will include a comprehensive evaluation of all 29 funded programs. Due to the timing of this report we focus only on reporting quantitative data for Round One programs.

Table 1. Round One THEC STEM Professional Development Funded Programs

Institution	Focus Area
Tennessee Technological University	Chemistry
Lipscomb University	Chemistry
East Tennessee State University	Chemistry
Tennessee Technological University	3-5 Science
East Tennessee State University	3-5 Science
Tennessee Technological University	Middle Math
University of Tennessee-Chattanooga	Math
Tennessee Technological University	1-3 Math
Austin Peay State University	3-5 Math
Middle Tennessee State University	2-6 Math
University of Tennessee-Chattanooga	K-2 Math

II. RESEARCH METHODS

RESEARCH QUESTIONS

Three research questions, listed below, guided this evaluation. All are aligned with the primary objectives of the THEC STEM PD Program:

1. What impact, if any, do THEC STEM professional development programs have on teachers' pedagogical skills and STEM content knowledge?
2. What impact, if any, do THEC STEM professional development programs have on teachers' opinions regarding the teaching of STEM?
3. Which funded STEM professional development programs demonstrate significant growth in Teacher Quality (pedagogical skills and content) and should be considered for inclusion as best practice for Tennessee?

CORE CONCEPTUAL FRAMEWORK

Much has been learned through recent attempts at designing professional development programs for STEM teachers. As the knowledge base on educational reform and improving teacher quality has grown over the past decade (e.g., Johnson, Kahle, & Fargo, 2007a, 2007b; Johnson & Fargo, 2010; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2007; Putnam & Borko, 1997) it has become more evident that traditional professional development formats do not result in sustained change in practice. Professional development linked to state and/or district reform initiatives have demonstrated the ability to transform educational practice systemically (Desimone, 2009). However, since enactment of the *No Child Left Behind Act of 2001* few attempts have been made to explore the ability of effective teacher quality programs to achieve systemic reform (Desimone, 2009; Johnson et al., 2007b).

Desimone (2009) published a seminal paper wherein she conducted a rigorous review of empirical studies of professional development to produce a core conceptual framework for research-based, effective professional development, defined as models that have had positive impact on "increasing teacher knowledge and skills and improving their practice, which hold promise for student achievement" (p. 183). The components of the core conceptual framework include content knowledge focus, active learning experiences, coherence with state/district goals and standards, extended duration of a program across academic year(s), and collective participation of teams of teachers from same school.

THEC required all submitted proposals to include these five core components in the design of their programs. All funded PD projects included the core components as the basis into which they inserted their content and context. At the end of the THEC STEM PD program, we expect to report details on the funded programs and the content and context of programs that were successful in achieving change in teacher practice.

In most of the published research on professional development in small settings, it has taken at least two years before significant change in teacher effectiveness has been realized. The THEC STEM PD program has provided the setting for the first large-scale implementation of the research-based core conceptual framework for effective professional development. Moreover, Tennessee has taken steps to integrate research into the significant Race to the Top investment, and the evaluation of the THEC STEM PD program will provide much-needed insight into educational reform.

DATA COLLECTION AND ANALYSIS

The evaluation of Round One STEM PD programs included a variety of qualitative and quantitative data to investigate the impact of THEC STEM PD. The data collection and analysis activities for this report included teacher classroom observations in digital recording format and two surveys completed by participating teachers. Each of these is described in more detail below.

Teacher Observation Data

Teacher observations were conducted for use in determining potential increased use of STEM pedagogical skills and STEM content knowledge for THEC STEM PD participants. Each participating teacher in all funded STEM PD programs was asked to submit three digital recordings of an appropriate STEM lesson. The first recording was to be conducted prior to beginning participation in the THEC STEM PD program. The second was to occur at the mid-point of participation (August 2012) and the final recording was to be completed and submitted by December 2012.

Classroom Observation Instrument

The Local Systemic Change (LSC) Classroom Observation Protocol is an observation tool used to assess the degree of instructional reform in math and science. The LSC protocol was developed by Horizon Research for use with the National Science Foundation's (NSF) funded State Systemic Initiatives (SSI) as a measure of reform-based instructional practices. The LSC Classroom Observation Protocol is being used as the measure of growth in teacher pedagogical skill use and is one measure of teacher content knowledge for the THEC STEM PD program. The LSC tool is valid for use in this evaluation based on the research-based foundation and wide-scale implementation of the LSC protocol in many empirical studies. Using the LSC, teacher instruction is observed and given ratings on 32 items included in four domains (see Table 2).

Table 2. LSC Domains

Domain	Number of Items
Design of Lesson	10
Implementation of Lesson	7
Classroom Culture	6
Math/Science Content	9

The *Design of Lesson* domain focuses on the structure of the observed lesson and investigates a variety lesson considerations such as the sequencing of instructional activities, roles of students and teachers, resources available, eliciting of prior knowledge, time provided for sense making, attention to diversity, and collaborative learning. The *Implementation of Lesson* domain examines the use of investigative STEM strategies employed by the teacher, as well as the pace of the lesson, attention to student understanding, questioning strategies, and both formative and summative assessments. The *Classroom Culture* domain assesses a teacher's ability to create and facilitate a classroom environment which supports active participation, respect for ideas, effective collaboration, and inquiry into student ideas, questions, and real-world connections. The *Mathematics/Science Content* domain examines teacher understanding of content, as well as appropriateness of the level of content included in the lesson, the level of student engagement with content, and interdisciplinary and real-world connections presented by the teacher.

Each item within each domain ranges is scored on a scale of 0 to 5, with 0 being used when there is no evidence of a component within a domain, and a score of 5 awarded when a component is used "to a great extent". Each domain has multiple questions that are scored individually, and an overall rating (i.e., mean score) for each domain is generated (see Table 3).

Table 3. LSC Overall Rating

Score	Title
0-1.9	Ineffective Instruction
2-2.9	Elements of Effective Instruction
3-3.9	Beginning of Effective Instruction
4-4.9	Accomplished, Effective Instruction
5	Exemplary Instruction

An overall score of 0 to 1.9 is characterized with a rating of *Ineffective Instruction*. The LSC protocol describes this as a classroom where there is "little or no evidence of student thinking or engagement with important ideas of mathematics/science. Instruction is highly unlikely to enhance students' understanding of the discipline or to develop their capacity to successfully do mathematics or science". With this rating, the delivered lesson is characterized as either *passive learning* or *activity for activity's sake*. Passive learning is when students are passive recipients of information from the teacher

or textbook. Activity for activity's sake happens when a hands-on activity is employed with no clear purpose and does not lead to student conceptual development of STEM.

An overall score of 2-2.9 receives the rating of *Elements of Effective Instruction*. The LSC protocol describes this as a classroom where "instruction contains some elements of effective practice but there are serious problems in the design, implementation, content, and/or appropriateness for many students in the class". Examples of this are inappropriate content and/or level of content, lack of ability to address student difficulties, lack of opportunities for inquiry and investigation of student ideas, and problem solving.

An overall score of 3-3.9 is classified as *Beginning Stages of Effective Instruction*. The LSC protocol describes this as a classroom where, "instruction is purposeful and characterized by quite a few elements of effective practice". In this classroom, students are engaged in meaningful work at times but there are still a few weaknesses with the delivery of the lesson.

An overall score of 4-4.9 is characterized as *Accomplished, Effective Instruction*. The LSC protocol describes this as a classroom that is, "purposeful and engaging for most students". Students are engaged in meaningful work, including investigations, and the lesson is well designed and implemented. Some limitations in ability to adapt content and/or pedagogy still exist and ability to respond to student needs is also limited. Instruction is "*quite likely*" to enhance student ability to do STEM.

An overall score of 5 is *Exemplary Instruction*. The LSC protocol describes this a classroom where, "*purposeful instruction* [is occurring] *and all students are highly engaged most or all of the time with meaningful work*". The lesson is "*artfully implemented*"; the teacher is flexible and responds to student needs and interests; and instruction is highly likely to enhance student understandings of the discipline and to develop their capacity to do STEM.

Response Rate - Teacher Observation Data

For Round One, 252 teachers were observed at least once. Of those 252 teachers, 77 teachers (30.6 percent) completed two full observations, which were then scored, and 124 teachers (49.2 percent) completed and had scored three full observations. These teachers will serve as the sample for this report, as they participated in the entire PD program and provide the most accurate measure of change over time. Of the 124 teachers with three observations, a majority of participants are female (83.9 percent, n = 104) and White (95.2 percent, n = 118).

Analysis of Teacher Observation Data

Teacher videos were rated by a team of evaluators and analyzed quantitatively. All videos were viewed and scored by two independent raters using the LSC Classroom Observation Protocol in four domains, including design of lesson, implementation of lesson, mathematics/science content knowledge, and classroom culture, as well as an overall rating. This measure is used to determine improvement in teacher pedagogical skills and content knowledge as demonstrated through actual teacher practice.

Total scores for each domain were computed. Each domain section was comprised of a different number of total items (see Table 2). Individual item ratings ranged from 1-5 with 1 being lowest and 5 being highest (see Table 3). In addition to the domain rating, an overall rating was also assigned to each teacher for each lesson. To assess teacher growth in specific classroom practices over time and by program classification (high school chemistry, elementary science, primary math, elementary math, middle grades math) a 3-Within, 5-Between Repeated Measures ANOVAs with post-hoc investigation for differences at each observation time and between program classification groups was conducted. Finally, growth examinations between all observation time points using 3-Within Repeated Measures ANOVAs with post-hoc investigation for each specific program's STEM Teacher Quality results are conducted. Since sample sizes for individual programs are small, one-tailed tests were run to increase the sensitivity for finding statistically significant differences over time.

Teacher Survey Data

Two measures were used in this evaluation to determine teacher-reported growth in use of effective pedagogical skills, as well as potential change in opinions for participants in the funded THEC STEM PD programs. This data was in addition to classroom observation data, which also examined use of effective pedagogical content knowledge. Participants completed appropriate questionnaires for their grade band and content area. Participants also completed the surveys in a pre/post manner for the program online through Survey Monkey, prior to participation in the PD and at the end of the PD program.

Teacher Survey Instruments

Two surveys were used in this evaluation. The LSC Teacher Questionnaires (e.g., mathematics and science versions for K-8 and 9-12) were selected based upon their alignment with the LSC Classroom Observation protocol (used for the classroom observational data) and previous use in the NSF funded SSIs (http://www.horizon-research.com/LSC/news/heck_rosenberg_crawford_2006a.php). Additionally, the Survey of Enacted Curriculum (SEC), developed by the SEC Collaborative (https://secure.wceruw.org/seconline/secWebHome.htm), which has been used extensively in Georgia, Kansas, Kentucky, Michigan, Mississippi, and Ohio, is a second research-based instrument used for the evaluation. Collectively, the two instruments were used to measure preparedness to teach STEM, influences on instruction, beliefs regarding STEM teaching, parental and principal support, and quality of PD experiences.

Response Rate - Teacher Survey

A total of 168 teachers from the 11 Round One programs completed both a pre- and post-survey. These 168 teachers serve as the sample for this report. Of this sample, 115 participants (68 percent) were from Math K-8 programs, 33 participants (19.5 percent) were from Science K-8 programs, 20 participants (11.8 percent) were from Science 9-12 programs, and only 1 teacher (0.6 percent) was from Math 9-12 programs.

Analysis of Teacher Survey Data

A 2-between 2-within Factorial ANOVA was employed to assess overall growth from pre/post regardless of the PD group and also look for differences in growth by PD content area (science vs. math). Next, multiple Chi-Square Tests of Independence were employed to examine pre- to post-survey response percent growth for individual items regardless of the PD program. Finally, because it is very difficult to change teacher beliefs and perceptions, one-tailed tests were implemented to increase the power for finding statistical differences. Further, we considered any pre/post improvement at the $p < .10$ to be statistically significant.

Teacher Content Assessments

Each program developed their own content assessments (25 items as requested by the RFP) to determine participant growth in content knowledge. Each program submitted copies of assessments, keys, and a spreadsheet with individual teacher responses to each item for pre/post.

Content Assessment Instrument

Each professional development program created their own assessment of teacher content knowledge aligned with content and grade levels covered in their individual program. As a result, all teacher content knowledge assessment items are different across tests. However, all assessment developers were to follow the same guidelines when creating and distributing tests: 1) pre- and post-test items given to teachers should consist of the same items on both tests; 2) all items should be objective type items (scored as correct/incorrect rather than subjectively scored with a rubric); 3) assessments should be comprised of 25 items; and 4) teachers needed the same identification number in each pre- and post-test files to allow for pre/post content knowledge comparison. Most of the eleven round one programs followed these guidelines with the exception of three programs which used subjectively scored items (programs 7 and 9), a differing number of pre- and post-test items (program 3), or did not identify teachers with the same code in pre- and post-test files (program 3). As such, data from programs 3, 7, and 9 were not included in analyses because they did not follow the assessment creation and distribution guidelines in ways that made comparison of pre/post teacher content knowledge results impossible. While some programs distributed more or less than 25 items on their assessments, participants in these groups were not eliminated from analysis because percentage correct was used as the metric for comparison rather than total number of items correct.

Regardless of the Tennessee Race to the Top STEM PD program teachers were involved in, teachers' math/science content knowledge significantly improved from pre-test (M = 69.15%, SD = 17.76%) to post-test (M = 79.81%, SD = 15.42%); $t(160) = 10.00$, $p < .000$. The effect size is considered large ($_p^2$=.363) with 36.3 percent of the variance in teacher content knowledge accounted for by time of the test. The overall teacher pre- and post-test average content knowledge percent correct growth over the program was from 69.15 percent correct at baseline to 79.81 percent correct at end of program. A one-way ANOVA was used to analyze program developed content knowledge assessment data.

Limitations

All quantitative research is subject to limitations from methodological threats to internal and external validity (Onwuegbuzie, 2000). Internal validity focuses on the research design and asks if it is appropriate to support the differences found in the dependent variable as a result of the independent variable and nothing else. External validity addresses a study's ability to generalize findings from one study to and across populations, settings, and times. For this evaluation study, two major methodological limitations to validity are acknowledged: 1) teacher participation in data collection, and 2) nature of the content knowledge tests.

Teacher participation in data collection is a potential external validity limitation in this evaluation study. Out of 307 total participating teachers in the THEC STEM PD programs, response rates for completing the teacher survey at least once was 81.4 percent (n=250), having one classroom observation performed was 82.1 percent (n=252), and 72.3 percent (n=222) completed the program developed content knowledge assessment for teachers (pre/post). While these overall response rates are high, when considering that this evaluation was of a longitudinal nature, the response rates are not quite as impressive. Only 54.1 percent (n=166) of participating THEC STEM PD teachers completed both pre- and post-surveys, 40.4 percent (n=124) had three full classroom observations recorded, and 52.4 percent (n=161) produced usable pre/post achievement test scores. Further, because some THEC STEM PD participants did not participate in the data collection process, findings of this evaluation are vulnerable to non-response error. Non-response error may occur when a significant number of THEC STEM PD teachers choose to not respond and these non-respondents are significantly different from those THEC participants who responded and thus the results may become non-generalizable to the larger THEC STEM PD program sample. Any time a response rate is under 60-70 percent non-response needs to be examined further. In this evaluation, THEC participant demographics (e.g., program content, program grade level focus, gender, as ethnicity) for those responding to data collection procedures are similar to that of the overall THEC participant group. As such, we can say that there does not appear to be any systematic non-response issues making this a lesser concern than if there were specific sub-groups of individuals choosing to not participate.

The nature of the program developed content knowledge tests for teachers is an internal limitation for this evaluation study. All content knowledge tests were developed by the individual professional development programs to focus on the specific content each program was covering. While this does allow for greater content validity for these assessment outcomes, there is limited (if any) comparability across assessments. Thus, there is no way of knowing if one assessment was significantly more challenging or easier than another assessment. Consequently, comparability of growth from pre/post across programs attributing differences to type of PD delivered is certainly confounded by the differences in tests and should be done with extreme caution. It is acceptable to look at growth from pre/post for an individual program, but comparing one program's growth to another may have little to do with the PD implemented and more to do with the assessment used to collect the data.

III. FINDINGS OVERALL FOR THEC STEM PD INVESTMENT – RESEARCH QUESTION 1

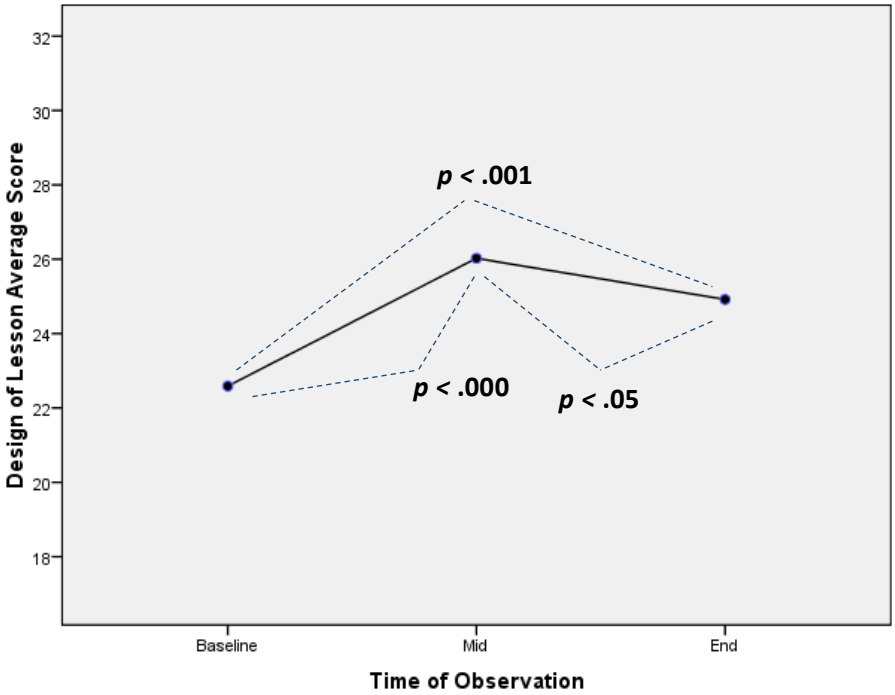
CLASSROOM OBSERVATION FINDINGS

The Local Systemic Change Classroom Observation Protocol (LSC) was used to examine teacher observations in four key areas: design of lesson, implementation of lesson, culture of instruction, and content knowledge delivered. Analysis of these videos revealed significant improvement in all four areas as indicated by findings presented below.

Design Of Lesson

An analysis of data for the 11 round one programs involved in the THEC STEM PD program indicated there was significant growth in the Design of Lesson construct, which encompasses the extent of planning, organization, resources, equity, collaboration, flow, assessments, and sense making that takes place in the lesson delivery. At baseline, the mean score average (2.26) was rated a Level 2: Elements of Effective Instruction (M = 22.59, SD = 5.78), which increased to 2.60 (M = 26.02, SD = 5.29) at the second observation point midway through the professional development program, and decreased but remained in the (average score of 2.49) "elements of effective instruction" range at the final observation (M = 24.92, SD = 5.47), $F(2) = 19.25$, $p < .000$. The effect size is considered large (η_p^2=.139), with 13.9 percent of the variance in Design of Lesson scores accounted for by time of the observation. Figure 1 shows the statistically significant overall increase in average Design of Lesson scores over time although there was a significant decrease from mid-program to end observation points.

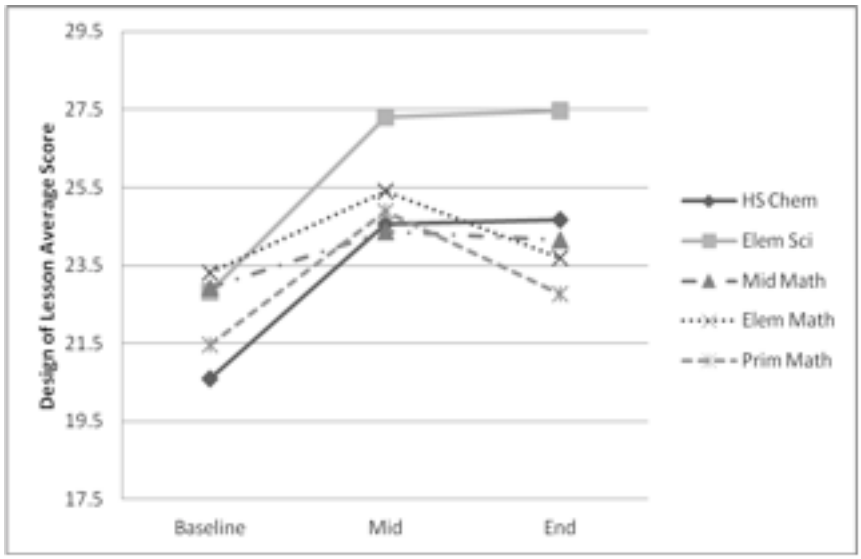
Figure 1. Design Average Score Over Time for Round One Programs



Average scores could have an overall range of 10-50, since there are 10 items on a 5-point scale in this sub-section. Statistically significant increases were noted between baseline and mid as well as baseline and end. A statistically significant decrease was found from the mid- to end-time point.

State level findings did not vary by type of program (e.g., mathematics, science, or grade range), meaning there was not a statistically significant difference in design of lesson between program classifications, $F(4) = 1.95$, $p > .05$. The average design of lesson score across time ranged from 2.34 (High School Chemistry) to 2.61 (Elementary Science), which are equivalent to a Level 2: Elements of Effective Instruction. However, there was a statistically significant interaction between program classification and time of observation for design of lesson, $F(8) = 2.65$, $p < .01$. This means as time went on, the group overall improved. The effect size is considered medium ($\eta_p^2 = .082$), with 8.2 percent of the variance in design of lesson score accounted for by the interaction between observation time and program classification. Figure 2 shows that all program classifications increased in design score from baseline to mid-program observations. From mid- to end-of-program observation points all program classifications decreased in design of lesson score, with the exception of elementary science programs, which instead slightly increased in average design of lesson score. Although elementary science programs appear to have a different trend compared to the other programs from mid- to end-observation point, post-hoc analyses indicate that there were no statistically significant differences in average design of lesson score at any observation point.

Figure 2. Design Average Score Over Time by Program Classification for Round One Programs

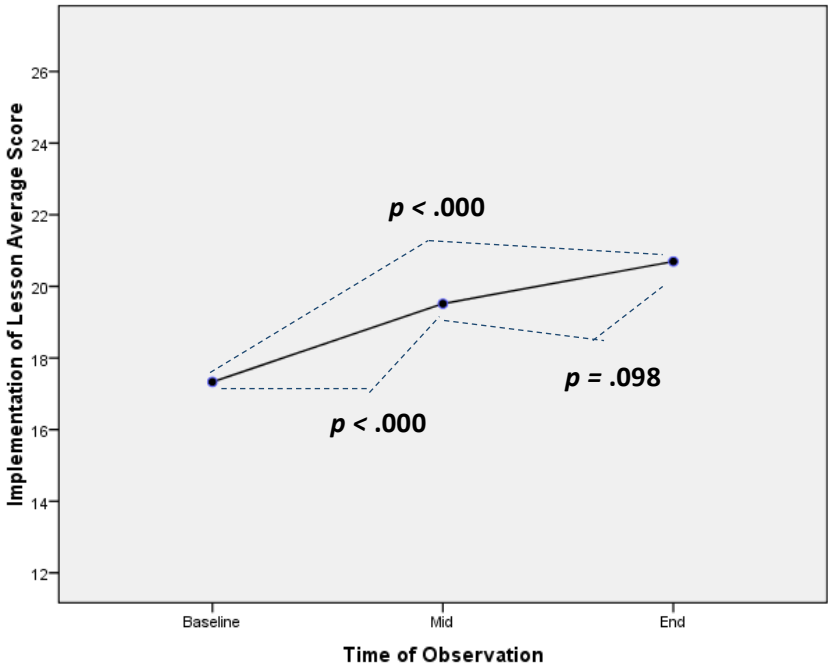


Average scores could have an overall range of 10 -50, since there are 10 items on a 5-point scale in this sub-section. No statistically significant differences were noted between program classifications at any observation time.

Implementation Of Lesson

Regardless of program classification, teachers involved in Tennessee's Race to the Top STEM PD schools significantly improved their Implementation of Lesson scores from their average baseline rating of 2.48 or a Level 2: Elements of Effective Instruction (M = 17.33, SD = 4.39), to a average rating of 2.79 (M = 19.52, SD = 4.39) at the second observation recorded at the mid-point of the professional development program, scores finally rose to an average rating of 2.96 or a Level 3 at the end-point observation (M = 20.69, SD = 5.01), $F(2) = 22.07$, $p < .000$. The implementation of lesson construct considers the level of investigative mathematics/science in the lesson, quality of classroom management strategies, pace of the lesson, ability to modify instruction based upon student understanding, teacher questioning strategies, and formative assessments. The effect size is considered large ($_p^2 = .156$) with 15.6 percent of the variance in Implementation of Lesson scores accounted for by time of the observation. Figure 3 shows the statistically significant increase in average Implementation of Lesson scores over time.

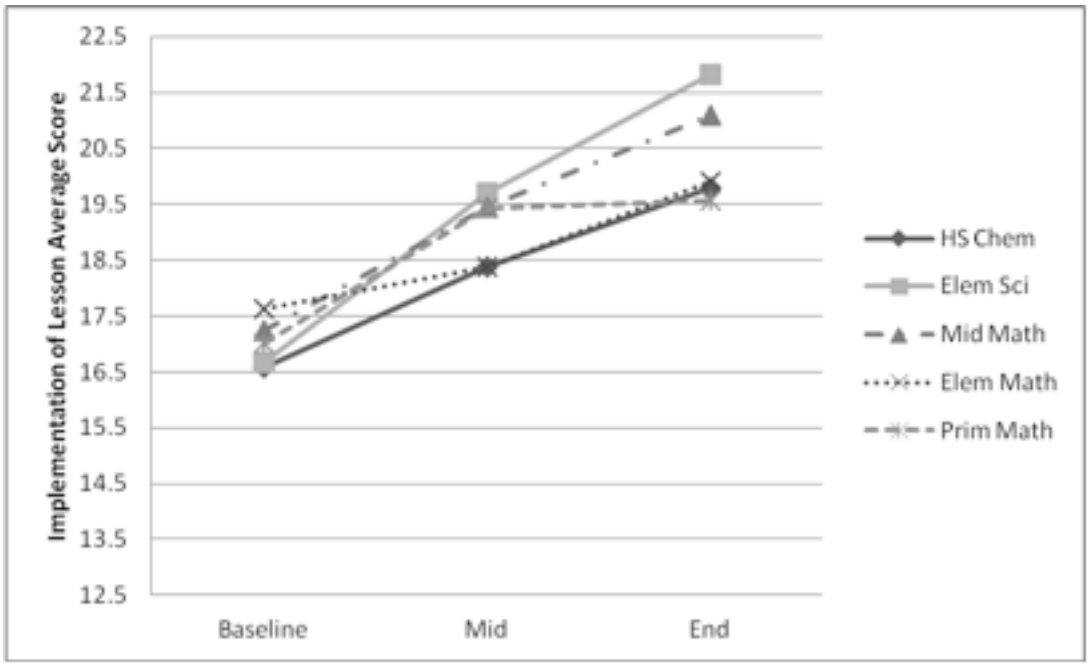
Figure 3. Implementation Average Score Over Time for Round One Programs



Average scores could have an overall range of 7-35, since there are seven items on a 5-point scale for this sub-section. Statistically significant increases were noted between baseline and mid-observations as well as baseline and end observation time points. Although Implementation scores increased from mid to end this increase was not statistically significant.

Similar to the Design of Lesson findings, there was not a statistically significant difference in implementation of lesson between program classifications, $F(4) = .692$, $p > .05$. The average implementation of lesson score across time ranged from 2.62 (High School Chemistry) to 2.85 (Primary Math). A statistically significant interaction between program classification and time of observation does not exist for implementation of lesson, $F(8) = 1.65$, $p > .05$. Figure 4 shows that all program classifications increased in implementation score from baseline to mid observations. From mid to end observation point all program classifications again increased in implementation of lesson score, with the exception of primary math programs that instead decreased in average implementation of lesson score. Although primary math programs appear to have a different trend compared to the other programs from mid- to end-observation point, there are no statistically significant differences in average implementation of lesson score at any observation point.

Figure 4. Implementation Average Score Over Time by Type for Round One Programs

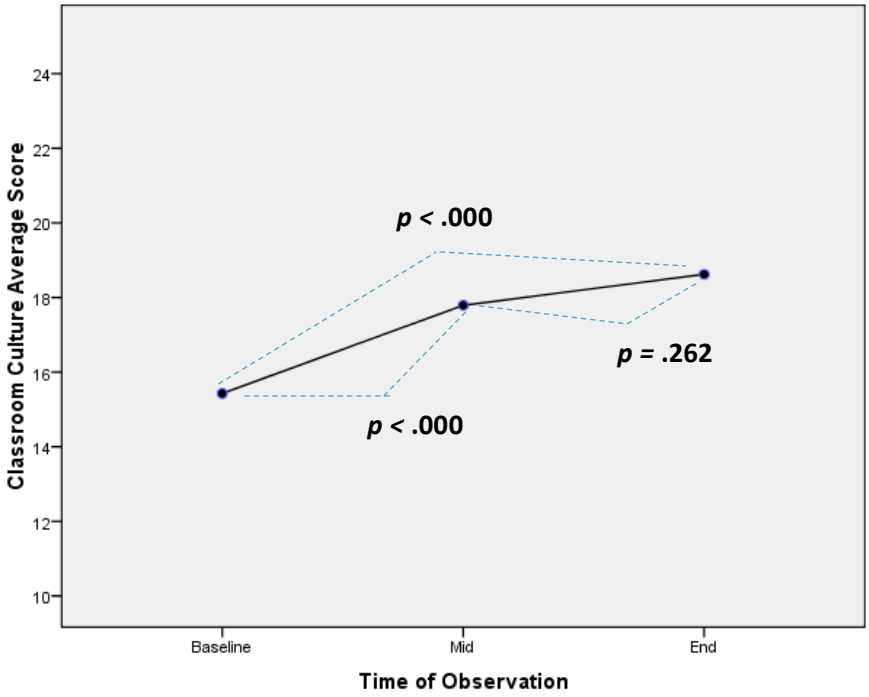


Average scores could have an overall range of 7-35, since there are seven items on a 5-point scale for this sub-section. No statistically significant differences were noted between program classifications at any observation time.

Classroom Culture

The THEC STEM PD participants also significantly improved their overall Classroom Culture scores from baseline average rating of 2.57 or a Level 2: Elements of Effective Instruction (M = 15.43, SD = 3.86), to an average rating of 2.97 or Level 3: Beginning Stages of Effective Instruction (M = 17.79, SD =3 .67) on the second observation recorded at the mid-point of the professional development program. This rating increased to an average rating of 3.10 (M = 18.62, SD = 4.50) at the end-point observation, $F(2) = 27.56$, $p < .000$. The effect size is considered large ($_p^2 = .188$), with 18.8 percent of the variance in Classroom Culture scores accounted for by time of the observation. Figure 5 shows the statistically significant increase in average Classroom Culture scores over time. Classroom Culture refers to the amount of active participation of all students and level of collaborative learning, including allowing students to explore their own ideas, questions, conjectures, and propositions or to challenge the ideas of others.

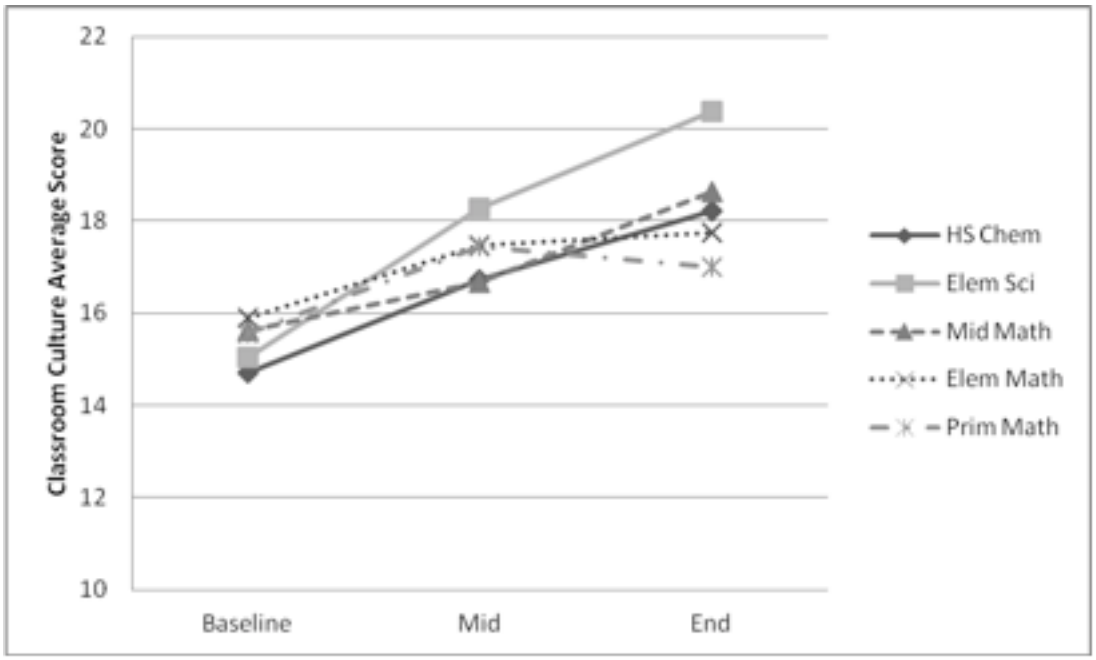
Figure 5. Classroom Culture Average Score Over Time for Round One Programs



Average scores could have an overall range of 6-30 since there are six items on a 5-point scale for this sub-section. Statistically significant increases were noted between baseline and mid-time points. Although there was another average increase from mid- to end-time point, this increase was not statistically significant.

Again, similar to the Design of Lesson and Implementation of Lesson constructs, there was not a statistically significant difference in classroom culture between program classifications, $F(4) = .927$, $p > .05$, meaning all programs classifications (e.g., mathematics, science, grade levels) increased their ability to create effective classroom culture for their students across the duration of the THEC STEM PD programs. The average classroom culture score across time ranged from 2.75 (High School Chemistry) to 3.01 (Elementary Science). A statistically significant interaction between program classification and time of observation existed for classroom culture, $F(8) = 2.83$, $p > .01$. The effect size is considered medium ($_{p}^{2} = .087$), with 8.7 percent of the variance in Classroom Culture scores accounted for by the interaction of time of the observation and program classification. Figure 6 shows that all program classifications increased in classroom culture score from baseline to mid-observations.

Figure 6. Classroom Culture Average Score Over Time by Program Classification for Round One Programs



Average scores could have an overall range of 6-30 since there are six items on a 5-point scale for this sub-section. No statistically significant differences were noted between program classifications at any observation time.

From mid- to end-observation point all program classifications again increased in classroom culture score with the exception of primary math programs, which instead decreased in average classroom culture score. Although primary math programs appear to have a different trend compared to the other programs from mid- to end-observation point, there are no statistically significant differences in average classroom culture score at any observation point.

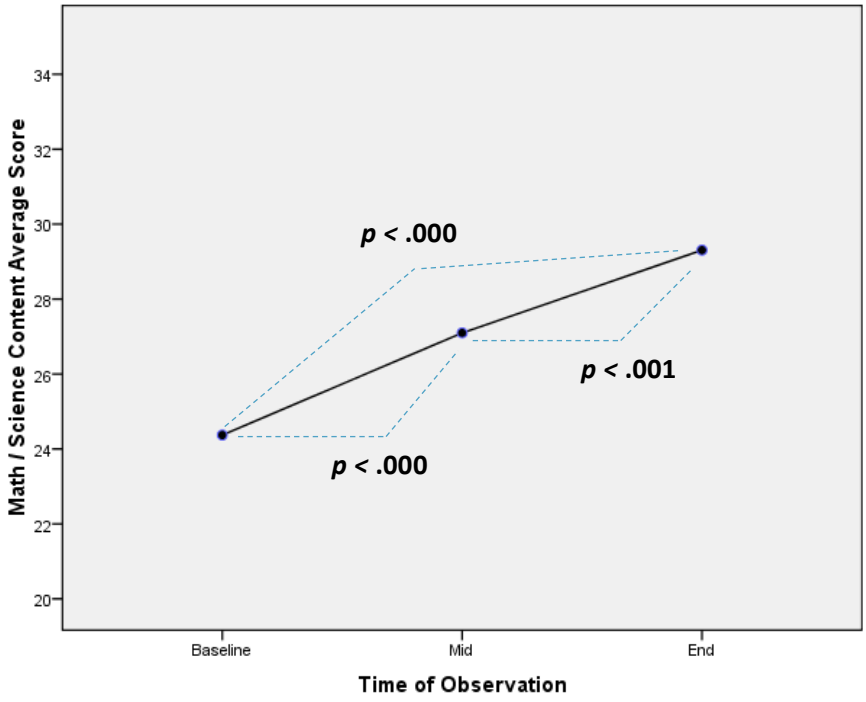
Mathematics/Science Content Domain

THEC STEM PD participants significantly improved their Mathematics/Science Content scores from a baseline score of 2.70, which is rated as a Level 2: Elements of Effective Instruction (M = 24.37, SD = 5.25), to an average rating of 3.01, improving to a rating of Level 3: Beginning Stages of Effective Instruction (M = 27.10, SD = 4.90) at the second observation point mid-way through the professional development program. By the end of the program, participants experienced further growth, with an average score of 3.26 overall (M = 29.31, SD = 5.81), $F(2) = 32.54$, $p < .000$. The effect size is considered large ($_p^2 = .215$), with 21.5 percent of the variance in Mathematics/Science Content scores accounted for by time of the observation. Figure 7 shows the statistically significant increase in average Mathematics/Science Content scores over time.

Similar to Design of Lesson, Implementation of Lesson, and Classroom Culture constructs, there was not a statistically significant difference in mathematics/science content between program

classifications, $F(4) = 946$, $p > .05$. The average mathematics/science content score across time ranged from 2.89 (Middle Grades Math) to 3.09 (Elementary Science). A statistically significant interaction between program classification and time of observation exists for mathematics/science content, $F(8) = 2.44$, $p > .05$. The effect size is considered medium ($_p^2 = .076$), with 7.6 percent of the variance in mathematics/science content scores accounted for by the interaction of time of the observation and program classification.

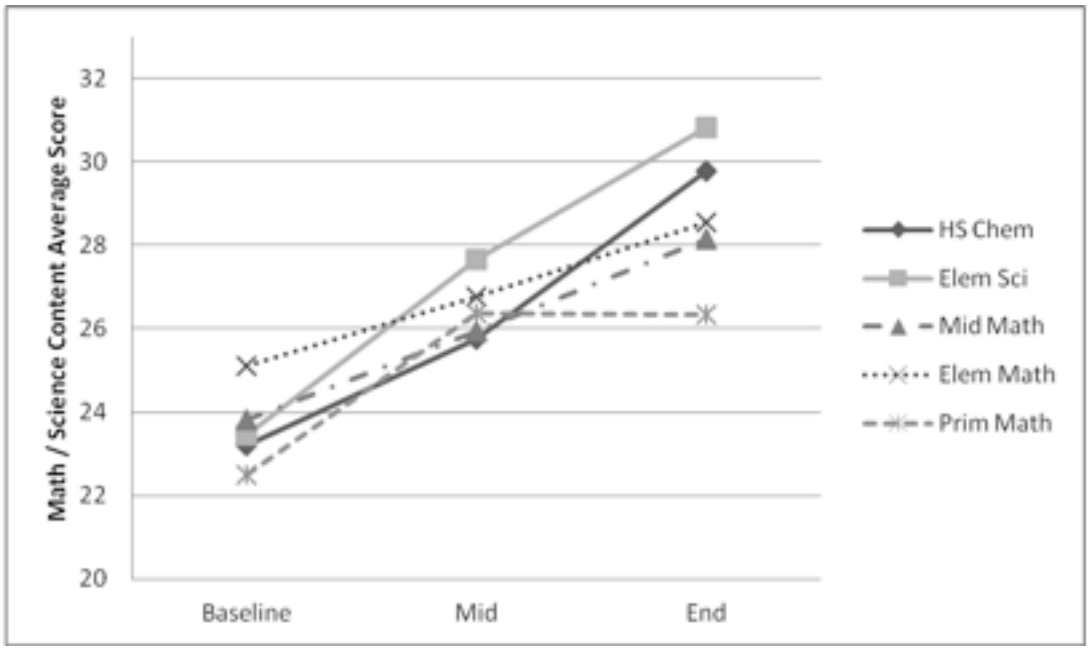
Figure 7. Mathematics/Science Content Average Score Over Time for Round One Programs



Average scores could have an overall range of 9 – 45 since there are 9 items on a 5-point scale for this sub-section. Statistically significant increases were noted between all time points.

Figure 8 shows that all program classifications increased in math/science content score from baseline to mid-observations. From mid- to end-observation point all program classifications again increased in mathematics/science content score with the exception of primary math programs, which instead decreased in average mathematics/science content score. Although primary math programs appear to have a different trend compared to the other programs from mid- to end-observation point, there were no statistically significant differences in average mathematics/science content score at any observation point.

Figure 8. Mathematics/Science Content Average Score Over Time by Program Classification for Round One Programs



Average scores could have an overall range of 9-45, since there are nine items on a 5-point scale for this sub-section. No statistically significant differences were noted between program classifications at any observation time.

CONTENT KNOWLEDGE ASSESSMENT FINDINGS

For all types of PD programs there was statistically significant growth from pre- to post-test in terms of teacher content knowledge. While each program type showed statistically significant average increases from pre- to post-test in teacher content knowledge, Table 4 shows that teachers participating in Elementary Math and Elementary Science programs appeared to make the greatest gains with each program type moving their teachers' content knowledge up almost two full letter grades (see Table 4). Further statistical analysis (One-Way ANOVA) revealed a statistically significant difference between groups in terms of pre-post teacher content knowledge growth; $F(4) = 6.09$, $p < .000$. Post-hoc analysis indicates that both Elementary Math and Elementary Science programs had significantly greater teacher content knowledge growth when compared to Middle Grades Math ($p < .01$ & $p < .05$ respectively) and Primary Math ($p < .001$ & $p < .05$ respectively).

Table 4. Pre- and Post-Average Percent Correct by Program Classification

Program Classification	Pre-test	Post-test	% Growth	Significant Growth
High School Chemistry	66.91% (D)	75.27% (C)	+8.36% points	Yes (p<.05)
Elementary Science	75.54% (C)	89.86% (B)	+14.32% points	Yes (p<.000)
Middle Grades Math	69.84% (D)	75.87% (C)	+6.03% points	Yes (p<.01)
Elementary Math	51.67% (F)	71.17% (C)	+19.50% points	Yes (p<.000)
Primary Math	71.88% (C)	78.63% (C)	+6.75% points	Yes (p<.05)

**Note.* Pre- and Post-test letter grades are also provided in the table based upon a grading scale where A=90-100%, B=80-89%, C=70-79%, D=60-69%, F=59% and below.

IV. FINDINGS OVERALL FOR THEC STEM PD INVESTMENT – RESEARCH QUESTION 2

TEACHER SURVEY FINDINGS

An examination of the surveys that participants completed pre- and post-program revealed findings related to teacher opinions, frequency of use in instructional practices, student activities, instructional influences, teacher preparedness, principal perceptions, parental support, and professional development experiences.

Teacher Opinions Related to STEM Teaching

This construct examined teacher opinions regarding implementing effective STEM instructional strategies and access to associated resources necessary for doing so. A 10-item self-reported level of agreement construct, designed on a 5-point Strongly Disagree – Strongly Agree scale, evaluated teacher opinions. Overall teacher responses on this scale could range from 10-50. The THEC STEM PD participants demonstrated statistically significant improvement in opinions toward teaching mathematics/science from pre- to post-survey administration regardless of the PD program, $F(1) = 3.30$, $p < .05$. Additionally, there was a significant difference between groups with mathematics teachers having better attitudes at pre- and post-survey administration, $F(1) = 5.98$, $p < .01$. However, the difference was nominal, with mathematics teachers starting and finishing approximately 2 points higher than science teachers, who experienced similar growth.

Teacher attitudes significantly increased in agreement in areas such as feeling supported to try new teaching ideas, cohesion of school-wide teaching vision, cooperation by sharing materials, and support by local agencies. Agreement with resource issues (i.e., time and computer access) was unchanged and remained relatively low (less than 50 percent agreement at pre/post). Enjoyment for teaching science/math agreement did not change, however, because it was extremely high at the pre-survey (93.3 percent) and remained similarly high at post-survey (95.8 percent).

Teacher Perceived Importance Related to STEM Teaching

This construct examined teacher-attributed importance of various use of instructional strategies, which are effective for STEM education. Thirteen items measured on a Not Important – Very Important scale assessed teacher importance. Overall teacher responses on this scale could range from 13-52. THEC STEM PD participants demonstrated statistically significant improvement in

reported importance of use of effective mathematics/science instructional strategies from pre- to post-survey administration regardless of the PD program, $F(1) = 1.14$, $p = .143$. Additionally, this growth was similar for all content areas, as there was not a significant difference between content area groups from pre- to post-survey administration, $F(1) = 0.78$, $p = .190$.

Teachers significantly increased their reported perceived importance of strategies in areas such as determining how to develop lessons (i.e., concrete experiences shared before abstract, use students' prior understanding, and connect content to other disciplines). Teachers' perceived importance of how students should engage with science content also significantly increased (i.e., work in cooperative groups, inquiry-oriented activities, project/lab/research reports, computer use, and using a variety of contexts). Finally, the importance of using a variety of assessment methods (i.e., performance-based, portfolios, and informal questioning) also appeared to be significantly more important to teachers after participating in their PD program. The perceived importance of developing students' conceptual understanding of the content and having students participate in appropriate hands-on activities both remained unchanged and high. More than 80 percent of the teachers surveyed reported these items were fairly or very important at both pre- and post-survey administration.

Instructional Influences

This construct examined the external influences teachers experienced that impacted whether or not they chose to use effective STEM pedagogy. Teacher perceived instructional influences were evaluated with 12 items on a 3-point scale assessing degree to which a factor inhibits or encourages effective instruction. Overall scores could range from 12-36. THEC STEM PD participants experienced statistically significant growth in this area – which means their impression of the influence of negative external pressures on their decisions to use effective pedagogy decreased from the beginning to end of program participation, $F(1) = 5.45$, $p < .01$. There was a statistically significant difference between groups based on content focus, $F(1) = 10.48$, $p < .001$. Teachers in the math PD programs averaged approximately a 2-point increase (on the 5-point scale), while teachers in the science PD programs averaged approximately only a .5-point increase. In practical terms, teachers from the science PD programs on average reported they had mixed feelings on whether the items inhibited or encouraged effective instruction, while teachers in the math PD programs reported this pre-survey but shifted closer to believing the items encouraged effective instruction at the end of the professional development program.

In all instances except for one which stayed similar from pre/post (state/district testing policies/practices), teachers perceptions of factors influencing their instruction became more positive as they shifted to feeling the factors encouraged effective instruction at a greater rate. However, at the post-survey more than 50 percent of the respondents reported that factors such as funds, time, and public attitudes still inhibited effective instruction.

Teacher Preparedness

This construct examined teacher perceived preparedness for teaching STEM content and use and delivery of effective STEM pedagogy. Teacher preparedness was assessed through 19 items on a 4-point scale (Not Prepared, Somewhat Prepared, Fairly Well Prepared, and Very Well Prepared) examining participants' self-reported sense of preparedness for STEM teaching in regard to content and pedagogical skills. Scores could range from 19-76. THEC STEM PD participants demonstrated statistically significant increases in preparedness to use various effective mathematics/science instructional strategies from beginning to end of program, $F(1) = 128.25$, $p < .000$. Additionally, there was no statistically significant difference between groups based on content focus (mathematics/science), $F(1) = 0.27$, $p = .602$. Overall, teachers increased from feeling Somewhat Prepared to Fairly Well Prepared and Very Well Prepared. Teachers reported feeling more prepared to do things such as provide concrete experiences before abstract concepts, develop student conceptual understanding, engage students in inquiry-oriented activities, and lead a class using investigative strategies.

Frequency of Use of Effective Pedagogy

Teacher frequency of use of effective pedagogy was determined through participant self-reported data on 14 survey items on a 5-point scale (Never, Rarely, Sometimes, Often, and Almost All Lessons). Overall scores could range from 14-70. THEC STEM PD participants reported statistically significant gains in use of effective pedagogy from pre- to post-survey, $F(1) = 10.09$, $p < .001$. Additionally, there was no statistically significant difference between groups based on content focus, $F(1) = 2.98$, $p = .086$.

Four instructional practices are noted as significant (introduce content through formal presentations, demonstrate principles, teach using real works contexts, and assign homework) because there was a higher frequency of teachers indicating that they used these practices than expected at both pre- and post-survey. All other instructional practices saw a significantly positive shift, with all being near or more than 60 percent of teachers indicating Frequently Used, except for the item regarding notebooks or journals. This item still saw a significantly positive shift but less than 50 percent of teachers reporting doing this frequently at post-survey.

Student Activities

This construct examined the use of effective STEM instructional activities with student as the focus. The use of cooperative groups, student generated questions for investigation, communicating findings with others, use of technology, and other student-centered practices were the context for this construct. Student Activities employed in the classroom were evaluated with 20 items on a 5-point scale assessing how often a teacher has students engage in various effective instructional activities (Never, Rarely, Sometimes, Often, and Almost All Lessons). Overall scores could range from 20-100. A statistically significant increase in use of effective student activities was found for THEC STEM PD program participants, regardless of PD program, from pre- to post-survey, $F(1) = 31.12$, $p < .000$. Additionally, there was no statistically significant difference between groups based on content focus, $F(1) = 0.85$, $p = .358$. Teachers increased their use of effective student

instructional practices from Sometimes to Between Sometimes and Often. Two instructional practices are noted as significant because a higher frequency of teachers indicated that they frequently had students "work in cooperative learning groups" and a lower frequency indicated that they had students "read from textbook" than expected at both times. All other instructional practices saw a significantly positive shift from pre- to post-survey.

Parental Support

This construct examined the role of parents in STEM teachers' classrooms who participated in the THEC STEM PD programs. Parental Support was evaluated by six items on a 4-point scale assessing how many parents assist with different activities in the classroom (None, A Few, About Half, and About All). Overall scores could range from 6-24. A statistically significant increase in Parental Support was found for THEC STEM PD program participants regardless of PD program from pre- to post-survey, $F(1) = 7.28$, $p < .01$. Additionally, there was a statistically significant difference between groups based on content focus, $F(1) = 4.91$, $p < .05$, with math teachers reporting more parental support at both the pre- and post-survey administration. Most items showed teachers felt unsupported by parents both before and after, with a vast majority of teachers selecting None or Few parents helping with all activities. Areas of significant growth included parents volunteering (1 percent to 7 percent), donating money or materials for the class (6 percent to 11 percent), attending parent-teacher conferences (30 percent to 37 percent), and voicing support for instruction (4 percent to 10 percent).

Principal Support

This construct examined the role of administrative support in the teaching of STEM. Principal Support was evaluated by nine items on a 5-point scale assessing the degree of agreement a teacher feels with the statements (SD, Disagree, No Opinion, Agree, and SA). Overall scores could range from 9-45. A statistically significant increase in Principal Support was found regardless of PD program from pre- to post-survey, $F(1) = 6.23$, $p < .01$. Additionally, there was not a statistically significant difference between groups based on content focus, $F(1) = 2.22$, $p < .139$. On average, teachers increased approximately 2 points on the Principal Support scale moving from between No Opinion and Agree to averaging a response of Agree.

Two Principal Support areas ("encourages selection of content and instructional strategies to address individual students learning" and "accepts the noise that comes with an active classroom") were notable because they had unexpectedly high levels of agreement at both pre/post. The item "acts as a buffer between teachers and external pressures" had a significant change in the negative direction with fewer agreeing at post-survey but still close to agreement. All other Principal Support items saw a significant shift from less to more agreement (e.g., providing materials/equipment for science/math, providing time for teachers to meet and share ideas, encouraging teachers to observe other science/math teachers, and encouraging teachers to make connections across disciplines).

Professional Development Experiences

This construct examined the experiences and impressions of the THEC STEM PD participants regarding the individual program they participated in. PD Experiences were evaluated using three items on a 5-point scale assessing the extent to which participation in the district-offered professional development had increased teachers' abilities (Not at All to A Great Extent). Overall scores could range from 3-15. A statistically significant increase in PD Experiences was found regardless of PD program from pre- to post-survey, $F(1) = 17.01$, $p < .000$. Additionally, there was a statistically significant difference between groups based on content focus, $F(1) = 13.34$, $p < .000$. On average, math teachers felt more positively about their PD Experiences at the post-survey than did teachers in the science programs in the areas of impact on their content knowledge (21 percent to 41 percent), impact on their understanding of how children think about and learn mathematics/science (24 percent to 38 percent), and impact on ability to implement high-quality science/mathematics instructional materials (25 percent to 38 percent).

V. CONCLUDING OBSERVATIONS

Round One of the THEC STEM PD Program revealed substantial growth in STEM teacher quality across the state of Tennessee. In this section we will present some concluding observations and highlights of the evaluation report. Individual narratives for each program are included as appendices to this report.

IMPROVED PEDAGOGICAL SKILLS

The Round One funded STEM PD programs demonstrated significant growth in STEM pedagogical skills, as observed in participant-submitted digital recordings of their instruction. The ability of teachers to design effective STEM lesson increased from 2.26 to 2.49 on the 5-point scale. Teacher implementation of effective STEM instruction also increased significantly from 2.48 to 2.96. Additionally, participants were able to transform their learning environments and create classroom culture, which supports investigative STEM education (2.57 to 3.10).

Participants' self-reported data on administered pre- and post-surveys indicated significant growth overall in opinions related to their own preparedness to teach STEM, frequency of use of effective STEM pedagogy (e.g., cooperative groups, technology, connections between science/math), use of student-centered activities, and connecting learning to the real-world.

IMPROVED CONTENT KNOWLEDGE

Classroom observations of teachers also revealed significant growth in content knowledge delivered during instruction (2.70 at baseline to 3.26 at end of program). Further, this growth was also reflected in program-developed assessments of content knowledge. Analysis of overall program developed content assessment data for THEC STEM PD programs revealed statistically significant growth from pre- to post-test ($F(94) = 6.09$, $p < .000$).

IMPROVED OPINIONS

Teachers who attended THEC STEM PD programs exhibited improved attitudes toward the teaching of STEM, as well as more positive experiences with parent and principal support. Further, participants felt more supported by colleagues, valued the use of inquiry, technology, and collaborative learning. Importantly, participants valued the PD experience. Time for collaborating with other teachers was one area in which participants did not see improvement (likely in their own schools) during the PD program duration.

PROGRAMS CONSIDERED BEST PRACTICE

An examination of the evaluation data at the program level for the 11 THEC STEM PD programs revealed several programs that had significant impact on transforming STEM teacher quality (pedagogical skills) and content knowledge. The programs that improved both content knowledge and teacher quality, which could be considered best practice in our opinion, are as follows:

1. TN Tech – Chemistry
2. ETSU – Chemistry
3. TN Tech – 3-5 Science
4. ETSU – 3-5 Science
5. Austin Peay – 3-5 Mathematics

SUMMARY

This annual report for THEC on the STEM PD Programs has focused on the Round One STEM PD programs. Overall, the evaluation has revealed teacher participation in the THEC STEM programs has resulted in overall growth in science and mathematics teacher effectiveness and attitudes in the state of Tennessee. At an individual program level, findings revealed many THEC funded programs also had significant impact on participants in all areas. However, some programs had mixed, neutral, or negative impacts on teachers. Individual program narratives found in the Appendix of this report provide further detail on program level findings and conclusions. Moving forward, researchers will further investigate the impact of the THEC STEM PD portfolio using both data from the programs referenced in this report as well as data collected from the 18 Round Two programs.

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APPENDIX – PROGRAM NARRATIVES

Austin Peay State University (APSU)–Assad and Wells, PIs……29
East Tennessee State University (ETSU)–Rhoton and Zhao, PIs……37
East Tennessee State University (ETSU)–Tai and Ho, PIs……..44
Lipscomb University–Hutchinson and Boyd, PIs……... 52
Middle Tennessee State University (MTSU)–Winters and Kimmins, PIs……60
Tennessee Technological University (TTU)–Anthony and Smith, PIs……68
Tennessee Technological University (TTU)–Baker and Fromke, PIs……...76
Tennessee Technological University (TTU)–Gore and Hunter, PIs…… 83
Tennessee Technological University (TTU)–Ramey and Rust, PIs ……91
University of Tennessee-Chattanooga (UTC)–McAllister and Ebiefung, PIs……...99
University of Tennessee-Chattanooga (UTC)–Wigal and Cowan, PIs……....106

Program Narrative
Austin Peay State University (APSU)
Assad and Wells, PIs

PROGRAM SETTING AND PARTICIPANTS

The Austin Peay State University (APSU) Momentum program was a partnership between Education and Mathematics at APSU and five LEAs (Dickson, Houston, Montgomery, Robertson, and Stewart). The program was designed to deliver a mathematics professional development program for 30 elementary teachers. The summer institute included 10 days, combined with 5 Saturday sessions spread out across the academic year for a total of 130 hours of professional development programming.

The goal of the Momentum project was to increase student achievement in mathematics by increasing elementary teachers' capacity to teach mathematics in a STEM-centered environment. Specific program objectives were to:

1. Deepen elementary teachers' content knowledge of the Common Core State Standards for Mathematics through problem solving.
2. Broaden elementary teachers' pedagogical content knowledge by making connections to children's literature and science and by incorporating appropriate technology.
3. Strengthen teachers' understanding of the role of STEM in developing numeracy.
4. Deepen students' understanding of the core concepts of algebraic thinking, measurement, and data analysis.

PROGRAM ALIGNMENT WITH CORE CONCEPTUAL FRAMEWORK

The APSU program aligned somewhat with the Core Conceptual framework in the five areas, detailed in the program proposal. **Content knowledge** focus was aligned, included developing numeracy through the use of selected children's literature. Selected content was aligned with the state standards for science and two Common Core State Standard domains including operations with number and algebraic thinking, as well as measurement and data.

Active learning was listed as a focus for the APSU program, to be achieved either individually or in groups in the project proposal. However, this focus was not clearly or explicitly detailed. It was stated that project staff would model the use of formative assessment.

The state purpose of **Coherence** in the proposal was to "provide a smooth transition from professional development to the classroom" according to the proposal. The focus did not explicitly discuss addressing teacher beliefs and/or alignment with school/district current reforms. In regards to **duration**, the program included a 27-hour academy (5 days), 53 hours in workshops, and 40

hours of online discussion group work. The duration section of the proposal was only one sentence long – therefore providing little insight into the planning for each component. **Collective participation** was achieved from including at least two teachers from each selected elementary school, according to the proposal.

FINDINGS FROM OBSERVATIONS

Fifteen teachers in the APSU program were observed at least once. Only two teachers submitted all three required videos, and this is the group that was examined for impact of the program on their instructional practice. Overall, there was significant growth for the two participants in the APSU program participants in all four measured areas: design, implementation, classroom culture and content knowledge.

At baseline, the APSU program participants were categorized at the level of "ineffective instruction" on the design of lesson (score of 1.70). By the end of the program, design of lesson mean score had grown to 2.75 to "elements of effective instruction", representing significant growth. The design of lesson construct examines the extent of planning, organization, resources, equity, collaboration, flow, assessments, and sense making that takes place in the lesson delivery.

APSU participants' implementation of lesson rating also grew significantly for participants overall across the program from a baseline score of 1.86 ("ineffective instruction") to a mean score of 3.79 at the end of the program ("beginning stages of effective instruction"). The implementation of lesson construct examines level of investigative mathematics/science in the lesson, quality of classroom management strategies, pace of the lesson, ability to modify instruction based upon student understanding, teacher questioning strategies, and formative assessments.

Content knowledge was another area of significant growth for the APSU program participants. At baseline, the mean score for teachers in the program was 2.06 ("elements of effective instruction"). By the end of the program, the mean had raised to 3.78 ("beginning stages of effective instruction"). This means that during observations, science content delivered was significant and worthwhile and appropriate for the developmental needs of students. Teacher-provided content was accurate, and some connections to real-world contexts were used. Participants also incorporated some abstraction, theory building, and connections to other disciplines in observed lessons.

APSU Momentum participants also significantly raised their score on the construct of classroom culture from a baseline score of 1.75 ("ineffective instruction") to a final score of 3.67 ("beginning stages of effective instruction"). Implementation of strategies including collaborative learning, centering instruction on student generated questions, and ideas and intellectual rigor were not evident through observations. All students were actively engaged in meaningful learning that respected ideas consistently in classroom observations conducted at the end of the program.

FINDINGS FROM SURVEYS

An examination of the surveys that APSU Momentum participants completed in a pre/post manner revealed findings related to teacher opinions, frequency of use in instructional practices, student activities, instructional influences, teacher preparedness, principal perceptions, parental support, and professional development experiences.

Teacher opinions regarding the importance of use of effective instructional strategies and support necessary to be successful are included in this section of the survey.

Areas of Increased Agreement in teacher opinions related to the teaching of mathematics:

- Importance of developing students' conceptual understanding of mathematics (78 percent to 83 percent)
- Importance of considering student prior understanding when planning instruction (82 percent to 83 percent)
- Importance of making connections between science/math and other disciplines (78 percent to 83 percent)
- Importance of engaging students in hands-on activities (85 percent to 8 percent)
- Importance of engaging students in inquiry-oriented activities (62 percent to 82 percent)
- Importance of having students prepare project/laboratory/research reports (19 percent to 41 percent)
- Importance of using computers (26 percent to 59 percent)
- Importance of engaging students in applications of mathematics in a variety of contexts (56 percent to 88 percent)
- Importance of using performance-based assessments (56 percent to 71 percent)
- Importance of using portfolios (19 percent to 35 percent)
- Importance of using informal questioning to assess student understanding (67 percent to 82 percent)
- Importance of using materials for investigative science/math instruction (56 percent to 65 percent)
- Importance of time to collaborate with peers (30 percent to 71 percent)
- Importance of support of the school by local organizations, institutions, and/or business (26 percent to 47 percent).
- Importance of teachers regularly sharing ideas and materials for mathematics (67 percent to 88 percent)
- Importance of support to try out new ideas in teaching mathematics (82 percent to 94 percent)

Areas of Increased Disagreement – The only area of decline for APSU participants was in regards to the importance of use of cooperative learning groups with students, which was at 15 percent at baseline and dropped to 24 percent disagreement at the end of the program.

Instructional Influences were a second area of focus in the survey. APSU Momentum participants reported positive growth in all areas of influences that encourage effective instruction at the end of the program.

Encourages Effective Instruction – The following influences were perceived as having a more positive relationship on teaching mathematics effectively by the end of the program:

- Access to computers for science instruction (56 percent to 82 percent)
- Time for planning and preparing lessons (39 percent to 53 percent)
- Time for collaboration with other teachers (52 percent to 65 percent)
- Time for professional development (59 percent to 77 percent)
- Funds for purchasing supplies (30 percent to 58 percent)
- State and/or district curriculum frameworks (52 percent to 59 percent)
- State and/or district testing policies and practices (41 percent to 47 percent)
- Quality of instructional materials (52 percent to 59 percent)
- Management of instructional resources at the district level (46 percent to 65 percent)
- Importance that school places on science/math (74 percent to 82 percent)
- Consistence of science/math reform efforts with other school/district reforms (56 percent to 82 percent)
- Public attitudes toward reform (44 percent to 53 percent)

Teacher Preparedness comprised the third construct of the survey. APSU program participants experienced growth in perceptions of preparation to deliver effective science instruction in all areas of this construct. That is, more teachers agreed that they were well prepared than when the program began:

- Providing concrete experiences before abstract concepts (67 percent to 100 percent)
- Developing student conceptual understanding (67 percent to 94 percent)
- Considering prior understanding when planning curriculum & instruction (89 percent to 100 percent)
- Making connections between science/math and other disciplines (70 percent to 100 percent)
- Using cooperative learning groups (77 percent to 94 percent)
- Use of hands-on activities (67 percent to 100 percent)
- Engaging students in inquiry-oriented activities (52 percent to 100 percent)
- Having students prepare project/laboratory/research reports (33 percent to 82 percent)
- Using computers (70 percent to 100 percent)
- Engaging students in applying science/math in a variety of contexts (63 percent to 100 percent)
- Using performance based assessments (70 percent to 94 percent)

- Using portfolios (15 percent to 82 percent)
- Using informal questioning to assess student understanding (74 percent to 100 percent)
- Leading a class using investigative strategies (56 percent to 94 percent)
- Managing students engaged in hands-on/project-based work (85 percent to 100 percent)
- Helping students take responsibility for their own learning (71 percent to 94 percent)
- Recognizing and responding to student diversity (82 percent to 94 percent)
- Encouraging students' interest in science/math (82 percent to 100 percent)
- Using strategies that encourage participation of females and minorities in science/math (59 percent to 88 percent)

Frequency of Use of Instructional Practices consists of APSU teacher reported frequency of use of specific effective instructional practices.

Increased Use – Teachers reported more frequent use of all practices that from baseline to end of program:

- Teaching science in real-world contexts (81 percent to 94 percent)
- Arranging seating to facilitate student discussion (78 percent to 88 percent)
- Using open-ended questions (74 percent to 94 percent)
- Requiring students to use evidence to support their claims (70 percent to 82 percent)
- Encouraging students to explain concepts to one another (82 percent to 88 percent)
- Encouraging students to consider alternative explanations (59 percent to 94 percent)
- Allowing students to work at their own pace (77 percent to 82 percent)
- Helping students see connections between mathematics and other disciplines (63 percent to 77 percent)
- Using pre-assessments (74 percent to 88 percent)
- Embedding assessment in regular class activities (82 percent to 94 percent)
- Reading and commenting on student journals (41 percent to 59 percent)

Student Activities are the activities that students are engaged in within the science classroom. APSU teachers were asked questions regarding the frequency of use of various student activities. Findings revealed Momentum participants reported increases in all effective student activities.

Frequent Use – Participants reported more frequent use for these student activities from baseline to the end of the program:

- Participation in student-led discussions (40 percent to 76 percent)
- Participation in discussions with the teacher to further understanding

(85 percent to 94 percent)
- Working in cooperative learning groups (78 percent to 88 percent)
- Making formal presentations in class (19 percent to 47 percent)
- Reading other (non-textbook) science/math related materials in class (33 percent to 50 percent)
- Working on solving a real-world problem (56 percent to 88 percent)
- Sharing ideas or solve problems with each other in small groups (74 percent to 94 percent)
- Engaging in hands-on science/math activities (63 percent to 94 percent)
- Following specific instructions in an activity or investigation (54 percent to 82 percent)
- Designing or implementing their own investigation (15 percent to 47 percent)
- Working on models or simulations (14 percent to 47 percent)
- Writing reflections in a notebook or journal (41 percent to 53 percent)
- Taking tests requiring open-ended responses (48 percent to 65 percent)
- Working on portfolios (7 percent to 35 percent)
- Working on extended science/math investigations or projects (4 percent to 41 percent)
- Taking short-answer tests (52 percent to 71 percent)

Principal Perceptions are the impressions that participants have regarding their administrator's perceptions of the teaching and learning of science/math. Momentum participants revealed positive feelings regarding all aspects of this construct.

Areas of Increased Agreement – Teachers agreed that their principal provides encouragement and/or support in the following areas:

- Selection of science/math content and strategies to address individual students' learning (93 percent to 100 percent)
- Accepting the noise that comes with an active classroom (81 percent to 94 percent)
- Encouraging implementation of current national standards (78 percent to 94 percent)
- Encouraging innovative instructional practices (93 percent to 94 percent)
- Acting a buffer between teachers and external pressures (63 percent to 81 percent)
- Encouraging me to observe other exemplary science teachers (52 percent to 59 percent)
- Providing materials/equipment for science/math (74 percent to 82 percent)

Parental Support was reported to be low by participants in the APSU program. All of the participants indicated that few parents volunteer to assist with class activities (100 percent).

Further, low parental support was also reported in regards to attendance at PTA or math/science nights (88 percent), voicing support for instructional approaches (100 percent) and attendance at parent-teacher conferences (65 percent). On a positive note, 100 percent of teachers agreed parents donate money or materials for classroom instruction.

Professional Development (PD) Experiences is an area of the survey where participants indicate their impressions of the ability of the PD program to increase their skills. Momentum participants' did experience some growth in positive attitudes toward PD across the program. Teachers felt their participation in the PD increased their content knowledge (77 percent), and understanding of how children think about and learn mathematics (88 percent). Further, 82 percent of APSU participants felt participation had increased their ability to implement high-quality mathematics instructional materials.

FINDINGS FROM CONTENT ASSESSMENT

The APSU Momentum program did not follow the guidelines required by the evaluation for the format of their assessment. Rather than developing and administering an objective assessment, the program opted for a rubric format and therefore, this data could not be included in part of this evaluation of the THEC STEM PD program.

CONCLUDING OBSERVATIONS FOR PROGAM

The APSU program delivered 130-hours of content to 30 teachers of elementary school mathematics. The focus of the program on the integration of Common Core mathematics standards with literacy and science helped to achieve a more real-world orientation for the teaching of mathematics. The project infused technology including the use of Geometer's Sketchpad to make learning more accessible for children.

Findings indicate that participation in the Momentum program had a significant impact on mathematics teacher quality. The APSU program was designed to include the five criteria in the Core Conceptual Framework (content focus, active participation, duration, coherence, and collective participation).

In respect to classroom observation data, the two APSU teachers experienced significant gains in all four domains (design, implementation, content, and classroom culture) across the program. Additionally, teachers in this program reported implementation of investigative science instructional strategies, including those that require a high-level of ability to facilitate student scientific discourse (e.g., using evidence, explaining concepts to others, considering alternative explanations, work with models and simulations, and record, represent, and analyze data). Teachers also overwhelmingly felt more prepared to deliver effective science instruction, with increases in all areas of the construct. Frequency of use of investigative science strategies also increased. Principal support is an area that also experienced growth across the program. Parental support in the form of supplied materials for classroom instruction was high, though participation at parent-teacher meetings, PTA, mathematics night events and other forms of support was low. The APSU program impact was clearly articulated by participants in a transformation of their beliefs regarding the use of effective practice, as well as

their impressions of influence of the program on their teaching. Overall, this program demonstrated significant gains in including teacher quality, teacher opinions, preparedness, and observed content knowledge.

Program Narrative
East Tennessee State University (ETSU)
Rhoton and Zhao, PIs

PROGRAM SETTING AND PARTICIPANTS

The East Tennessee State University (ETSU) Modeling Instruction of Chemistry in High-schools (MICH) program was a partnership between ETSU and eight school districts (Bristol City, Greene, Greenville City, Hawkins, Johnson, Kingsport City, Sullivan, and Washington) in Northeast Tennessee. The program was designed to deliver a 14-month intensive professional development program for 20 high school teachers of chemistry. A 12-day summer institute was completed, along with 6 monthly workshops, sustained school visits, and online support, for a total of 108-hours of professional development programming.

The goals of this project included enabling participants to:

1. Demonstrate enhanced pedagogical knowledge and skills, and teach their chemistry courses using Modeling Instruction – a flexible, robust, research-based pedagogical framework that is effective for all levels of students.
2. Demonstrate an improved knowledge of chemistry concepts through Modeling Instruction, enrolling in more rigorous science courses.

PROGRAM ALIGNMENT WITH CORE CONCEPTUAL FRAMEWORK

The MICH program aligned with the Core Conceptual framework in all five areas, detailed in the program proposal. First, MICH focused on chemistry **content knowledge**, aligned with the state standards of high school chemistry. Specific content focus included atomic structure, matter and energy, interactions of matter, structure and properties of matter, and reactions.

Active learning was a focus, including engaging participants first in the role of the learner as facilitators modeled the use of pedagogy. Misconceptions were addressed through inquiry activities. Opportunities for reflection were also included. Participants were provided opportunities to practice using Modeling Instruction in the workshop as well through leading various activities with their peers.

Coherence was achieved through an alignment with state chemistry standards and assessments. An additional focus was on transforming teacher beliefs through the proposed activities. The **duration** of the program included 108-hours of contact with participants, which is consistent with the framework. This was achieved through 98-hours of face-to-face workshops and 10-hours of work in the online environment. **Collective participation** was achieved by including two chemistry teachers from each school according to the proposal.

FINDINGS FROM OBSERVATIONS

The ETSU MICH program had 19 teachers who were observed at least once. Eleven teachers submitted all three required videos, and this is the group that was examined for impact of the program on their instructional practice. Overall, there was significant growth for participants in the ETSU Chemistry program participants in all four measured areas: design, implementation, classroom culture, and content knowledge.

ETSU chemistry program participants were characterized as delivering "ineffective instruction" (score of 1.96) on the design of lesson at baseline. Observations at the end of the program revealed significant growth to 2.46 ("elements of effective instruction"). The design of lesson construct examines the extent of planning, organization, resources, equity, collaboration, flow, assessments, and sense making that takes place in the lesson delivery.

The implementation of lesson rating also grew significantly for participants overall across the program. At baseline ETSU MICH teachers received a 2.29 ("elements of effective instruction") but improved to a score of 2.84 by end of program. The implementation of lesson construct examines level of investigative mathematics/science in the lesson, quality of classroom management strategies, pace of the lesson, ability to modify instruction based upon student understanding, teacher questioning strategies, and formative assessments.

ETSU teachers at baseline received a score for science content knowledge of 2.55 ("elements of effective instruction"). By the end of the program, ETSU MICH participants had experienced significant growth (3.20, "beginning stages of effective instruction"). This means that during observations, science content delivered was significant and worthwhile and appropriate for the developmental needs of students. Teacher-provided content was accurate, and some connections to real-world contexts were used. Participants also incorporated some abstraction, theory building, and connections to other disciplines in observed lessons.

Classroom culture was another area of significant growth for the ETSU MICH teachers. The overall group began at 2.29 ("elements of effective instruction"). However, by the end of the program, MICH participants had raised improved considerably and gained a score of 3.02 ("beginning stages of effective instruction"). Implementation of strategies, including collaborative learning, centering instruction on student generated questions, and ideas and intellectual rigor, were not evident through observations. All students were actively engaged in meaningful learning that respected ideas consistently in classroom observations conducted at the end of the program.

FINDINGS FROM SURVEYS

An examination of the surveys that participants completed in a pre/post manner revealed findings related to teacher opinions, frequency of use in instructional practices, student activities, instructional influences, teacher preparedness, principal perceptions, parental support, and professional development experiences.

Teacher opinions regarding the importance of use of effective instructional strategies and support necessary to be successful are included in this section of the survey. More MICH teachers reported that participation in hands-on activities (75 percent to 82 percent) and inquiry-based activities (80 percent to 82 percent) were important. However, on the following items, more teachers rated them as not or somewhat important:

- Importance of making connections between science and other disciplines (25 percent to 55 percent)
- Importance of using cooperative learning (40 percent to 46 percent)
- Importance of using project/laboratory/research reports (35 percent to 55 percent)
- Importance of students' using computers (55 percent to 82 percent)
- Importance of applying science in various contexts (35 percent to 64 percent)
- Importance of using performance-based assessments (55 percent to 64 percent)
- Importance of using informal questioning (25 percent to 37 percent)

Instructional Influences were a second area of focus in the survey. The MICH participants reported some positive growth in influences that encourage effective instruction. However, in many cases, the majority of participants still felt the influences inhibited effective science teaching.

Encourages Effective Instruction – The following influences were perceived as having a more positive relationship on teaching chemistry effectively by the end of the program:

- State and/or district curriculum frameworks (45 percent to 55 percent)
- Quality of available instructional materials (55 percent to 73 percent)
- Access to computers for science instruction (55 percent to 64 percent)
- Management of instructional resources at the district or school level (25 percent to 55 percent)
- Importance that school places on science/math (40 percent to 55 percent)
- Funds for equipment and supplies (25 percent to 46 percent)
- Time available for professional development (25 percent to 46 percent)
- Public attitudes toward reform (15 percent to 27 percent)

Inhibits Effective Instruction – Participants reported the time available for teachers to work with other teachers was a negative influence on effective chemistry instruction (80 percent to 90 percent).

Teacher Preparedness comprised the third construct of the survey. ETSU MICH program participants experienced growth in perceptions of preparation to deliver effective science instruction in all but two areas of this construct.

Growth in Perceived Preparation – Teachers who participated in the program reported being better prepared in the following areas at the end of the program:

- Providing concrete experiences before abstract concepts (80 percent to 91 percent)
- Developing student conceptual understanding (75 percent to 91 percent)
- Considering prior understanding when planning curriculum and instruction (55 percent to 91 percent)
- Making connections between science/math and other disciplines (80 percent to 82 percent)
- Using cooperative learning groups (80 percent to 82 percent)
- Engaging students in inquiry-oriented activities (60 percent to 82 percent)
- Having students prepare project/laboratory/research reports (60 percent to 73 percent)
- Using computers (74 percent to 91 percent)
- Engaging students in applying science/math in a variety of contexts (45 percent to 82 percent)
- Using performance based assessments (60 percent to 91 percent)
- Using informal questioning to assess student understanding (90 percent to 91 percent)
- Leading a class using investigative strategies (60 percent to 91 percent)
- Managing students engaged in hands-on/project-based work (75 percent to 100 percent)
- Recognizing and responding to student diversity (63 percent to 100 percent)
- Encouraging students' interest in science/math (75 percent to 100 percent)
- Using strategies that encourage participation of females and minorities in science/math (38 percent to 100 percent)

Decline in Perceived Preparation – ETSU participants felt less prepared in helping students take responsibility for their own learning (25 percent to 36 percent) at the end of the program.

Frequency of Use of Instructional Practices consists of ETSU teacher reported frequency of use of specific instructional practices. Participants reported increase in most areas.

Increased Use – There were several practices for which more participants reported frequent use from pre- to post-survey administration. These practices included:

- Teaching science in real-world contexts (85 percent to 91 percent)
- Requiring students to use evidence to support their claims (75 percent to 91 percent)

- Encouraging students to explain concepts to one another (75 percent to 82 percent)
- Encouraging students to consider alternative explanations (50 percent to 72 percent)
- Allowing students to work at their own pace (55 percent to 64 percent)
- Embedding assessment in regular class activities (75 percent to 82 percent)
- Assigning science/math homework (65 percent to 73 percent)

Decreased Use – More participants reported infrequent use of two practices from baseline to end of the program:

- Arranging seating to facilitate student discussion (38 percent to 100 percent)
- Using pre-assessments (50 percent to 64 percent)

Student Activities are the activities that students are engaged in within the classroom. ESTU MICH participants were asked questions regarding the frequency of use of various student activities. There were mixed findings in regards to the frequency of use of effective student activities from baseline to end of program.

Frequent Use – Participants reported more frequent use of some student activities by the end of the program. These included having students:

- Participating in student-led discussions (30 percent to 82 percent)
- Participating in discussions with the teacher to further understanding (65 percent to 82 percent)
- Working in cooperative learning groups (95 percent to 100 percent)
- Sharing ideas or solve problems with each other in small groups (60 percent to 64 percent)
- Engaging in hands-on science/math activities (80 percent to 91 percent)
- Working on models or simulations (10 percent to 27 percent)
- Recording, representing, and/or analyzing data (56 percent to 82 percent)
- Writing reflections in a notebook or journal (30 percent to 55 percent)
- Taking short-answer tests (50 percent to 55 percent)
- Taking tests requiring open-ended responses (25 percent to 55 percent)

Decreased Use – More teachers in the program also reported decreased use of some student activities that are considered effective practice:

- Making formal presentations to the class (75 percent to 91 percent)
- Reading from textbook (80 percent to 90 percent)
- Following specific instructions in an activity or investigation (30 percent to 55 percent)
- Designing or implementing his or her own investigation (85 percent to 90 percent)

- Working on portfolios (80 percent to 100 percent)

Principal Perceptions are the impressions that participants have about their administrator's perceptions of the teaching and learning of science/math. ETSU MICH participants revealed positive feelings regarding this construct.

Areas of Increased Agreement – Teachers agreed that their principal provides encouragement and/or support in the following areas:

- Encouraging selection of science/math content and strategies to address individual students' learning (80 percent to 82 percent)
- Accepting the noise that comes with an active classroom (90 to 91 percent)
- Providing materials/equipment for science/math (45 percent to 73 percent)
- Encouraging teachers to make connections across disciplines (60 percent to 82 percent)
- Acting as a buffer between teachers and external pressures (75 percent to 80 percent)

Parental Support was reported to be very low by participants in the ETSU MICH program. All of the participants indicated that few parents volunteer to assist with class activities, donate money for materials, attend parent-teacher conferences or PTA or math/science nights, or voice support for various instructional approaches.

Professional Development (PD) Experiences is an area of the survey where participants indicate their impressions of the ability of the PD program to increase their skills. ETSU MICH participants were positive regarding the impact the program had on their ability to implement high-quality science instructional materials (64 percent). However, only 37 percent thought the PD had increased their content knowledge, and only 46 percent thought their understanding of how children think about science had been increased.

FINDINGS FROM CONTENT ASSESSMENT

Twenty participants in the ETSU program completed both the pre- and post-assessment that was developed by ETSU. On the pre-test, teacher average percentage was 85 percent correct. This percentage increased to 91 percent on the post-test.

CONCLUDING OBSERVATIONS FOR PROGRAM

ETSU's MICH program implemented a nationally recognized program approach "Modeling Instruction," and findings indicate participation had a significant impact on teacher quality. The MICH professional development program was designed to include the five criteria in the Core Conceptual Framework (content focus, active participation, duration, coherence, and collective participation).

In respect to classroom observation data, ETSU teachers experienced significant gains in all four domains (design, implementation, content, and classroom culture) across the program. Additionally, teachers in this program reported implementation of investigative science instructional strategies, including those that require a high level of ability to facilitate student scientific discourse (e.g., using evidence, explaining concepts to others, considering alternative explanations, working with models and simulations, and recording, representing, and analyzing data). However, teachers reported decreased use of some investigative strategies that should be aligned with those previously mentioned (e.g., designing their own investigations, participating in field work), which may reveal that this PD program was structured on implementing this specific curriculum which may not have had an emphasis on all of the effective strategies for teaching science. Therefore, it is difficult to determine teacher ability to develop and implement further inquiry-based instruction beyond the scope of this PD.

MICH teachers reported more support from principals. Reported PD experiences included less than 40 percent of teachers feeling their content knowledge was impacted. However, it may be that the content might was a review for some teachers. The chemistry content seemed reinforcing in nature, and most of the emphasis of the PD was centered on learning the new instructional approach. Participants did feel prepared to implement the curriculum at the end of the program. Parental support reported was very low. Participants in the MICH program realized gains in content knowledge on the pre/post assessment. Overall, this program demonstrated significant gains in teacher quality and on some key areas of preparation aligned with the program.

Program Narrative
East Tennessee State University (ETSU)
Tai and Ho, PIs

PROGRAM SETTING AND PARTICIPANTS

The East Tennessee State University (ETSU) Reaching for Excellence in Elementary School Science through Inquiry, Standards, Problem-based and Cloud Computing Technology-based (ISPT-based) program was a partnership between ETSU education and chemistry faculty and five school districts (Bristol, Greene, Hawkins, Kingsport City, and Sullivan) in Northeast Tennessee. The program was designed to deliver a 16-month intensive professional development program for 20 teachers in grades 3-5. A twelve-day summer institute was completed, along with five additional workshops, for a total of one hundred two hours of professional development programming.

The goals of this project included the following:

1. Participant teachers will demonstrate enhanced scientific knowledge, advanced pedagogical knowledge and skills, and improved pedagogical content knowledge (PCK).
2. Students of participating teachers will engage in science learning through ISPT-based investigation, have increased interest, curiosity and awareness of opportunities in science learning, and demonstrate improved science achievement scores.

The objectives of this project included the following:

1. Teachers will learn advanced and standards-based science content.
2. Teachers will learn advanced and research-based pedagogical methodology.
3. Teachers will implement ISPT-based instructional strategies and model them in their classrooms.
4. Teachers will advance their effectiveness in science teaching aligned with the revised and more challenging state standards as measured by TVAAS.
5. Students will advance their achievement in science as measured by TCAP.

PROGRAM ALIGNMENT WITH CORE CONCEPTUAL FRAMEWORK

ETSU's ISPT-based program aligned with the Core Conceptual framework in all five areas, detailed in the program proposal. First, the ETSU program focused on elementary science **content knowledge**, aligned with the state standards for grades 3-5 and including content such as cells and heredity, ecosystems and biodiversity, Earth and universe, energy and temperature, gases, liquids and solids, electricity and magnetism, force and motion, and light and sound. A detailed timeline for the program and coverage of content was provided.

Active learning was described as a focus in the proposal, including the four active learning dimensions in the ISPT-based program. The dimensions were peer collaboration, planning for classroom implementation, addressing student need, and presenting and discussing. The teachers worked in groups to develop inquiry-based, standards-based, and problem-based science lessons for their students. It does not appear that any curriculum materials were provided to teachers. Rather, lessons were teacher developed.

Coherence was described in the proposal as including connections with goals, alignment with state and district standards and assessments, and communication with others. The **duration** of the program included 102 hours of contact with participants, which is consistent with the framework. This was achieved through a combination of a twelve-day summer institute and five Saturday workshops across the academic year. **Collective participation** was achieved by including two elementary teachers from each school and from the same grade level, according to the proposal.

FINDINGS FROM OBSERVATIONS

The ETSU ISPT-based program had 22 teachers who were observed at least once. Seventeen teachers submitted all three required videos, and this is the group that was examined for impact of the program on their instructional practice. Overall, there was significant growth for participants in the ETSU program participants in all four measured areas: design, implementation, classroom culture, and content knowledge.

At baseline, the ETSU ISPT-based program participants received a mean score of 2.33 (characterized as delivering "elements of effective instruction"), which increased to a final mean score of 2.78 by the end of the program. The design of lesson construct examines the extent of planning, organization, resources, equity, collaboration, flow, assessments, and sense making that took place in the lesson delivery.

ETSU ISPT-based program participants also experienced growth in the area of implementation of lesson. The baseline mean rating for teachers was 2.55 ("elements of effective instruction") and improved to a mean of 3.26 at end of program ("beginning stages of effective instruction"). Teacher ability to implement effective science instruction improved considerably. The implementation of lesson construct examines level of investigative mathematics/science in the lesson, quality of classroom management strategies, pace of the lesson, ability to modify instruction based upon student understanding, teacher questioning strategies, and formative assessments.

ETSU teachers at baseline received a score for science content knowledge of 2.63 ("elements of effective instruction"). By the end of the program, ETSU participants had experienced significant growth to 3.54 ("beginning stages of effective instruction"). This means that during observations, science content delivered was significant and worthwhile and appropriate for the developmental needs of students. Teacher-provided content was accurate, and some connections to real-world contexts were used. Participants also incorporated some abstraction, theory building, and connections to other disciplines in observed lessons.

Classroom culture was another area of significant growth for the ETSU elementary science teachers.

The overall group began at a score of 2.54 ("elements of effective instruction"). However, by the end of the program, participants had raised improved considerably with a score of 3.44 ("beginning stages of effective instruction"). Implementation of strategies including collaborative learning, centering instruction on student generated questions, and ideas and intellectual rigor were not evident through observations. All students were actively engaged in meaningful learning that respected ideas consistently in classroom observations conducted at the end of the program.

FINDINGS FROM SURVEYS

An examination of the surveys that participants completed in a pre/post manner revealed findings related to teacher opinions, frequency of use in instructional practices, student activities, instructional influences, teacher preparedness, principal perceptions, parental support, and professional development experiences.

Teacher opinions regarding the importance of use of effective instructional strategies and support necessary to be successful are included in this section of the survey.

Areas of Increased Agreement in teacher opinions related to the teaching of science:

- Making connections between science/math and other disciplines (74 percent to 100 percent)
- Participating in hands-on activities (90 percent to 100 percent)
- Using inquiry-based activities (90 percent to 91 percent)
- Using informal questioning (63 percent to 80 percent)

In addition, more participants felt supported by colleagues (68 percent to 73 percent), had a shared vision with colleagues of effective science instruction (47 percent to 56 percent) and reported regularly sharing ideas and materials related to science with colleagues (53 percent to 55 percent).

Areas of Increased Disagreement in teacher opinions related to the teaching of science:

- Using project/laboratory/research reports (56 percent to 64 percent)
- Students' using computers (53 percent to 64 percent)
- Using portfolios (74 percent to 91 percent)

Further, more participants disagreed that they felt well-prepared to teach investigative science (68 percent to 73 percent), that they had adequate time to collaborate with colleagues (68 percent to 82 percent), and that they had adequate access to computers for teaching science (32 percent to 64 percent).

Instructional Influences were a second area of focus in the survey. The ETSU participants reported positive growth in influences that encourage effective instruction at the end of the program, with over 50 percent agreement on most items.

Encourages Effective Instruction – The following influences were perceived as having a more positive relationship on teaching science effectively by the end of the program:

- State and/or district curriculum frameworks (47 percent to 64 percent)
- Quality of available instructional materials (42 percent to 55 percent)
- Access to computers for science instruction (37 percent to 55 percent)
- Management of instructional resources at the district or school level (28 percent to 55 percent)
- Time available for teachers to work with other teachers (37 percent to 50 percent)
- Importance that school places on science/math (42 percent to 50 percent)
- Consistence of science/math reform efforts with other school/district reforms (37 percent to 55 percent)
- Public attitudes toward reform (37 percent to 60 percent)
- Funds for purchasing equipment and supplies for science (36 percent to 46 percent)
- State and/or district testing policies and practices (15 percent to 27 percent)
- Time available for teacher professional development (42 percent to 46 percent)

Teacher Preparedness comprised the third construct of the survey. ETSU program participants experienced growth in perceptions of preparation to deliver effective science instruction in all areas of this construct.

- Providing concrete experiences before abstract concepts (65 percent to 92 percent)
- Developing student conceptual understanding (84 percent to 92 percent)
- Considering prior understanding when planning curriculum and instruction (79 percent to 92 percent)
- Making connections between science/math and other disciplines (90 percent to 92 percent)
- Using cooperative learning groups (90 percent to 92 percent)
- Using hands-on activities (74 percent to 92 percent)
- Engaging students in inquiry-oriented activities (63 percent to 100 percent)
- Having students prepare project/laboratory/research reports (42 percent to 83 percent)
- Using computers (84 percent to 92 percent)
- Engaging students in applying science/math in a variety of contexts (48 percent to 92 percent)
- Using performance based assessments (74 percent to 83 percent)
- Using portfolios (26 percent to 33 percent)
- Leading a class using investigative strategies (68 percent to 100 percent)
- Managing students engaged in hands-on/project-based work

(84 percent to 100 percent)
- Helping students take responsibility for their own learning (84 percent to 92 percent)
- Recognizing and responding to student diversity (79 percent to 92 percent)
- Encouraging students' interest in science/math (89 percent to 90 percent)
- Using strategies that encourage participation of females and minorities in science/math (58 percent to 92 percent)

Frequency of Use of Instructional Practices consists of frequency of ETSU teacher reported use of specific instructional practices. Participants reported increases in most areas.

Increased Use – There were several practices for which participants reported increased use across the program:

- Demonstrating a science-related principle or phenomenon (55 percent to 64 percent)
- Teaching science in real-world contexts (84 percent to 100 percent)
- Arranging seating to facilitate student discussion (95 percent to 100 percent)
- Requiring students to use evidence to support their claims (74 percent to 100 percent)
- Encouraging students to consider alternative explanations (68 percent to 82 percent)
- Allowing students to work at their own pace (55 percent to 64 percent)
- Helping students to see connections between science/math and other disciplines (79 percent to 82 percent)
- Reading and commenting on student journals (53 percent to 73 percent)

Decreased Use – More participants decreased their use of some practices from baseline to end of the program:

- Encouraging students to explain concepts to one another (21 percent to 52 percent)
- Using pre-assessments (26 percent to 74 percent)

Student Activities are the activities that students are engaged in within the classroom. ESTU participants were asked questions regarding the frequency of use of various student activities. There were mixed findings in regards to the frequency of use of effective student activities from baseline to end of program.

Frequent Use – Participants reported more frequent use of some student activities across the program:

- Participating in student-led discussions (42 percent to 84 percent)
- Participating in discussions with the teacher to further understanding

(73 percent to 82 percent)
- Working in cooperative learning groups (84 percent to 91 percent)
- Reading other (non-textbook) science/math related materials in class (42 percent to 73 percent)
- Engaging in hands-on science/math activities (53 percent to 73 percent)
- Designing or implementing his or her own investigation (5 percent to 36 percent)
- Working on models or simulations (16 percent to 27 percent)
- Participating in field work (5 percent to 9 percent)
- Recording, representing and/or analyzing data (26 percent to 36 percent)
- Writing reflections in a notebook or journal (36 percent to 81 percent)

Decreased Use – More teachers also reported infrequent use of some student activities that are considered effective practice by the end of the program:

- Making formal presentations to the class (89 percent to 91 percent)
- Reading from textbook (32 percent to 36 percent)
- Working on solving a real-world problem (26 percent to 46 percent)
- Sharing ideas or solving problems with each other in small groups (32 percent to 45 percent)
- Working on extended science/math investigations or projects (84 percent to 91 percent)
- Taking short-answer tests (52 percent to 82 percent)
- Taking tests requiring open-ended responses (67 percent to 73 percent)

Principal Perceptions are the impressions that participants have about their administrator's perceptions of the teaching and learning of science/math. ETSU participants revealed positive feelings regarding this construct.

Areas of Increased Agreement – Teachers agreed their principal provides encouragement and/or support in the following areas:

- Selecting science/math content and strategies to address individual students' learning (79 percent to 82 percent)
- Encouraging innovative instructional practices (79 percent to 91 percent)
- Encouraging me to observe other exemplary science teachers (53 percent to 55 percent)
- Encouraging teachers to make connections across disciplines (79 percent to 90 percent)
- Acting as a buffer between teachers and external pressures (68 percent to 73 percent)

Parental Support was reported to be very low by participants in the ETSU program. All of the participants indicated that few parents volunteer to assist with class activities, donate money for materials, attend PTA or math/science nights, or voice support for various instructional approaches.

Professional Development (PD) Experiences is an area of the survey where participants indicated their impressions of the ability of the PD program to increase their skills. Less than 50 percent of ETSU participants were positive regarding the impact the program had on their ability to implement high-quality science instructional materials (37 percent), increased content knowledge (46 percent) and their understanding of how children think about science (46 percent).

FINDINGS FROM CONTENT ASSESSMENT

Twenty participants completed both the pre/post assessment that was developed by ETSU. On the pre-test, the nine teachers answered 80 percent of the items correctly. The percentage correct increased to 85 percent on the post-test. This was determined to be statistically significant growth.

CONCLUDING OBSERVATIONS FOR PROGRAM

The ISPT-based program implemented strategies including inquiry-based learning, standards-based focus, problem-based learning, and technological applications in their PD program for elementary teachers of grades 3-5. In this program, teachers developed their own instructional materials through guidance provided by program staff. In the proposal, the ETSU professional development program provided focus on the five criteria in the Core Conceptual Framework (content focus, active participation, duration, coherence, and collective participation).

In respect to classroom observation data, ETSU teachers experienced significant gains in all four domains (design, implementation, content, and classroom culture) across the program. Additionally, teachers in this program reported implementation of investigative science instructional strategies, including those that require a high-level of ability to facilitate student scientific discourse (e.g., using evidence, considering alternative explanations, and recording, representing, and analyzing data). On the other hand, participants reported decreased use of many investigative science activities with students by the end of the program (e.g., solving real-world problems, solving problems in small groups, extended science investigations, field work). This may be why the gains, though significant, did not result in a mean score on any of the teacher quality ratings of 4 or greater.

Principal support was an area of reported growth from baseline to end of program, as more than 50 percent of participants felt supported in all respects of this construct. Teachers reported parental support reported to be very low. The research has demonstrated that elementary teachers, in particular often feel less self-efficacy to teach science/mathematics. This might explain the lower-than-expected ratings of the perceived impact of the PD on their ability to implement the instructional materials they were provided (46 percent), as well as their understandings of how children learn (36 percent), and content knowledge (37 percent) despite significant gains demonstrated in their observed teacher quality and self-reported use of practices. However, classroom observations revealed significantly improved teacher quality, including content knowledge. ETSU developed and administered pre/post assessments also revealed content

knowledge gains for participants. Overall, this program demonstrated significant gains in all areas, including teacher quality, teacher opinions, preparedness, and content knowledge.

Program Narrative
Lipscomb University
Hutchinson and Boyd, PIs

PROGRAM SETTING AND PARTICIPANTS

Lipscomb University's Hands-on Chemistry program was a partnership between the College of Arts & Sciences and the College of Education to deliver a 12-month intensive professional development program for 24 high school teachers of chemistry. Lipscomb partnered with five LEAs (Davidson/MNPS, Humphreys, Robertson, Sumner, and Williamson) for this program. Five summer workshop days were conducted, along with five Saturday sessions and an online component, for a total of eighty contact hours of instruction. The goals of this project included enabling participants to:

1. Recognize, understand, and apply Tennessee science standards in chemistry and embedded math and engineering as they connect to chemistry.
2. Incorporate hands-on activities into their classrooms and laboratories to meet the Tennessee chemistry standards while reaching all levels of students.
3. Explore real-world application of chemistry through business partnerships.
4. Convert "cookbook" labs and design new labs as inquiry-based learning experiences with appropriate formative assessment instruments.
5. Perform inquiry-based demonstrations that actively engage students.
6. Integrate research-based teaching strategies and pedagogy into their teaching.
7. Adapt and utilize civic engagement and service learning approaches with chemistry content and laboratories.
8. Adapt current social/scientific topics into learning modules to illustrate state standards.
9. Create integrated science labs connecting chemistry to other sciences and society.

PROGRAM ALIGNMENT WITH CORE CONCEPTUAL FRAMEWORK

The proposed Lipscomb Hands-on Chemistry program aligned with the Core Conceptual framework with a focus on chemistry **content knowledge** delivered through a lens of content and pedagogy delivered by the chemistry and education faculty. Modeling of effective integration of content with increasing pedagogical skill was also included. **Active learning** was a focus including the use of multiple inquiry-based laboratory exercises conducted in teams. Teachers were first in the role of learner then shifted to focus on developing lessons for their classrooms. At least 80 percent of activities were to be focused on active learning experiences. **Coherence** was achieved through a combination of alignment with teachers' own personal goals and state standards and assessments. An additional focus was on transforming teacher beliefs through the proposed activities. The **duration** of the program included 80-hours of contact with participants, which is consistent with

the framework. This was achieved through a 40-hour, 1-week intensive summer workshop, combined with 20-hours of web-based work, and 4 5-hour Saturday Science and reunion activities. **Collective participation** was achieved by including two chemistry teachers from each school, according to the proposal.

FINDINGS FROM OBSERVATIONS

The submission rate for teacher-provided videos of their teaching for the Hands-on Chemistry program at Lipscomb was less than optimal. Fourteen teachers submitted at least one video. However, only five teachers submitted all three required videos, and this is the group that was examined for impact of the program on their instructional practice. Overall, there was no significant change for participants in the Lipscomb Hands-on Chemistry program participants in three of the four measured areas: implementation, classroom culture, and content knowledge. Additionally, there was a significant decrease for participants in ability to design an effective chemistry lesson (decrease from a score of 2.32 to 2.12 at program end).

At baseline, Lipscomb program participants were characterized as "elements of effective instruction" on the design of lesson (score of 2.32). However, by the end of the program, the overall score had decreased within the same range to a score of 2.12. The design of lesson examines the extent of planning, organization, resources, equity, collaboration, flow, assessments, and sense making that takes place in the lesson delivery.

Lipscomb University participants began the program with an implementation of lesson at an "elements of effective instruction" level (score of 2.57). At the end of the program the score was virtually unchanged at 2.54. The implementation of lesson construct examines level of investigative mathematics/science in the lesson, quality of classroom management strategies, pace of the lesson, ability to modify instruction based upon student understanding, teacher questioning strategies, and formative assessments.

Teachers in the Lipscomb program began with science content knowledge rated in the "beginning stages of effective instruction" range (score of 2.91). However, participants demonstrated no statistically significant growth in observed lessons across the program, with a final rating of 3.09. This means that most of the time during observations, science content delivered was significant and worthwhile and appropriate for the developmental needs of students. Teacher-provided content was accurate, and some connections to real-world contexts were used. However, participants did not incorporate abstraction, theory building, and connections to other disciplines in observed lessons.

Lipscomb participants did not experience any significant change across the program in the final area of classroom culture. The overall group began with a score of 2.77 ("elements of effective instruction") and ended at 2.73. Implementation of strategies including collaborative learning, centering instruction on student generated questions, and ideas and intellectual rigor were not evident during observations. Active participation of all students was not observed as being encouraged and respected in a consistent manner.

FINDINGS FROM SURVEYS

An examination of the pre/post surveys that participants completed revealed findings related to teacher opinions, frequency of use in instructional practices, student activities, instructional influences, teacher preparedness, principal perceptions, parental support, and professional development experiences.

Teacher opinions were mixed at the end of the program as compared to the baseline, prior to participation in the program.

Areas of Increased Agreement in teacher opinions related to the teaching of chemistry:

- Teachers collaborated to share ideas more (57 percent to 100 percent)
- Teachers shared a common vision of effective science/math instruction (88 percent to 100 percent)
- Teachers recognized the importance of connecting math/science to other disciplines (63 percent to 100 percent)
- Teachers valued the use of cooperative learning groups (25 percent to 100 percent)
- Teachers planned to use appropriate hands-on activities (75 percent to 100 percent)
- Teachers planned to use performance based assessment (63 percent to 100 percent)
- Teachers recognized the importance of having students do research/lab reports (50 percent to 100 percent)
- Teachers engaged students in inquiry-oriented activities (63 percent to 100 percent)

Areas of Increased Disagreement in teacher opinions related to the teaching of chemistry:

- Importance of using computers (50 percent to 100 percent)
- Importance of engaging students in applications of science/math in a variety of contexts (38 percent to 100 percent)
- Importance of using portfolios (87 percent to 100 percent)
- Availability of materials for investigative science/mathematics instruction (50 percent to 100 percent)
- The science/math program in my school is supported by local organizations, institutions, and/or business (63 percent to 100 percent)

Instructional Influences were a second area of focus in the survey. The Lipscomb Hands-on Chemistry participants reported overwhelmingly negative experiences with variables in this area at the end of the program.

Encourages Effective Instruction – Teachers reported that only one item encouraged the use of effective instruction: state and/or district curriculum frameworks. Their agreement with this item increased from 38 percent to 100 percent over the project period.

Inhibits Effective Instruction – At the end of the program teachers unanimously rated all other items in this area as inhibitors of effective instruction:

- State and/or district testing policies and practices (62 percent to 100 percent)
- Quality of instructional materials (25 percent to 100 percent)
- Access to computers (38 percent to 100 percent)
- Funds for supplies (25 percent to 100 percent)
- Management of instructional resources at the district or school level (63 percent to 100 percent)
- Time for planning and preparing lessons (38 percent to 100 percent)
- Time for collaboration with other teachers (38 percent to 100 percent)
- Time available for professional development (50 percent to 100 percent)
- Importance school places on science/math (13 percent to 100 percent)
- Consistence of science/math reform efforts with other school/district reforms (50 percent to 100 percent)
- Public attitudes toward reform (50 percent to 100 percent)

Teacher Preparedness comprised the third construct of the survey. Lipscomb program participants experienced growth in perceptions of preparation to deliver effective science instruction in almost all areas.

Growth in Preparation – Teachers who participated in the program felt better prepared in the following areas than they did before the program:

- Providing concrete experiences before abstract concepts (62 percent to 100 percent)
- Developing student conceptual understanding (75 percent to 100 percent)
- Considering prior understanding when planning curriculum and instruction (63 percent to 100 percent)
- Making connections between science/math and other disciplines (63 percent to 100 percent)
- Using cooperative learning groups (62 percent to 100 percent)
- Using hands-on activities (50 percent to 100 percent)
- Engaging students in inquiry-oriented activities (50 percent to 100 percent)
- Having students prepare project/laboratory/research reports (75 percent to 100 percent)
- Using computers (38 percent to 100 percent)
- Engaging students in applying science/math in a variety of contexts (63 percent to 100 percent)
- Using performance based assessments (75 percent to 100 percent)

- Using informal questioning to assess student understanding (75 percent to 100 percent)
- Leading a class using investigative strategies (63 percent to 100 percent)
- Managing students engaged in hands-on/project-based work (88 percent to 100 percent)
- Helping students take responsibility for their own learning (63 percent to 100 percent)
- Recognizing and responding to student diversity (63 percent to 100 percent)
- Encouraging students' interest in science/math (75 percent to 100 percent)
- Using strategies that encourage participation of females and minorities in science/math (38 percent to 100 percent)

Decline in Preparation – There was only one area in which Lipscomb participants' teachers said they felt less prepared following participation in the program: Use of portfolios (75 percent to 100 percent).

Frequency of Use of Instructional Practices consists of teacher reported use of specific instructional practices. Lipscomb Hands-on Chemistry program participants reported increases in some areas and declines in others.

Increased Use – There were several practices for which participants reported more frequent use by end of program:

- Teaching science in real-world contexts (63 percent to 100 percent)
- Using open-ended questions (75 percent to 100 percent)
- Requiring students to use evidence to support their claims (75 percent to 100 percent)
- Using assessment to find out what student know before or during a unit (75 percent to 100 percent)
- Assigning science/math homework (63 percent to 100 percent)
- Reading and commenting on student reflections in journals (63 percent to 100 percent)

Decreased Use – More participants reported decreased use of some practices from baseline to end of the program:

- Demonstrating of a science/math principle or phenomenon (62 percent to 100 percent)
- Arranging seating to facilitate student discussion (38 percent to 100 percent)
- Encouraging students to explain concepts to one another (38 percent to 100 percent)
- Encouraging students to consider alternative explanations (46 percent to 63 percent)
- Allowing students to work at their own pace (25 percent to 100 percent)

- Helping students see connections between math/science and other disciplines (25 percent to 100 percent)

Student Activities are the activities that students are engaged in within the classroom. Participants were asked questions regarding the frequency/infrequency of use of various student activities. There were mixed findings in regards to the frequency of use of effective student activities from baseline to end of program.

Frequent Use – Participants reported more frequent use for some student activities by end of program:

- Participating in discussions with the teacher to further understanding (50 percent to 100 percent)
- Working in cooperative learning groups (50 percent to 100 percent)
- Reviewing homework/worksheet assignments (75 percent to 100 percent)
- Working on solving a real-world problem (63 percent to 100 percent)
- Sharing ideas or solve problems with each other in small groups (75 percent to 100 percent)
- Engaging in hands-on science/math activities (50 percent to 100 percent)
- Following specific instructions in an activity or investigation (50 percent to 100 percent)
- Designing or implementing his or her own investigation (13 percent to 100 percent)
- Working on models or simulations (38 percent to 100 percent)
- Working on extended science/math investigations or projects that are a week or more in duration (25 percent to 100 percent)
- Writing reflections in a notebook or journal (50 percent to 100 percent)

Decreased Use – More teachers in the Hands-on Chemistry program reported less frequent use of some student activities that are considered effective practice by the end of the program:

- Participating in student-led discussions (63 percent to 100 percent)
- Making formal presentations to the class (88 percent to 100 percent)
- Reading other (non-textbook) science/math related materials in class (63 percent to 100 percent)
- Participating in field work (88 percent to 100 percent)
- Recording, representing, and/or analyzing data (63 percent to 100 percent)
- Working on portfolios (88 percent to 100 percent)
- Taking short-answer tests (68 percent to 100 percent)
- Taking tests requiring open-ended responses (63 percent to 100 percent)

Principal Perceptions are the impressions that participants hold about their administrator's perceptions of the teaching and learning of science/math. Lipscomb Hands-on Chemistry

participants revealed mixed feelings regarding this construct that did not change much pre- to post-program.

Areas of Increased Agreement – Teachers agreed that their principal provides encouragement and/or support in the following areas:

- Selection of science/math content and strategies to address individual students' learning (75 percent to 100 percent)
- Providing materials/equipment for science/math (75 percent to 100 percent)
- Time for teachers to meet and share ideas (75 percent to 100 percent)
- Encouraging teachers to make connections across disciplines (71 percent to 100 percent)

Areas of Increased Disagreement – Teachers did not agree that their principals provided encouragement and/or support in the following areas:

- Accepting the noise that comes with an active classroom (100 percent)
- Encouraging teachers to observe other science/math teachers (100 percent)
- Acting as a buffer between teachers and external pressures (100 percent)

Parental Support was reported to be very low by participants in the Lipscomb Hands-on Chemistry program both pre- and post-survey. All of the participants indicated that few parents volunteer to assist with class activities, donate money for materials, attend parent-teacher conferences or PTA or math/science nights, or voice support for various instructional approaches.

Professional Development (PD) Experiences is an area of the survey where participants indicate their impressions of the ability of the PD program to increase their skills. The Hands-on Chemistry participants reported they did not believe the PD program had increased their science/math content knowledge.

However, participants felt that the PD had impacted their understanding of students (50 percent to 100 percent) and ability to implement high-quality science/math instructional materials (50 percent to 100 percent).

FINDINGS FROM CONTENT ASSESSMENT

Nine participants completed both the pre and post assessment that was developed by Lipscomb. On the pre-test, the nine teachers answered 82 percent of the items correctly. The percentage correct increased to 96 percent on the post-test. This was determined to be statistically significant growth.

CONCLUDING OBSERVATIONS FOR PROGRAM

Lipscomb University's Hands-on Chemistry professional development program specifically addressed the five components of the Core Conceptual Framework (content focus, active

participation, duration, coherence, and collective participation) in the grant proposal as part of their planned focus. However, program outcomes indicate that Hands-on Chemistry did not have a significant impact on teacher quality. Specifically, classroom observation data revealed no significant change in the areas of implementation of the lesson, classroom culture, and science content. Further, participant ability to design an effective science lesson significantly decreased by the end of program.

Teacher survey findings were mixed. In their self-reports, participants indicated increased use of some effective strategies for teaching chemistry (e.g., use of real-world contexts, open-ended questions, evidence to support claims, pre-assessments, homework, and journaling). However, the frequency of use of other important investigative science strategies decreased in frequency of use by end of program (e.g., connections between science/math and other disciplines, allowing students to work at own pace, seating to facilitate student discourse, student field work, recording and analyzing data, and student-led discussions).

Interestingly, teachers reported they felt much more prepared to implement effective science teaching. For example, the use of cooperative groups, inquiry, computers, management, diversity, generating student interest, and developing conceptual understandings of science were all areas 100 percent of participants agreed they were prepared for. Unfortunately, participants' perceived preparedness did not translate into observable implemented practice in classroom observations, so it is unclear if they were truly prepared and decided not to implement, or if they were not as prepared as they thought they were.

Participants overwhelmingly felt there were instructional influences that negatively influenced instruction, and these impediments were reported as much more prevalent at the end of the program, including state testing policies, availability of instructional materials, computer access, funding for supplies, time for planning and collaboration, and public attitudes toward reform.

Teacher perceptions of administrative support were mixed. Agreement grew across the program regarding principal support of innovative instructional practices, provisions for materials and equipment, and time for collaboration. Areas in which perceptions declined were related to the noise level of active classrooms, time to observe other exemplary teachers, and the level of administrative buffering between teachers and external forces. Parental support was reported as very low. Teachers reported they felt the PD program had great impact on their ability to understand how children think about/learn science and/or mathematics, as well as their ability to implement effective science instruction. However, participants reported the PD had little impact on their science content knowledge. Overall, this program demonstrated only minimal gains in teacher attitudes and perceived preparedness. There was little to no evidence of program impact on improving teacher quality and content knowledge.

Program Narrative
Middle Tennessee State University (MTSU)
Winters and Kimmins, PIs

PROGRAM SETTING AND PARTICIPANTS

The MTSU EMPOWER program was a partnership between the College of Education and the College of Arts & Sciences to deliver grade 2-6 mathematics focused program for elementary teachers. The 15-month professional development program included 120 contact hours for 40 teacher participants. MTSU partnered with three LEA's (Hardeman, Hardin, and McNairy) for the EMPOWER program. A ten-day summer workshop was combined along with 16-hours of online work. The goals of the project included three main areas:

1. Increasing teachers' pedagogical content knowledge in number and operation.
2. Improving teachers' beliefs about mathematics, about learning/knowing mathematics, and about children's learning and doing mathematics.
3. Enhancing teachers' instructional effectiveness in mathematics.

The objectives of the EMPOWER included the following:

1. The average participant's performance on a pedagogical content knowledge exam will improve significantly from pre-project to post-project.
2. The average participant's performance on a mathematics belief survey will improve significantly from pre-project to post-project.
3. All teachers will utilize manipulatives and the CRA model in their classrooms following the summer institute.
4. All teachers will write an action plan for implementing Project EMPOWER instructional strategies into classrooms.

PROGRAM ALIGNMENT WITH CORE CONCEPTUAL FRAMEWORK

The proposed MTSU program aligned with aspects of the five components of the Core Conceptual framework, with a focus on mathematics **content knowledge** delivered through the use of *Reconceptualizing Mathematics, Integrating Arithmetic and Algebra in Elementary School,* and *Reasoning Algebraically about Operations* curriculum materials. The format of these tools included videos, cases, and student work designed to help teachers better understand how students think about and learn mathematics. Appropriate pedagogy was modeled for number and operation and algebra in the middle school by the four team members (two PI's and two master teachers). **Active learning** was a focus, including spreading the duration of the program across a 14-month period. Instructors modeled pedagogy for teachers participating in the role of "student".

Coherence included a purposeful focus on addressing existing teacher beliefs for EMPOWER participants, as well as purposeful alignment with partnering district level needs. The **duration** of the program included 84-hours of contact with participants, which is consistent with the framework. This was achieved through a summer institute, combined with 16-hours of web-based work and Saturday sessions. **Collective participation** was ensured by including at least a pair of teachers from any given school.

FINDINGS FROM OBSERVATIONS

The submission rate for teacher-provided videos of their teaching for the program at MTSU was very good. There were 31 participants who submitted at least one video and 22 submitted the required three videos for the evaluation. Unfortunately, an analysis of submitted data revealed no significant change in any of the four constructs (e.g., design of lesson, implementation of lesson, classroom culture, and mathematics content) related to change in teacher practice and content knowledge across the program.

At baseline, EMPOWER program participants were characterized as "elements of effective instruction" on the design of lesson construct (score of 2.51) which actually decreased slightly by the end of program (score of 2.37). The design of lesson construct examines the extent of planning, organization, resources, equity, collaboration, flow, assessments, and sense making that takes place in the lesson delivery.

MTSU program participants began the program with an implementation of lesson at a score of 2.65 ("elements of effective instruction") and improved this mean score slightly to 2.75 ("elements of effective instruction") by the end of program, which was not statistically significant. The implementation of lesson construct examines level of investigative mathematics/science in the lesson, quality of classroom management strategies, pace of the lesson, ability to modify instruction based upon student understanding, teacher questioning strategies, and formative assessments.

Teachers in the MTSU program began with mathematics content knowledge rated at a score of 2.99 ("elements of effective instruction"). Again, teachers made some improvements across the program realizing an improved mean score of 3.22 ("beginning stages of effective instruction") by the end of the program, though this was not a statistically significant gain. This means that some of the time during observations, mathematics content delivered was significant and worthwhile and appropriate for the developmental needs of students. Teacher-provided content was accurate, and some connections to real-world contexts were used. Participants did not incorporate abstraction, theory building, and connections to other disciplines in observed lessons.

Classroom culture for EMPOWER participants was the final area that did not demonstrate significant improvement. At baseline, the mean score for teachers in the program was 2.83, which grew slightly to a mean of 2.90 ("elements of effective instruction") at the end of the program. Implementation of strategies, including collaborative learning, centering instruction on student generated questions, and ideas and intellectual rigor, were not evident through observations. Active participation of all students was not observed as being encouraged and respected in a consistent manner.

FINDINGS FROM SURVEYS

An examination of the surveys that MTSU EMPOWER participants completed pre/post program revealed findings related to teacher opinions, frequency of use in instructional practices, student activities, instructional influences, teacher preparedness, principal perceptions, parental support, and professional development experiences.

Teacher opinions were more positive at the end of the program as compared to the baseline, prior to participation in the program.

Areas of Increased Agreement – in teacher opinions related to the teaching of mathematics:

- Teachers collaborated to share ideas more (79 percent to 85 percent)
- Importance of support from colleagues to try out new ideas in teaching mathematics (88 percent to 93 percent)
- Importance of school support by local organizations, institutions (29 percent to 33 percent)
- Importance of considering student prior understanding when planning mathematics curriculum and instruction (85 percent to 89 percent)
- Importance of using performance-based assessment (49 percent to 70 percent)
- Importance of developing student's conceptual understanding of mathematics (79 percent to 89 percent)
- Importance of project/laboratory/research reports (15 percent to 33 percent)
- Importance of using computers (46 percent to 63 percent)
- Importance of connecting math/science to other disciplines (58 percent to 70 percent)
- Importance of having students participate in appropriate hands-on activities (25 percent to 50 percent)
- Importance of engaging students in inquiry-oriented activities (51 percent to 70 percent)
- Importance of engaging students in applications of science/math in a variety of contexts (55 percent to 77 percent)
- Importance of using performance based assessment (49 percent to 70 percent)

Areas of Increased Disagreement – Participants experienced a decline in the use of portfolios from baseline (79 percent) to end of program (82 percent).

Instructional Influences were a second area of focus in the survey. The MTSU participants reported growth in positive influence of variables in this area at the end of the program.

Encourages Effective Instruction – The following influences were perceived as having a more positive relationship on teaching mathematics effectively by the end of the program:

- State and/or district testing polices and practices (42 percent to 63 percent)
- Access to computers (58 percent to 67 percent)
- Funds for equipment and supplies (49 percent to 67 percent)
- Time to work with other teachers (30 percent to 70 percent)
- Time for professional development (42 percent to 82 percent)
- Public attitudes toward reform (39 percent to 63 percent)
- Quality of available materials (63 percent to 82 percent)
- System of managing instructional resources at district or school level (44 percent to 67 percent)
- The importance the school places on mathematics/science (82 percent to 89 percent)
- Consistency of science/math reform efforts with other school/district reforms (49 percent to 82 percent)
- Time to plan and prepare lessons (38 percent to 74 percent)

Teacher Preparedness comprised the third construct of the survey. Participants in the EMPOWER program experienced gains in most areas of preparedness across the program, as indicated by more teachers indicating that they were fairly well or well prepared.

- Providing concrete experiences before abstract concepts (76 percent to 85 percent)
- Developing student conceptual understanding (70 percent to 93 percent)
- Considering students' prior understanding when planning curriculum and instruction (85 percent to 89 percent)
- Making connections between science/mathematics and other disciplines (76 percent to 82 percent)
- Using cooperative learning groups (84 percent to 89 percent)
- Using hands-on activities (88 percent to 96 percent)
- Engaging students in inquiry-oriented activities (50 percent to 70 percent)
- Having students prepare project/laboratory/research reports (24 percent to 44 percent)
- Using computers (79 percent to 82 percent)
- Engaging students in applying science/math in a variety of contexts (72 percent to 77 percent)
- Leading a class using investigative strategies (42 percent to 67 percent)
- Managing a class of students engaged in hands-on/project-based work (79 percent to 89 percent)
- Helping students take responsibility for their own learning (73 percent to 82 percent)
- Using strategies that encourage participation of females and minorities

in science/math (58 percent to 63 percent)
- Encouraging students' interest in science/mathematics (84 percent to 89 percent)

Decline in Preparation – In two areas MTSU participants' felt less prepared following participation in the program: use of performance-based assessment (15 percent to 19 percent) and recognizing and responding to student diversity (18 percent to 22 percent).

Frequency of Use of Instructional Practices consists of teacher-reported frequency of use of specific instructional practices. EMPOWER program participants reported more frequent use of most strategies at the end of the program:

- Arranging seating to facilitate student discussion (79 percent to 82 percent)
- Using open-ended questions (79 percent to 82 percent)
- Requiring students to provide evidence to support their claims (76 percent to 82 percent)
- Encouraging students to consider alternative explanations (64 percent to 82 percent)
- Helping students see connections between math/science and other disciplines (55 percent to 74 percent)
- Using of formative assessment (56 percent to 71 percent)
- Embedding assessment in regular class activities (75 percent to 78 percent)

Decline in Frequency of Use – MTSU participants did experience some decline in use of the following practices across the program: use of demonstrations (15 percent to 22 percent), using real-world contexts for teaching mathematics (6 percent to 15 percent), and allowing students to work at their own pace (9 percent to 19 percent).

Student Activities are the activities that students are engaged in within the classroom. MTSU participants were asked questions regarding the frequency of use of various student activities. Findings in regards to the frequency of use of effective student activities from baseline to end of program revealed an increase in most areas of this construct for EMPOWER teachers.

Frequent Use – Participants reported more frequent use for these student activities by end of program:

- Participating in student-led discussions (46 percent to 70 percent)
- Making formal presentations to the class (30 percent to 43 percent)
- Engaging in hands-on science/math activities (73 percent to 89 percent)
- Designing or implementing his or her own investigation (36 percent to 52 percent)
- Working on models or simulations (40 percent to 48 percent)
- Working on extended mathematics investigations of projects (12 percent to 37 percent)
- Recording, representing, and/or analyzing data (15 percent to 23 percent)

- Writing reflections in a notebook or journal (22 percent to 33 percent)
- Working on portfolios (6 percent to 15 percent)
- Taking tests requiring open-ended responses (30 percent to 41 percent)
- Participating in field work (6 percent to 22 percent)

Decreased Use – More teachers in the EMPOWER program also reported infrequent use of some student activities that are considered effective practice:

- Working in cooperative learning groups (9 percent to 15 percent)
- Participating in discussions with the teacher to further mathematics understanding (15 percent to 22 percent)
- Sharing student ideas or solve problems with each other in small groups (9 percent to 22 percent)

Principal Perceptions are the impressions that participants have about their administrator's perceptions of the teaching and learning of science/math. Participants in the MTSU program had positive views on support from their leadership from baseline to end of program.

Areas of Increased Agreement – Participants in this program did experience a decline in perceived agreement from baseline to end of program, but more than 50 percent of teachers still agreed they received encouragement and/or support in the following areas:

- Encouraging selection of science/mathematics content and instructional strategies to address individual students' learning (94 percent to 93 percent)
- Encouraging the implementation of current national standards in science/math education (100 percent to 89 percent)
- Encouraging innovative instructional practices (97 percent to 93 percent)
- Providing materials/equipment for science/math (91 percent to 70 percent)
- Providing time for teachers to meet and share ideas (64 percent to 63 percent)
- Encouraging me to observe exemplary science/mathematics teachers (55 percent to 56 percent)
- Accepting the noise that comes with an active classroom (97 percent to 82 percent)
- Encouraging teachers to make connections across disciplines (78 percent to 74 percent)
- Acting as a buffer between teachers and external pressures (82 percent to 65 percent)

Parental Support was reported to be very low by participants in the MTSU program. Most participants indicated that few parents volunteer to assist with class activities (96 percent), donate money or materials (96 percent), voice support for various instructional strategies (92 percent), or attend parent-teacher conferences (89 percent), and/or PTA or math/science nights (93 percent).

Professional Development (PD) Experiences is an area of the survey where participants indicate their impressions of the ability of the PD program to increase their skills. MTSU participants reported positive impressions of the impact of the PD at the end of the program in regards to impact on content knowledge (77 percent), as well as the impact on understanding how students learn (88 percent), and ability to implement high-quality science/math instructional materials (82 percent).

FINDINGS FROM CONTENT ASSESSMENT

The MTSU program developed and administered a 25-item, objectively scored assessment for use in the evaluation. An analysis of program submitted data indicated statistically significant growth from baseline (52 percent correct) to end of the program (71 percent correct) in teacher mathematics content knowledge assessed.

CONCLUDING OBSERVATIONS FOR PROGRAM

The MTSU professional development program addressed the components of the Core Conceptual Framework (content focus, active participation, duration, and coherence) in the grant proposal as part of their planned focus. However, measured outcomes indicated the EMPOWER intervention did not have a statistically significant impact on teacher quality (e.g., ability to implement the lessons, classroom culture, and math content knowledge).

Teacher survey findings were mostly positive for the MTSU mathematics program. In their self-reports, participants indicated increased use of some effective strategies for teaching mathematics (e.g., arranging seating for discussion, alternative explanations, connections between mathematics/science and other disciplines, formative assessments). Additionally, participant's felt more prepared to implement effective mathematics teaching in their self-reports. For example, the use of development of student conceptual understanding, use of hands-on, inquiry, computers, diversity, and helping students take responsibility for their own learning were all areas more participants reported feeling prepared to use. Unfortunately, participants' perceived preparedness and reported frequency of use did not translate into observable gains in implemented practice in classroom observations.

MTSU participants experienced positive growth in perceptions of instructional influences on promoting effective instruction. Specifically, EMPOWER teachers felt state and district curriculum frameworks, testing policies and practices, quality of instructional materials, access to computers, funds for equipment and supplies, time to collaborate, time to plan, time for professional development, and public attitudes toward reform all supported effective instruction.

Teacher perceptions of administrative support were very positive. Parental support was reported as very little with 89-96 percent agreement by end of program. In regards to participant impressions of the PD program, the majority of MTSU participants reported that they felt the program had more impact than previous PD experiences on their ability to understand how children think about/learn science and/or mathematics (88 percent), mathematics content knowledge (77 percent), and their ability to implement effective mathematics instruction (82 percent). Overall, it appears the MTSU

program had begun to have some positive impacts on teacher beliefs, use of strategies, and program-specific assessed content knowledge. There were no significant gains in teacher quality measures indicating teachers may not have been supported to implement actual changes in pedagogy during the scope of the duration of this program and/or evaluation.

Program Narrative
Tennessee Technological University (TTU)
Anthony and Smith, PIs

PROGRAM SETTING AND PARTICIPANTS

The Developing Middle School Mathematics Teachers' Pedagogical Content Knowledge program at Tennessee Technological University was a partnership between the College of Arts & Sciences and the College of Education to deliver an 8-month intensive professional development program for 30 teachers of middle school mathematics. TTU partnered with 11 LEA's (Bledsoe, Clay, Fentress, Overton, Pickett, Van Buren, Warren, White, Putnam, Sequatchie, and DeKalb) for this program. Ten summer workshop days were conducted, along with four Saturday sessions at the Millard Oakley STEM Center, and some work was done on a project wiki, for a total of 90 contact hours of instruction. The goals of this project included enabling participants to:

1. Strengthen and enhance their mathematical content knowledge by developing a deeper understanding of the algebra/geometry content outlined in the Common Core and TN curriculum standards, and focusing on a conceptual understanding of the algebra/geometry topics they teach.
2. Become familiar with research-based strategies for developing their students' understanding of algebra/geometry content.
3. Broaden their knowledge of appropriate resources (manipulatives, technologies) for teaching algebra/geometry.

PROGRAM ALIGNMENT WITH CORE CONCEPTUAL FRAMEWORK

The proposed TTU program aligned with four of the five components of the Core Conceptual framework, with a focus on mathematics **content knowledge** delivered through co-presentation of content and pedagogy delivered by the mathematics and education faculty. An interactive, activity-based, hands-on, minds-on approach was planned to model the teaching strategies the participants were to learn. The program utilized the Cognitively Guided Instruction and Developing Mathematical Ideas Projects for developing teachers' knowledge of mathematics for teaching. An exploration of how children think about and understand proportionality, equality, similarity, and scaling was included.

Active learning was a focus, including the use of guided-discovery investigations from the Connected Mathematics Project. Teachers first experienced the curriculum in the role of the learner and then replicated the investigations in their own classrooms. At least 80 percent of activities were to be focused on active learning experiences. **Coherence** was achieved through a combination of alignment with state standards and local district current reforms and needs. Additionally, program activities were structured to include a purposeful focus on addressing existing teacher beliefs. The

duration of the program included 90-hours of contact with participants, which is consistent with the framework. This was achieved through a 60-hour summer institute, combined with 6-hours of web-based work and 24 hours of Saturday sessions (4 total). **Collective participation** was not clear, as the proposal stated the program would include 1-4 teachers from identified middle schools.

FINDINGS FROM OBSERVATIONS

The submission rate for teacher-provided videos of their teaching for the program at TTU was very good. All 30 teachers submitted at least one video. However, only 26 teachers submitted all three required videos, and this is the group that was examined for impact of the program on their instructional practice. Overall, results were mixed. While there were significant gains in implementation of lesson, classroom culture, and mathematics content, there was no significant change in teacher ability to design instruction.

At baseline, TTU mathematics program participants were characterized as "elements of effective instruction" on the design of lesson construct (score of 2.27) and increased some but not significantly by the end of program (2.42). The design of lesson construct examines the extent of planning, organization, resources, equity, collaboration, flow, assessments, and sense making that takes place in the lesson delivery.

TTU Mathematics program participants began the program with an implementation of lesson at a score of 2.45 ("elements of effective instruction") and improved this mean score to 3.01 ("beginning stages of effective instruction") by the end of program. The implementation of lesson construct examines level of investigative mathematics/science in the lesson, quality of classroom management strategies, pace of the lesson, ability to modify instruction based upon student understanding, teacher questioning strategies, and formative assessments.

Teachers in the TTU mathematics program began with science content knowledge rated at a score of 2.65 ("beginning stages of effective instruction"). Again, teachers made significant improvements across the program realizing an improved mean score of 3.13 ("beginning stages of effective instruction") by the end of the program. This means that most of the time during observations, mathematics content delivered was significant and worthwhile and appropriate for the developmental needs of students. Teacher-provided content was accurate, and some connections to real-world contexts were used. Participants did not incorporate abstraction, theory building, and connections to other disciplines in observed lessons.

Classroom culture is the final area of significant growth for TTU participants. At baseline, the mean score for teachers in the program was 2.60, which grew to an improved mean of 3.10 ("beginning stages of effective instruction") at the end of the program. Implementation of strategies, including collaborative learning, centering instruction on student generated questions, and ideas and intellectual rigor, were not evident through observations. Active participation of all students was not observed as being encouraged and respected in a consistent manner.

FINDINGS FROM SURVEYS

An examination of the surveys that participants completed pre/post program revealed findings related to teacher opinions, frequency of use in instructional practices, student activities, instructional influences, teacher preparedness, principal perceptions, parental support, and professional development experiences.

Teacher opinions were mixed at the end of the program as compared to the baseline, prior to participation in the program.

Areas of Increased Agreement in teacher opinions related to the teaching of mathematics:

- Importance of collaborating to share ideas more (59 percent to 77 percent)
- Teachers in the school share a common vision of effective science/math instruction (77 percent to 85 percent)
- Teachers were well supplied with materials for mathematics (27 percent to 58 percent)
- Importance of connecting math/science to other disciplines (70 percent to 77 percent)
- Importance of using performance-based assessment (50 percent to 58 percent).
- Teachers enjoyed the teaching of mathematics (90 percent to 96 percent)
- Importance of informal questioning to assess student understanding (62 percent to 96 percent).

Areas of Increased Disagreement in teacher opinions related to the teaching of mathematics:

- Importance of using computers (67 percent to 69 percent)
- Importance of engaging students in applications of science/math in a variety of contexts (30 percent to 35 percent)
- Importance of using cooperative learning groups (33 percent to 43 percent),
- Importance of using portfolios (80 percent to 96 percent)
- Importance of time to collaborate with peers (67 percent to 69 percent)

Instructional Influences were a second area of focus in the survey. The TTU participants reported mixed experiences with variables in this area at the end of the program.

Encourages Effective Instruction – The following influences were perceived as having a more positive relationship on teaching mathematics effectively by the end of the program:

- State and/or district curriculum frameworks (43 percent to 62 percent)
- Quality of available materials (43 percent to 73 percent)
- Time to plan and prepare lessons (20 percent to 42 percent)

- Time for professional development (57 percent to 62 percent)
- The importance the school places on mathematics/science (83 percent to 85 percent)
- Public attitudes toward reform (37 percent to 46 percent)

Inhibits Effective Instruction – The following influences were perceived as having a more negative relationship on teaching mathematics effectively by the end of the program:

- State and/or district testing polices and practices (60 percent to 69 percent)
- Access to computers (54 percent to 62 percent)
- Funds for equipment and supplies (70 percent to 85 percent)
- Consistency of science/math reform efforts with other school/district reforms (43 percent to 54 percent)

Teacher Preparedness comprised the third construct of the survey. Participants in the TTU program experienced gains in all areas of preparedness across the program, as indicated by more teachers indicating that they were fairly well or well prepared.

- Providing concrete experiences before abstract concepts (74 percent to 96 percent)
- Developing student conceptual understanding (83 percent to 96 percent)
- Making connections between science/math and other disciplines (60 percent to 77 percent)
- Using cooperative learning groups (70 percent to 84 percent)
- Using hands-on activities (53 percent to 92 percent)
- Engaging students in inquiry-oriented activities (43 percent to 85 percent)
- Having students prepare project/laboratory/research reports (10 percent to 42 percent)
- Using computers (70 percent to 77 percent)
- Engaging students in applying science/math in a variety of contexts (63 percent to 96 percent)
- Using performance based assessments (83 percent to 85 percent)
- Leading a class using investigative strategies (53 percent to 96 percent)
- Managing students engaged in hands-on/project-based work (67 percent to 92 percent)
- Helping students take responsibility for their own learning (57 percent to 89 percent)
- Recognizing and responding to student diversity (63 percent to 89 percent)
- Encouraging students' interest in science/math (87 percent to 96 percent)
- Using strategies that encourage participation of females and minorities in science/math (63 percent to 81 percent)

Decline in Preparation – In one area fewer TTU participants' teachers felt less prepared following participation in the program: Use of informal questioning (90 percent to 86 percent).

Frequency of Use of Instructional Practices consists of teacher-reported frequency of use of specific instructional practices. TTU program participants reported more frequent use of all strategies at the end of the program:

- Introducing content through formal presentations (62 percent to 76 percent)
- Teaching science in real-world contexts (80 percent to 85 percent)
- Using open-ended questions (80 percent to 96 percent)
- Requiring students to use evidence to support their claims (73 percent to 93 percent)
- Using assessment to find out what student know before or during a unit (62 percent to 65 percent)
- Assigning science/math homework (73 percent to 77 percent)
- Reading and commenting on student reflections in journals (23 percent to 50 percent)
- Demonstration of a science/math principle or phenomenon (40 percent to 58 percent)
- Arranging seating to facilitate student discussion (77 percent to 92 percent)
- Encouraging students to explain concepts to one another (80 percent to 92 percent)
- Encouraging students to consider alternative explanations (57 percent to 85 percent)
- Allowing students to work at their own pace (80 percent to 85 percent)
- Helping students see connections between math/science and other disciplines (47 percent to 77 percent)

Student Activities are the activities that students are engaged in within the classroom. Participants were asked questions regarding the frequency of use of various student activities. Findings in regards to the frequency of use of effective student activities from baseline to end of program revealed an increase in most of the areas of this construct.

Frequent Use – Participants reported more frequent use for some student activities from beginning to end of program:

- Participating in student-led discussions (43 percent to 65 percent)
- Participating in discussions with the teacher to further understanding (72 percent to 93 percent)
- Working in cooperative learning groups (79 percent to 85 percent)
- Making formal presentations to the class (17 percent to 23 percent)
- Reading other (non-textbook) science/math related materials in class (17 percent to 31 percent)
- Reviewing homework/worksheet assignments (83 percent to 92 percent)
- Working on solving a real-world problem (70 percent to 89 percent)
- Sharing ideas or solve problems with each other in small groups (73 percent to 89 percent)

- Engaging in hands-on science/math activities (40 percent to 65 percent)
- Following specific instructions in an activity or investigation (47 percent to 73 percent)
- Designing or implementing his or her own investigation (7 percent to 19 percent)
- Working on models or simulations (7 percent to 19 percent)
- Working on extended science/math investigations or projects that are a week or more in duration (3 percent to 8 percent)
- Writing reflections in a notebook or journal (20 percent to 34 percent)
- Working on portfolios (3 percent to 15 percent)
- Taking tests requiring open-ended responses (30 percent to 46 percent)
- Recording, representing, and/or analyzing data (10 percent to 20 percent)

Decreased Use – More teachers in the TTU program also reported infrequent use of some student activities that are considered effective practice:

- Participating in field work (80 percent to 100 percent)
- Taking short-answer tests (48 percent to 65 percent)

Principal Perceptions are the impressions that participants have about their administrator's perceptions of the teaching and learning of science/math. Participants in the TTU program had very positive views on support from their leadership.

Areas of Increased Agreement – Teachers agreed their principal provided encouragement and/or support in the following areas:

- Encouraging selection of science/math content and instructional strategies to address individual students' learning (80 percent to 81 percent)
- Accepting the noise that comes with an active classroom (90 percent to 92 percent)
- Encouraging the implementation of current national standards in science/math education (83 percent to 92 percent)
- Providing materials/equipment for science/math (60 percent to 77 percent)
- Providing time for teachers to meet and share ideas (52 percent to 54 percent)
- Encouraging teachers to make connections across disciplines (63 percent to 85 percent)

Areas of Increased Disagreement – Teachers disagreed that their principals provided encouragement and/or support in the area of encouraging teachers to observe other science/math teachers (54 percent).

Parental Support was reported to be very low by participants in the TTU program. One hundred percent of participants indicated that few parents volunteer to assist with class activities, donate money for materials, or attend PTA or math/science nights.

Professional Development (PD) Experiences is an area of the survey where participants indicate their impressions of the ability of the PD program to increase their skills. Slightly more TTU participants reported positive impressions of the impact of the PD at the end of the program than at baseline. Impact on content knowledge increased from 42 percent to 46 percent, impact on understanding how students learn rose from 37 percent to 46 percent, and ability to implement high-quality science/math instructional materials increased from 32 percent to 46 percent. However, this opinion was still held by less than half of the participants who completed the survey.

FINDINGS FROM CONTENT ASSESSMENT

Nine participants in the TTU middle school mathematics program completed both the pre/post assessment that was developed by TTU. On the pre-test, the nine teachers answered 70 percent of the items correctly. The percentage correct increased to 76 percent on the post-test. This was determined to be significant growth.

CONCLUDING OBSERVATIONS FOR PROGRAM

The TTU professional development program specifically addressed four of the five components of the Core Conceptual Framework (content focus, active participation, duration, and coherence) in the grant proposal as part of their planned focus. Program outcomes indicate that the TTU intervention had some positive impact on some aspects of teacher quality (e.g., ability to implement the lessons, classroom culture, and math content knowledge). Classroom observation data revealed no significant change in the area of design of lesson.

Teacher survey findings were mostly positive for TTU. In their self-reports, participants indicated increased use of all included effective strategies for teaching mathematics (e.g., use of real-world contexts, open-ended questions, evidence to support claims, pre-assessments, homework, and journaling). Additionally, participant's felt much more prepared to implement effective science teaching in their self-reports. For example, the use of cooperative groups, inquiry, computers, management, diversity, generating student interest, and developing conceptual understandings of science were all areas more participants reported feeling prepared to use. To some extent, participants' perceived preparedness did translate into observable implemented practice in classroom observations.

Instructional influences that negatively influenced instruction included state-level testing policies, computer access, funding for supplies, and consistence of science/mathematics reform efforts with other school/district reforms. However, teachers felt time for professional development and time for planning and preparing were positive influences.

Teacher perceptions of administrative support were very positive. Agreement grew across the program regarding principal support of innovative instructional practices, provisions for materials

and equipment, time for collaboration, the noise level of active classrooms, and the level of administrative buffering between teachers and external forces. Parental support was reported as very little. In regards to participant impressions of the PD program, some teachers (46 percent) reported that they felt the program had more impact than previous PD experiences on their ability to understand how children think about/learn science and/or mathematics content knowledge, as well as their ability to implement effective science instruction. However, more than 50 percent of participants did not agree that the program had a great impact on them. Overall, this program demonstrated some gains in teacher quality, content knowledge, and attitudes and perceived preparedness. If there had been more focus on addressing coherence within the program (e.g., including teams of teachers rather than individual teachers in some cases), the ability to generate capacity and have a greater impact on all outcomes might have been possible.

Program Narrative
Tennessee Technological University (TTU)
Baker and Fromke, PIs

PROGRAM SETTING AND PARTICIPANTS

The Tennessee Technological University (TTU) Numeracy and Multiple Representations for Grades 1-3 Teachers (NMR) program was a partnership between TTU and nine Upper Cumberland LEAs (Cannon, Clay, Fentress, Overton, Pickett, Putnam, Van Buren, Warren and White). The program was designed to deliver a 17-month intensive professional development program for 30 teachers of grades 1-3. A 10-day summer institute was completed, along with 5 Saturday sessions and online support, for a total of 90-hours of professional development programming. The goals of this project was to transform the teaching of primary grade mathematics through increased teacher content and pedagogical content knowledge, explicit examination of teacher beliefs about teaching mathematics, proficiency in the use of modern technology appropriate for primary grade classroom, and teacher access to technology and equipment for teaching. The objectives of the NMR program were to:

1. Increase participants' content knowledge in mathematics as measured by a pre/post test.
2. Increase participants' pedagogical content knowledge as evidenced by pre/during/post videos of their teaching practices.
3. Change participants' beliefs about teaching mathematics as they experience math as primary grade students and then replicate the same project activities in their classrooms. Participants' postings to a grant project Wikispace will be used to measure change in beliefs.
4. Increase participants' proficiency with the use of innovative teaching tools such as the iPad. The integration of new technologies with more traditional math materials will transform participants' classrooms into active learning studios.

PROGRAM ALIGNMENT WITH CORE CONCEPTUAL FRAMEWORK

The TTU program aligned with the Core Conceptual framework in all five areas, detailed in the program proposal. First, NMR focused on mathematics **content knowledge**, aligned with the Common Core States Standards for Mathematics. Specific focus included multiple mathematical representations and connecting these representations to the content.

Active learning was a focus of at least 80 percent of activities, including engaging participants in active learning in the role of student while learning about direct instruction, the inquiry investigation model, and the pictorial math model. Teachers replicated the lessons in their classrooms. **Coherence** focused on addressing teacher beliefs. Further, participating LEAs agreed to adopt the new strategies and materials as part of their ongoing mathematics curriculum. The **duration** of the

program included 90-hours of contact extended across a 17-month period with participants, which is consistent with the framework. **Collective participation** was achieved by including two teachers from each participating elementary school.

FINDINGS FROM OBSERVATIONS

The TTU NMR program had 30 teachers who were observed at least once. However, only five teachers submitted all three required videos, and this is the group that was examined for impact of the program on their instructional practice. Overall, there was significant growth for participants in all four measured areas: design, implementation, classroom culture, and content knowledge.

NMR program participants were characterized as delivering "elements of effective instruction" (score of 2.02) on the design of lesson at baseline. Observations at the end of the program revealed significant growth to 2.66 ("elements of effective instruction"). The design of lesson construct examines the extent of planning, organization, resources, equity, collaboration, flow, assessments, and sense making that takes place in the lesson delivery.

The implementation of lesson rating also grew significantly for participants overall across the program. At baseline NMR teachers received a 2.40 ("elements of effective instruction") but improved to a score of 3.40 ("beginning stages of effective instruction") by end of program. The implementation of lesson construct examines level of investigative mathematics/science in the lesson, quality of classroom management strategies, pace of the lesson, ability to modify instruction based upon student understanding, teacher questioning strategies, and formative assessments.

NMR teachers at baseline received a score for mathematics content knowledge of 2.56 ("elements of effective instruction"). By the end of the program, TTU participants had experienced significant growth (3.42, "beginning stages of effective instruction"). This means that during observations, mathematics content delivered was significant and worthwhile and appropriate for the developmental needs of students. Teacher-provided content was accurate, and some connections to real-world contexts were used. Participants also incorporated some abstraction, theory building, and connections to other disciplines in observed lessons.

Classroom culture was another area of significant growth for the NMR teachers. The overall group began at 2.60 ("elements of effective instruction"). However, by the end of the program, MICH participants had raised improved considerably and gained a score of 3.43 ("beginning stages of effective instruction"). Implementation of strategies, including collaborative learning, centering instruction on student generated questions, and ideas and intellectual rigor, were evident through most observations. All students were actively engaged in meaningful learning that respected ideas consistently in classroom observations conducted at the end of the program.

FINDINGS FROM SURVEYS

An examination of the surveys that participants completed in a pre/post manner revealed findings related to teacher opinions, frequency of use in instructional practices, student activities,

instructional influences, teacher preparedness, principal perceptions, parental support, and professional development experiences.

Teacher opinions regarding the importance of use of effective instructional strategies and support necessary to be successful are included in this section of the survey.

Areas of Increased Agreement in teacher opinions related to the teaching of mathematics:

- Teachers feel supported by colleagues to try out new ideas (74 percent to 79 percent)
- Teachers have access to computers for teaching (40 percent to 54 percent)
- Importance of developing students' conceptual understanding of mathematics (83 percent to 93 percent)
- Importance of making connections between science/math and other disciplines (73 percent to 89 percent)
- Importance of use of cooperative learning groups (70 percent to 75 percent)
- Importance of use of hands-on activities (80 percent to 86 percent)
- Importance of use of inquiry-based activities (69 percent to 82 percent)
- Importance of engaging students in applications of mathematics in variety of contexts (63 percent to 77 percent)
- Importance of use of informal questioning (70 percent to 78 percent)

Areas of Decreased Agreement – NMR participants reported increased disagreement with the following items related to the teaching of mathematics. The first was time for teachers to share ideas and materials for mathematics (33 percent to 43 percent). The second area was related to existing collaboration time with other teachers within their school (53 percent to 57 percent).

Instructional Influences were a second area of focus in the survey. The TTU participants reported overwhelmingly positive growth in influences that encourage effective instruction. The following influences were perceived as having a more positive relationship on teaching mathematics effectively by the end of the program:

- State and/or district curriculum frameworks (47 percent to 61 percent)
- Quality of available instructional materials (38 percent to 57 percent)
- Access to computers for mathematics instruction (40 percent to 57 percent)
- Management of instructional resources at the district or school level (23 percent to 60 percent)
- Time available for teachers to plan and prepare lessons (27 percent to 54 percent)
- Time for teacher professional development (30 percent to 57 percent)
- Importance that school places on science/math (63 percent to 75 percent)
- Consistence of science/math reform efforts with other school/district reforms (53 percent to 64 percent)

Teacher Preparedness comprised the third construct of the survey. TTU NMR program participants experienced growth in perceptions of preparation to deliver effective mathematics instruction in all areas of this construct. Teachers who participated in the program reported being better prepared in the following areas:

- Providing concrete experiences before abstract concepts (63 percent to 89 percent)
- Developing student conceptual understanding (57 percent to 89 percent)
- Considering prior understanding when planning curriculum & instruction (90 percent to 100 percent)
- Making connections between science/math and other disciplines (67 percent to 96 percent)
- Using cooperative learning groups (87 percent to 100 percent)
- Using hands-on activities (87 percent to 100 percent)
- Engaging students in inquiry-oriented activities (50 percent to 82 percent)
- Having students prepare project/laboratory/research reports (17 percent to 64 percent)
- Using computers (63 percent to 97 percent)
- Engaging students in applying science/math in a variety of contexts (59 percent to 96 percent)
- Using performance based assessments (63 percent to 89 percent)
- Using portfolios (17 percent to 63 percent)
- Using informal questioning to assess student understanding (77 percent to 93 percent)
- Leading a class using investigative strategies (37 percent to 82 percent)
- Managing students engaged in hands-on/project-based work (80 percent to 96 percent)
- Recognizing and responding to student diversity (70 percent to 85 percent)
- Encouraging students' interest in science/math (73 percent to 93 percent)
- Using strategies that encourage participation of females and minorities in science/math (53 percent to 82 percent)
- Helping students take responsibility for their own learning (67 percent to 85 percent)

Frequency of Use of Instructional Practices consists of TTU teacher reported frequency of use of specific instructional practices. Participants reported increase in most areas.

Increased Use – There were several practices for which more participants reported more frequent use from baseline to end of the program. These practices included:

- Using open-ended questions (63 percent to 75 percent)
- Requiring students to use evidence to support their claims (63 percent to 71 percent)
- Encouraging students to explain concepts to one another

(67 percent to 75 percent)
- Encouraging students to consider alternative explanations (62 percent to 71 percent)
- Allowing students to work at their own pace (67 percent to 86 percent)
- Helping students see connections between mathematics and other disciplines (69 percent to 71 percent)
- Using pre-assessments (67 percent to 71 percent)
- Reading and commenting on student reflections in journals (23 percent to 39 percent)

Decreased Use – More participants reported more infrequent use of two practices from baseline to end of the program:

- Embedding assessment in regular class activities (10 percent to 25 percent)
- Teaching mathematics using real-world contexts (17 percent to 21 percent)

Student Activities are the activities that students are engaged in within the classroom. TTU NMR participants were asked questions regarding the frequency of use of various student activities and reported growth of use of most activities across the duration of the program. More participants reported frequent use for these student activities from baseline to end of program:

- Participating in student-led discussions (33 percent to 72 percent)
- Participating in discussions with the teacher to further understanding (80 percent to 85 percent)
- Making formal presentations to the class (17 percent to 39 percent)
- Reading other (non-textbook) mathematics related materials in class
- (40 percent to 50 percent)
- Working on solving real-world problem (73 percent to 75 percent)
- Designing or implement their own investigation (33 percent to 39 percent)
- Following specific instructions in an activity or investigation (77 percent to 86 percent)
- Working on models or simulations (27 percent to 54 percent)
- Working on extended mathematics investigations or projects (3 percent to 29 percent)
- Participating in field work (0 percent to 21 percent)
- Recording, representing, and/or analyzing data (31 percent to 50 percent)
- Writing reflections in a notebook or journal (33 percent to 61 percent)
- Working on portfolios (3 percent to 19 percent)

Infrequent Use – Teachers in the program also reported decreased use of some student activities that are considered effective practice. Teachers reported infrequent use of the following student activities from baseline to end of program:

- Engaging in hands-on mathematics activities (3 percent to 11 percent)

- Sharing ideas or solving problems with each other in small groups (27 percent to 29 percent)
- Taking short-answer tests (33 percent to 43 percent)
- Taking tests requiring open-ended responses (53 percent to 64 percent)

Principal Perceptions are the impressions that participants have about their administrator's perceptions of the teaching and learning of science/math. TTU participants revealed positive feelings regarding this construct. Teachers agreed that their principal provides encouragement and/or support in the following areas:

- Accepting the noise that comes with an active classroom (85 percent to 86 percent)
- Encouraging the implementation of current national standards (87 percent to 93 percent)
- Providing materials/equipment for science/math (48 percent to 54 percent)
- Time for teachers to meet and share ideas (53 percent to 71 percent)
- Encouraging teachers to make connections across disciplines (63 percent to 75 percent)
- Providing time for teachers to meet and share ideas (53 percent to 71 percent)

Parental Support was reported to be very low by participants in the NMR program. All of the participants indicated (100 percent) that few parents volunteer to assist with class activities, donate money for materials, and few attend parent-teacher conferences or PTA or math/science nights.

Professional Development (PD) Experiences is an area of the survey where participants indicate their impressions of the ability of the PD program to increase their skills. NMR participants were positive regarding the impact the program had on their content knowledge (54 percent) and 57 percent thought the PD had increased ability to implement high-quality mathematics instructional materials. However, only 48 percent thought their understanding of how children think about mathematics had been increased as a result of participation in the NMR program.

FINDINGS FROM CONTENT ASSESSMENT

Twenty-eight participants in the NMR program completed both the pre- and post-assessment that was developed by TTU. On the pre-test, teacher average percentage was 59 percent correct. This percentage increased to 70 percent on the post-test, representing significant growth across the program.

CONCLUDING OBSERVATIONS FOR PROGRAM

TTU's NMR program implemented a mathematics professional development program for teachers in grades 1-3 that included a three-pronged instructional model combining direct instruction, inquiry, and pictorial math. Participants were immersed in the modeling of ten lessons during the PD program to ensure they were able to deliver effectively when they retuned to their own

classrooms. The TTU professional development program was designed to include the five criteria in the Core Conceptual Framework (content focus, active participation, duration, coherence, and collective participation).

In respect to classroom observation data, TTU teachers experienced significant gains in all four domains (design, implementation, content, and classroom culture) across the program. Additionally, teachers in this program reported implementation of investigative mathematics instructional strategies, including those that require a high level of ability to facilitate student scientific discourse (e.g., using evidence, explaining concepts to others, considering alternative explanations, working with models and simulations, and recording, representing, and analyzing data). However, teachers reported decreased use of some investigative strategies that should be aligned with those previously mentioned (e.g., teaching of mathematics in real-world contexts, embedding assessment in regular class activities, having students solve problems with each other), which may reveal that this PD program was structured on implementing this NMR specific set of ten lessons as a primary focus. Therefore, it is difficult to determine if the NMR program generated teacher ability to develop and implement further mathematics instruction beyond the scope of this PD. It is clear that teachers did implement their provided lessons well, as evidenced by the observed classroom instruction in the provided videos.

TTU teachers reported more support from principals. Reported PD experiences affirmed that 54 percent of teachers felt their content knowledge was positively impacted. Further, program developed assessments and classroom observational data also demonstrated growth in content knowledge as well. Parental support reported was very low. Overall, this program demonstrated significant gains in teacher quality, teacher content knowledge, and on most key areas of teacher attitudes (including importance, use, and preparation) aligned with the program.

Program Narrative
Tennessee Technological University (TTU)
Gore and Hunter, PIs

PROGRAM SETTING AND PARTICIPANTS

The Tennessee Technological University (TTU) program, Embedding Inquiry and Technology/Engineering Standards into Physical Science Content for Grade 3-5 (referred to as "Embedding Inquiry" in this report), was a partnership between Education and Engineering at TTU and 10 school districts (Bledsoe, Clay, Cannon, Fentress, Overton, Pickett, Putnam, Van Buren, Warren, and White). The program was designed to deliver a 12-month intensive professional development program for 25 elementary teachers of grades 3-5. The summer institute included 10 days, combined with 5 Saturday sessions spread out across the academic year for a total of 90-hours of professional development programming.

The goal of the Embedding Inquiry project was to provide activities and strategies for increased understanding of physical science content and increased understanding of integrating inquiry, technology, and engineering to teach physical science concepts. Specific program objectives were to:

1. Increase pedagogical content knowledge of physical science, engineering, and technology, as demonstrated by improved pre/post test scores.
2. Develop an understanding of the profession of engineering and the engineering design process through problem-based learning. Participants will demonstrate competency through completion of an engineering design project and pre/post evaluation.
3. Develop and teach physical science lessons that integrate inquiry, technology, and engineering standards. Participants will demonstrate competency via critiques of three videotaped teaching lessons.

PROGRAM ALIGNMENT WITH CORE CONCEPTUAL FRAMEWORK

The TTU Embedding Inquiry program achieved alignment with the Core Conceptual framework in all five areas, detailed in the program proposal. A **content knowledge** focus was clear, as physical science concepts of matter, energy, motion, and forces in nature were the main focus. Selected content was aligned with the state standards for elementary science, including the embedded inquiry, technology, and engineering standards. Content was delivered through a three-pronged co-teaching approach, where education, chemistry, and engineering faculty collaborated to deliver the program.

Active learning was a primary focus for the TTU Embedding Inquiry program, as facilitators modeled the use of pedagogy and engaged participants in the role of the student who were engaged in inquiry-based, hands-on learning activities, investigations, and engineering design projects.

Individual and team-based activities were included. Participants learned how to use the Vernier probeware and received the Elementary Science Book from Vernier full of inquiry-based lessons integrating technology, as well as modules from Engineering is Elementary curriculum.

Coherence was a focus of the first Saturday workshop, wherein participants were provided with an exercise that had them reflect on their current beliefs regarding the teaching of elementary science. Their beliefs statement was revisited throughout the PD program. Additionally, content of the program was aligned with state standards and buy-in was achieved from partnering LEAs regarding the content and approach of the program. The program included a 60-hour summer institute (10 days) and five Saturday workshops (6-hours) for total **duration** of 90-hours of face-to-face work. Additionally, the program established an online community to serve as a forum for additional contact for participants and faculty, as well as a repository for resources, experiences, and ideas. **Collective participation** was achieved from including at least two teachers from each selected elementary school, according to the proposal.

FINDINGS FROM OBSERVATIONS

Twenty-six teachers in the TTU Embedding Inquiry program were observed at least once. Seventeen teachers submitted all three required videos, and this is the group that was examined for impact of the program on their instructional practice. Overall, there was significant growth for participants in the TTU program participants in all four measured areas: design, implementation, classroom culture and content knowledge.

At baseline, the TTU program participants demonstrated "elements of effective instruction" on the design of lesson (score of 2.25). By the end of the program, design of lesson mean score had grown to 2.77, representing significant growth. The design of lesson construct examines the extent of planning, organization, resources, equity, collaboration, flow, assessments, and sense making that takes place in the lesson delivery.

TTU participants' implementation of lesson rating also grew significantly for participants overall across the program from a baseline score of 2.32 ("elements of effective instruction") to a mean score of 3.03 at the end of the program ("beginning stages of effective instruction"). The implementation of lesson construct examines level of investigative mathematics/science in the lesson, quality of classroom management strategies, pace of the lesson, ability to modify instruction based upon student understanding, teacher questioning strategies, and formative assessments.

Content knowledge was another area of significant growth for the TTU program participants. At baseline, the mean score for teachers in the program was 2.51 ("elements of effective instruction"). By the end of the program, the mean had raised to 3.41 ("beginning stages of effective instruction"). This means that during observations, science content delivered was significant and worthwhile and appropriate for the developmental needs of students. Teacher-provided content was accurate, and some connections to real-world contexts were used. Participants also incorporated some abstraction, theory building, and connections to other disciplines in observed lessons.

TTU Embedding Inquiry participants also significantly raised their score on the construct of classroom culture from a baseline score of 2.65 ("elements of effective instruction") to a final score

of 3.47 ("beginning stages of effective instruction"). Implementation of strategies including collaborative learning, centering instruction on student generated questions, and ideas and intellectual rigor were not evident through observations. All students were actively engaged in meaningful learning that respected ideas consistently in classroom observations conducted at the end of the program.

FINDINGS FROM SURVEYS

An examination of the surveys that TTU Embedding Inquiry participants completed in a pre/post manner revealed findings related to teacher opinions, frequency of use in instructional practices, student activities, instructional influences, teacher preparedness, principal perceptions, parental support, and professional development experiences.

Teacher opinions regarding the importance of use of effective instructional strategies and support necessary to be successful are included in this section of the survey.

Areas of Increased Agreement in teacher opinions related to the teaching of STEM disciplines:

- Importance of considering student prior understanding when planning instruction (81 percent to 84 percent)
- Importance of making connections between science/math and other disciplines (81 percent to 96 percent)
- Importance of having students work in cooperative learning groups (70 percent to 92 percent)
- Importance of engaging students in inquiry-oriented activities (81 percent to 92 percent)
- Importance of having students prepare project/laboratory/research reports (50 percent to 54 percent)
- Importance of using computers (43 percent to 67 percent)
- Importance of using performance-based assessments (46 percent to 57 percent)
- Importance of using portfolios (27 percent to 33 percent)

All teacher participants agreed at the end of the program that they enjoyed teaching science/math. Also, the number of teachers who agreed that they understood the standards grew from 66 percent to 92 percent at the end of the program. More teachers reported collaboration with peers within their school as well (66 percent to 71 percent).

Areas of Increased Disagreement – The percentage of participants who believed engaging students in applying science/math in a variety of contexts was not important increased (19 percent to 29 percent). This was the only area of decrease in importance for TTU participants. At the end of the program slightly more teachers than in the beginning said the following were not important:

- Importance of having materials for investigative science/math instruction (81 percent to 83 percent)
- Importance of having time to collaborate with peers (54 percent to 58 percent)

- Importance of support of the school by local organizations, institutions, and/or business (73 percent to 75 percent)

Instructional Influences were a second area of focus in the survey. TTU participants reported some positive growth in influences that encourage effective instruction at the end of the program. However, in many cases, the majority of participants still felt the same influences inhibiting effective science teaching.

Encourages Effective Instruction – The following influences were perceived as having a more positive relationship on teaching science effectively by the end of the program:

- Access to computers for science instruction (19 percent to 35 percent)
- Time for planning and preparing lessons (36 to 46 percent)
- Time for collaboration with other teachers (35 percent to 42 percent)
- Funds for purchasing supplies (15 percent to 25 percent)

Inhibits Effective Instruction – The following influences were perceived as having a more negative relationship on teaching science effectively by the end of the program:

- State and/or district curriculum frameworks (39 percent to 54 percent)
- State and/or district testing policies and practices (54 percent to 63 percent)
- Quality of instructional materials (62 percent to 67 percent)
- Management of instructional resources at the district level (65 percent to 71 percent)
- Importance that school places on science/math (50 percent to 67 percent)
- Consistence of science/math reform efforts with other school/district reforms (58 percent to 71 percent)
- Public attitudes toward reform (65 percent to 83 percent)

Teacher Preparedness comprised the third construct of the survey. TTU program participants experienced growth in perceptions of preparation to deliver effective science instruction in all areas of this construct. That is, more teachers agreed that they were better prepared than when the program began:

- Providing concrete experiences before abstract concepts (50 percent to 96 percent)
- Developing student conceptual understanding (65 percent to 100 percent)
- Considering prior understanding when planning curriculum & instruction (77 percent to 92 percent)
- Making connections between science/math and other disciplines (69 percent to 100 percent)
- Using cooperative learning groups (85 percent to 100 percent)
- Using hands-on activities (89 percent to 96 percent)
- Engaging students in inquiry-oriented activities (58 percent to 96 percent)

- Having students prepare project/laboratory/research reports (35 percent to 71 percent)
- Using computers (27 percent to 71 percent)
- Engaging students in applying science/math in a variety of contexts (42 percent to 87 percent)
- Using performance based assessments (65 percent to 91 percent)
- Using portfolios (35 percent to 57 percent)
- Using informal questioning to assess student understanding (77 percent to 92 percent)
- Leading a class using investigative strategies (54 percent to 92 percent)
- Managing students engaged in hands-on/project-based work (65 percent to 100 percent)
- Helping students take responsibility for their own learning (77 percent to 100 percent)
- Recognizing and responding to student diversity (73 percent to 100 percent)
- Encouraging students' interest in science/math (77 percent to 100 percent)
- Using strategies that encourage participation of females and minorities in science/math (42 percent to 83 percent)

Frequency of Use of Instructional Practices consists of TTU teacher reported frequency of use of specific effective instructional practices.

Increased Use – Teachers reported more frequent use of several practices by the end of the program:

- Teaching science in real-world contexts (85 percent to 96 percent)
- Arranging seating to facilitate student discussion (89 percent to 96 percent)
- Using open-ended questions (89 percent to 82 percent)
- Requiring students to use evidence to support their claims (62 percent to 92 percent)
- Encouraging students to consider alternative explanations (65 percent to 75 percent)
- Allowing students to work at their own pace (50 percent to 58 percent)
- Using pre-assessments (54 percent to 67 percent)
- Reading and commenting on student journals (31 percent to 50 percent)

Student Activities are the activities that students are engaged in within the science classroom. TTU teachers were asked questions regarding the frequency of use of various student activities. Findings revealed TTU participants reported increases in most effective student activities.

Frequent Use – More participants reported frequent use of some student activities by the end of the program:

- Participating in student-led discussions (39 percent to 67 percent)

- Participating in discussions with the teacher to further understanding (76 percent to 88 percent)
- Working in cooperative learning groups (85 percent to 96 percent)
- Making formal presentations in class (8 percent to 25 percent)
- Reading other (non-textbook) science/math related materials in class (58 percent to 67 percent)
- Working on solving a real-world problem (27 percent to 71 percent)
- Sharing ideas or solve problems with each other in small groups (65 percent to 83 percent)
- Engaging in hands-on science/math activities (50 percent to 75 percent)
- Designing or implementing their own investigation (8 percent to 29 percent)
- Working on models or simulations (15 percent to 25 percent)
- Writing reflections in a notebook or journal (50 percent to 63 percent)
- Taking tests requiring open-ended responses (39 percent to 63 percent)
- Working on portfolios (15 percent to 25 percent)

Decreased Use – More TTU program participants reported decreased use of two student activities that are considered effective practice:

- Working on extended science/math investigations or projects (73 percent to 79 percent)
- Taking short-answer tests (35 percent to 50 percent)

Principal Perceptions are the impressions that participants have regarding their administrator's perceptions of the teaching and learning of science/math. TTU participants revealed mostly positive feelings regarding this construct.

Areas of Increased Agreement – Teachers agreed that their principal provides encouragement and/or support in the following areas:

- Selecting science/math content and strategies to address individual students' learning (73 percent to 79 percent)
- Encouraging innovative instructional practices (80 percent to 88 percent)
- Time for teachers to meet and share ideas (50 percent to 54 percent)
- Encouraging teachers to make connections across disciplines (65 percent to 75 percent)

Areas of Increased Disagreement – Teachers felt their principals do not provide encouragement and/or support in the following areas:

- Encouraging me to observe other exemplary science teachers (61 percent to 74 percent)
- Providing materials/equipment for science/math (76 percent to 79 percent)
- Acting as a buffer between teachers and external pressures

(19 percent to 42 percent)

Parental Support was reported to be very low by participants in the TTU program. All of the participants indicated that few parents volunteer to assist with class activities, donate money for materials, attend PTA or math/science nights, or voice support for traditional instructional approaches.

Professional Development (PD) Experiences is an area of the survey where participants indicate their impressions of the ability of the PD program to increase their skills. TTU Embedding Inquiry participants' did experience some growth in positive attitudes toward PD across the program. However, content knowledge was the only area in which teachers thought the TTU PD had a great impact on them (50 percent). Only 42 percent of participants agreed the TTU program had great impact on their ability to deliver high-quality instructional materials and understandings of how children think about science.

FINDINGS FROM CONTENT ASSESSMENT

TTU's Embedding Inquiry program had 23 participants who completed the pre/post assessment. There was significant growth from pre-test (72 percent correct) to post-test (94 percent correct).

CONCLUDING OBSERVATIONS FOR PROGRAM

The TTU Embedding Inquiry program delivered 90-hours of content to 25 teachers in grades 3-5. The focus of the program on integration of physical science content with engineering and technology standards is timely, as the Next Generation Science Standards (NGSS) reflect this approach. TTU project leaders included high-quality curriculum materials as the central component of the program, including Vernier Elementary Science, and Engineering is Elementary. Participants received a unique opportunity to participate in a true engineering design project and built their own submersible ROV's (remote operated vehicles).

Findings indicate that participation in the TTU program had a significant impact on teacher quality. In addition to the integration of innovative curriculum and delivery, the TTU program was designed to include the five criteria in the Core Conceptual Framework (content focus, active participation, duration, coherence, and collective participation).

In respect to classroom observation data, TTU teachers experienced significant gains in all four domains (design, implementation, content, and classroom culture) across the program. Additionally, teachers in this program reported implementation of investigative science instructional strategies, including those that require a high-level of ability to facilitate student scientific discourse (e.g., using evidence, explaining concepts to others, considering alternative explanations, work with models and simulations, and record, represent, and analyze data). Teachers also overwhelmingly felt more prepared to deliver effective science instruction, with increases in all areas of the construct. Frequency of use of investigative science strategies also increased. Principal support is an area that also experienced some growth across the program, though some participants felt under-resourced

and did not report being encouraged to observe other exemplary teachers. Parental support was reported as very low.

The research has demonstrated that elementary teachers, in particular often feel less self-efficacy to teach science/mathematics. This might explain the lower-than-expected ratings of the perceived impact of the PD on their ability to implement the instructional materials they were provided (42 percent), as well as their understandings of how children learn (42 percent), despite significant gains demonstrated in their observed teacher quality and self-reported use of practices. Approximately half of the participants (50 percent) did feel the program had a great impact on their science content knowledge, however. This was also observed during the submitted lessons from participants and their outcomes on the program developed pre/post assessment. Overall, this program demonstrated significant gains in all areas, including teacher quality, teacher opinions, preparedness, and content knowledge.

PROGRAM NARRATIVE
Tennessee Technological University (TTU)
Ramey and Rust, PIs

PROGRAM SETTING AND PARTICIPANTS

The Tennessee Technological University Departments of Chemistry and Curriculum & Instruction collaborated with the Millard Oakley STEM Center to deliver a 17-month intensive professional development program for 20 high school teachers of chemistry and physical science. TTU partnered with the 10 Upper Cumberland LEAs (Clay, DeKalb, Fentress, Overton, Pickett, Putnam, VanBuren, Warren, White, and York) to recruit participants. Ten summer institute days were conducted at the Oakley STEM Center, along with five Saturday sessions for a total of ninety contact hours of instruction. Participants were asked to replicate 10 inquiry lessons and to engage in ongoing reflection across the program regarding the teaching of chemistry. The program was aligned with the Chemistry I & II standards and included a focus on modeling of inquiry, use of simulations, electronic data collection, and micro-scale techniques for the teaching of chemistry.

The goal of the project was to transform the teaching of chemistry through increased teacher content and pedagogical content knowledge, explicit examination of teacher beliefs about teaching chemistry, proficiency in the use of modern technology appropriate for high school classrooms, and teacher access to technology and equipment for teaching.

Anticipated participant outcomes included:

1. Increase in conceptual chemistry knowledge.
2. Increase in pedagogical chemistry content knowledge.
3. Change in beliefs regarding teaching chemistry.
4. Proficiency in use of resources for the teaching of chemistry.

PROGRAM ALIGNMENT WITH CORE CONCEPTUAL FRAMEWORK

The proposed TTU Chemistry program aligned with the Core Conceptual framework with a focus on chemistry **content knowledge** delivered in a co-teaching model by chemistry and education faculty members. At least 80 percent of planned activities were focused on engaging teachers in **active learning** where they participated as students to learn new content through inquiry (using instructional models such as 5-E learning cycle, Legacy Cycle, etc.). Teachers first experienced the lessons then replicated them with their own students in their classrooms. Vernier probeware was a centerpiece of the program. **Coherence** was achieved through a combination of alignment with state chemistry standards as well as a focus on transforming teacher beliefs through the series of activities in the program. The **duration** of the program included 90-hours of contact with participants, which is consistent with the framework. **Collective participation** was not clear, as the

proposal stated the program would partner with 1-4 teachers from each high school. The framework states that a minimum of two teachers should be included from any given school/district.

FINDINGS FROM OBSERVATIONS

The submission rate for teacher-provided videos of their teaching for the TTU Chemistry program was less than optimal. Fifteen teachers submitted at least one video. However, only four teachers submitted all three required videos, and this is the group that was examined for impact of the program on instructional practice. Overall, TTU Chemistry program participants significantly improved their instruction in three of the four areas: design, implementation, and content knowledge. Classroom culture was not an area of significant growth or decline.

These four teachers in the TTU Chemistry program significantly improved their ability to design and implement effective instruction across the program. One focus of the program was for participants to deliver the 10 inquiry lessons that were modeled for them in the program to their own students. It is possible that teachers were implementing these lessons at the mid-point and end of the program in their recordings.

At baseline, TTU Chemistry program participants scored low on the design of lesson, at an "ineffective instruction" level (score of 1.63). However, by the end of the program, the overall score had increased to "beginning stages of effective instruction" level (score of 2.80). The design of lesson encompasses the extent of planning, organization, resources, equity, collaboration, flow, assessments, and sense making that takes place in the lesson delivery.

At baseline TTU Chemistry program participants scored low on implementation of lesson at an "elements of effective instruction" level (score of 2.14). This area was also improved through participation in the program, as participants scored significantly higher (score of 3.21) at the end point of the program (characterized as "beginning stages of effective instruction"). The implementation of lesson construct considers the level of investigative mathematics/science in the lesson, quality of classroom management strategies, pace of the lesson, ability to modify instruction based upon student understanding, teacher questioning strategies, and formative assessments. Moreover, TTU Chemistry participants were able to deliver more effective instruction at the end of their program.

Participants experienced growth in science content knowledge demonstrated in observed lessons across the program. The baseline rating for TTU Chemistry program teachers was 2.47, which falls under the "elements of effective instruction" level. However, significant growth was realized across the program, with the final rating of "beginning stages of effective instruction" and a score of 3.69. Most of the time during observations, science content delivered was significant and worthwhile and appropriate for the developmental needs of students. Additionally, teacher-provided content was accurate, and some connections to real-world contexts were used. However, teachers did not incorporate abstraction, theory building, and connections to other disciplines on a regular basis.

Classroom Culture was the one area in which TTU did not experience any significant change across the program. There was some growth, but not enough to be educationally significant (2.17 to 3.21). The overall group ended the program with a rating of "beginning stages of effective instruction."

They demonstrated some of the characteristics some of the time, but not consistently across observations. For example, active participation of all students may not have been accomplished or there were issues with the interactions among students during collaborative work. Additionally, instruction was structured in a manner that did not enable students to generate and explore their own ideas, questions, conjectures, and propositions or to challenge ideas of others.

FINDINGS FROM SURVEYS

An examination of the surveys that participants completed pre- and post-program revealed findings related to teacher opinions, frequency of use in instructional practices, student activities, instructional influences, teacher preparedness, principal perceptions, parental support, and professional development experiences.

Teacher opinions for TTU participants demonstrated both growth and decline in various areas of the construct.

Areas of Increased Agreement in teacher opinions related to the teaching of chemistry:

- Teachers felt more supported by colleagues (62 percent to 100 percent)
- Teachers collaborated to share ideas more (69 percent to 88 percent)
- Teachers have necessary supplies and/materials for science (23 percent to 63 percent)
- Importance of engaging students in appropriate hands-on activities (69 percent to 100 percent)
- Importance of having students uses computers (30 percent to 50 percent)

Areas of Decreased Agreement in teacher opinions related to the teaching of chemistry:

- Importance of considering student prior understanding when planning curriculum & instruction (62 percent to 38 percent)
- Importance of connections between science/math and other disciplines (69 percent to 25 percent)
- Importance of having students working in cooperative learning groups (39 percent to 13 percent)
- Importance of having students prepare project/laboratory/research reports (29 percent to 25 percent)
- Importance of engaging students in applications of science/math in a variety of contexts (69 percent to 38 percent)
- Importance of using performance-based assessments (42 percent to 13 percent)
- Importance of using portfolios (23 percent to 0 percent)
- Importance of using informal questioning to assess student understanding (62 percent to 25 percent)
- Teachers have time within the regular school week to collaborate

with other colleagues (23 percent to 13 percent)

Instructional Influences were a second area of focus in the survey. TTU program more participants reported positive experiences with variables this area at the end of the program.

Encourages Effective Instruction – The following influences were perceived as having a more positive relationship on teaching mathematics effectively by the end of the program:

- State and/or district curriculum frameworks (23 percent to 57 percent)
- Access to computers (39 percent to 71 percent)
- Time for teachers to plan lessons (46 percent to 100 percent)
- Time for teacher professional development (39 percent to 83 percent)
- Public attitudes toward reform (15 percent to 57 percent)

Inhibits Effective Instruction – Unfortunately, participants reported that time to collaborate with other teachers did not encourage effective instruction (57 percent). However, teachers' views about other items that were linked before the program to inhibiting effective instruction did not change much by the end of the program:

- State and/or district testing policies and practices (77 percent to 71 percent)
- Quality of instructional materials (62 percent to 57 percent)
- Funds for supplies (69 percent to 57 percent)
- Importance school places on science/math (54 percent to 43 percent)

Teacher Preparedness comprised the third construct of the survey. Data from the TTU Chemistry program revealed teachers who participated in the program felt better prepared to do some things, but less prepared at the end of the program in other areas.

Growth in Preparation – Teachers who participated in the program felt better prepared in the following areas:

- Providing concrete experiences before abstract concepts (46 percent to 63 percent)
- Developing student conceptual understanding (77 percent to 88 percent)
- Engaging students in inquiry-oriented activities (54 percent to 75 percent)
- Using computers (69 percent to 75 percent)
- Engaging students in applying science/math in a variety of contexts (62 percent to 75 percent)
- Leading a class using investigative strategies (62 percent to 88 percent)
- Using strategies that encourage participation of females and minorities in science/math (54 percent to 75 percent)

Decline in Preparation – Participants perceived they were less prepared at the end of the program in these areas:

- Having students work in cooperative learning groups (15 percent to 25 percent)
- Recognizing and responding to student diversity (15 percent to 38 percent)
- Using portfolios (69 percent to 75 percent)
- Considering student prior understanding when planning instruction (39 percent to 50 percent)
- Using performance based assessment (46 percent to 63 percent)

Frequency of Use of Instructional Practices consists of teacher-reported use of specific instructional practices. TTU Chemistry program participants reported increases in some areas and declines in others.

Increased Use – For several practices participants reported increased use at the end of the program:

- Demonstrating a science/math principle or phenomenon (62 percent to 100 percent)
- Teaching science in real-world contexts (69 percent to 75 percent)
- Arranging seating to facilitate student discussion (54 percent to 88 percent)
- Encouraging students to explain concepts to one another (46 percent to 75 percent)
- Encouraging students to consider alternative explanations (46 percent to 63 percent)
- Allowing students to work at their own pace (46 percent to 75 percent)
- Helping students see connections between math/science and other disciplines (69 percent to 75 percent)
- Embedding assessment in regular class activities (50 percent to 75 percent)

Decreased Use – More participants reported decreased use of the following practices over the course of the program:

- Requiring students to use evidence to support their claims (54 percent to 63 percent)
- Using assessment to find out what student know before or during a unit (54 percent to 63 percent)
- Reading and commenting on student reflections in journals (77 percent to 88 percent)

Student Activities are the activities in which students engage while in the classroom. Participants were asked questions regarding the frequency of use of various student activities. There were mixed findings in regards to the frequency of use of effective student activities from baseline to end of program.

Frequent Use – More participants reported frequent of use for the following student activities at the end of the program:

- Participating in discussions with the teacher to further understanding (69 percent to 86 percent)
- Working in cooperative learning groups (58 percent to 75 percent)
- Sharing ideas or solve problems with each other in small groups (54 percent to 75 percent)
- Engaging in hands-on science/math activities (39 percent to 75 percent)
- Following specific instructions in an activity or investigation (46 percent to 75 percent)

Decreased Use – More teachers in the TTU Chemistry program reported less frequent use of some student activities that are considered effective practice:

- Participating in student-led discussions (62 percent to 75 percent)
- Making formal presentations to the class (85 percent to 100 percent)
- Reading other (non-textbook) science/math related materials in class (92 percent to 100 percent)
- Working on solving a real-world problem (54 percent to 63 percent)
- Designing or implementing their own investigation (85 percent to 100 percent)
- Working on extended science/math investigations or projects that are a week or more in duration (92 percent to 100 percent)
- Participating in field work (92 percent to 100 percent)
- Writing reflections in a notebook or journal (85 percent to 100 percent)
- Taking short-answer tests (39 percent to 57 percent)
- Taking tests requiring open-ended responses (77 percent to 88 percent)

Principal Perceptions are the impressions that participants hold regarding their administrator's perception of the teaching and learning of science/math. Participants in the program experienced positive growth across all items in this area from pre- to post-survey administration.

In fact, 100 percent of teachers at the end of the program agreed that principals encourage (1) the selection of math/science instructional strategies to address individual students learning, (2) the implementation of current national standards in science/math education, and (3) innovative instructional practices. Other areas of growth included:

- Accepting the noise that comes with an active classroom (75 percent)
- Providing materials/equipment for science/math (50 percent)
- Providing time for teachers to meet and share ideas (38 percent - up from 23 percent at baseline)
- Encouraging teachers to observe other science/math teachers (63 percent)
- Encouraging teachers to make connections across disciplines (88 percent)

Parental Support was reported to be very low by participants in the TTU Chemistry program. 100 percent of participants indicated that few parents volunteer to assist with class activities, donate money for materials, attend parent-teacher conferences or PTA or math/science nights, or voice support for various instructional approaches.

Professional Development (PD) Experiences is an area of the survey where participants indicate their impressions of the ability of the PD program to increase their skills. In all three areas the TTU Chemistry program teachers all reported gains, including content knowledge (54 percent to 75 percent), understanding of students (62 percent to 75 percent) and ability to implement high-quality science/math instructional materials (62 percent to 75 percent).

FINDINGS FROM CONTENT ASSESSMENT

There were nine participants in the TTU Chemistry program that completed both the pre/post content assessment that was developed by TTU. On the pre-test, the nine teachers answered 64 percent of the items correctly. The percentage correct increased to 71 percent on the post-test. This growth was determined to not be statistically significant.

CONCLUDING OBSERVATIONS FOR PROGRAM

The TTU Chemistry professional development program was comprised of four of the criteria in the Core Conceptual Framework (content focus, active participation, duration, coherence). The fifth component, collective participation, was unable to be determined based upon the statement in the proposal, which indicated inclusion of one to four teachers from any given school.

Data collected for the evaluation indicated TTU's Chemistry PD program had a significant impact on teacher design and implementation of effective instruction. Additionally, teachers' exhibited content knowledge during observations also improved across the program.

Teachers reported increased use of some effective strategies for teaching chemistry (e.g., hands-on, demonstrations, student explanations of phenomena, embedded assessment). Further, participants felt well prepared to engage students in inquiry, lead investigations, use computers, and engage diverse groups in science. However, there were several areas in which teachers felt less prepared following the program (e.g., using student prior understanding, cooperative group work, performance-based assessments, portfolios) and many effective strategies that were not perceived as important (e.g., using student prior understanding in planning instruction, connections between math/science and other disciplines, using cooperative groups, use of scientific reports, use of computers, applying science/math to other contexts, performance-based assessments, portfolios, models and simulations, field work, writing in science/math, and informal questioning).

Participants overwhelmingly felt better supported by their principals and had positive experiences in the professional development. Parental support reported was very low. Participants in the TTU Chemistry program did not realize significant gains in content knowledge on the pre/post

assessment. Overall, this program demonstrated gains in some areas but did not produce significant gains in all areas.

Program Narrative
University of Tennessee–Chattanooga (UTC)
McAllister and Ebiefung, PIs

PROGRAM SETTING AND PARTICIPANTS

The University of Tennessee–Chattanooga Numeracy, Representation, and STEM Connections for K-2 Teachers (NUMERACY) program was a partnership between the School of Education and College of Arts & Sciences at the University of Tennessee–Chattanooga. This program was focused on development of pedagogical content knowledge for 32 teachers of grades K-2 mathematics. UTC partnered with 2 LEA's (Bradley and Marion) for the NUMERACY program. A ten-day summer workshop was combined along with 16 hours of online work. The goal of the project was to contribute to the immediate needs and long-term success of providing high quality, teacher professional development to Tennessee teachers through the STEM Innovation Network. The objectives of NUMERACY included:

1. To deliver high-quality, research-based STEM professional development to teachers of kindergarten and Grades 1-2 to increase pedagogical content knowledge in mathematics.
2. To align early elementary learning in mathematics with the First to the Top plan.
3. To contribute to the STEM professional development best practices warehouse of the STEM Innovation Network to assist in sustainability efforts.

PROGRAM ALIGNMENT WITH CORE CONCEPTUAL FRAMEWORK

The proposed UTC program aligned with four of the five components of the Core Conceptual framework, with a focus on mathematics **content knowledge** aligned with the Common Core Standards of Number and Operations in Base Ten, Operations and Algebraic Thinking, and Measurement and Data. Curriculum materials from the National Council of Teachers of Mathematics (e.g., Navigating through Algebra in Pre-kindergarten) were a stated focus of the program, enhanced by assessment techniques from two additional NCTM published works (e.g., Mathematics Assessment: A Practical Handbook for Grades K-2). Materials were selected based upon the focus on mathematics content, as well as the integration of other disciplines with real-world context. **Active learning** was a focus, including workshop activities consisting of large and small group and some general technology use. A facilitator model was proposed with some extended learning opportunities delivered through a constructivist approach.

Coherence included the use of experiential learning as a means to address existing teacher beliefs for NUMERACY participants. Further, all activities were aligned with state and Common Core standards, as well as with district-level desired focus on literacy – including inquiry and vocabulary. The **duration** of the program included a 17-month deployment of the program, including 120 hours

of contact with participants, which is consistent with the framework. **Collective participation** was unclear, as the proposal did not specifically state if teams of teachers from participating schools would be recruited.

FINDINGS FROM OBSERVATIONS

The submission rate for teacher-provided videos of their teaching for the program at UTC included eight teachers who submitted all three required videos and twenty-eight teachers who submitted at least one recording. Surprisingly, an analysis of submitted data revealed significant decreases in all three of four constructs (design of lesson, implementation of lesson, and classroom culture) related to effective mathematics teacher practice and content knowledge across the program.

At baseline, UTC program participants were characterized as "elements of effective instruction" on the design of lesson construct (score of 2.38) which significantly decreased by the end of program (2.03). The design of lesson construct examines the extent of planning, organization, resources, equity, collaboration, flow, assessments, and sense making that takes place in the lesson delivery.

UTC program participants began the program with an implementation of lesson at a score of 2.73 ("elements of effective instruction"), which significantly decreased to 2.48 by the end of program. The implementation of lesson construct examines level of investigative mathematics/science in the lesson, quality of classroom management strategies, pace of the lesson, ability to modify instruction based upon student understanding, teacher questioning strategies, and formative assessments.

Teachers in the NUMERACY program began with mathematics content knowledge rated at a score of 2.81 ("elements of effective instruction"). This area also experienced decline across the program to a score of 2.63 by the end of the program, though not statistically significant. This means that most of the time during observations, mathematics content delivered was not significant and worthwhile and appropriate for the developmental needs of students. Teacher-provided content was not always accurate, and few connections to real-world contexts were used. Participants did not incorporate abstraction, theory building, and connections to other disciplines in observed lessons.

Classroom culture for UTC participants was the final area that did not demonstrate significant improvement. At baseline, the mean score for teachers in the program was 2.65, which declined to a mean of 2.38 ("elements of effective instruction") at the end of the program. Implementation of strategies, including collaborative learning, centering instruction on student generated questions, and ideas and intellectual rigor, were not evident through observations. Active participation of all students was not observed as being encouraged and respected in a consistent manner.

FINDINGS FROM SURVEYS

An examination of the surveys that UTC NUMERACY participants completed pre- and post-program revealed findings related to teacher opinions, frequency of use in instructional practices, student activities, instructional influences, teacher preparedness, principal perceptions, parental support, and professional development experiences.

Teacher opinions were more positive at the end of the program as compared to the baseline, prior to participation in the program.

Areas of Increased Agreement – More teachers agreed with the following items after the program:

- Teachers collaborating to share ideas more (72 percent to 89 percent)
- Importance of school support by local organizations, institutions (24 percent to 33 percent)
- Importance of considering student prior understanding when planning mathematics curriculum and instruction (82 percent to 89 percent)
- Importance of making connections between mathematics and other disciplines (76 percent to 78 percent)
- Importance of using performance-based assessment (48 percent to 50 percent)
- Importance of developing student's conceptual understanding of mathematics (83 percent to 89 percent)
- Importance of having students prepare project/laboratory/research reports (21 percent to 22 percent)
- Importance of using computers (21 percent to 39 percent)
- Importance of engaging students in inquiry-oriented activities (66 percent to 78 percent)
- Importance of engaging students in applications of science/math in a variety of contexts (68 percent to 72 percent)
- Importance of using performance based assessment (48 percent to 50 percent)
- Importance of using informal questioning to assess student understanding (62 percent to 88 percent)

Instructional Influences were a second area of focus in the survey. The UTC participants reported growth in positive influence of variables in this area at the end of the program in three main areas of influence: state and/or district curriculum frameworks (41 percent to 56 percent), state and/or district testing policies and practices (17 percent to 28 percent), and consistence of science/mathematics reform efforts with other school/district reforms (48 percent to 50 percent).

Discourages Effective Instruction - More teachers reported that the following items discouraged the use of effective instruction by end of program:

- Access to computers (35 percent to 56 percent)
- Funds for equipment and supplies (59 percent to 83 percent)
- Time to work with other teachers (52 percent to 56 percent)
- Time for professional development (52 percent to 61 percent)
- Public attitudes toward reform (39 percent to 63 percent)
- Quality of available materials (45 percent to 50 percent)
- System of managing instructional resources at district or school level (52 percent to 65 percent)
- Consistency of science/math reform efforts with other school/district reforms (49 percent to 82 percent)
- Time to plan and prepare lessons (55 percent to 67 percent)
- Public attitudes toward reform (55 percent to 65 percent)

Teacher Preparedness comprised the third construct of the survey. Participants in the UTC program experienced gains in all areas of preparedness across the program, as indicated by more teachers indicating that they were fairly well or well prepared on each construct:

- Providing concrete experiences before abstract concepts (72 percent to 83 percent)
- Developing student conceptual understanding (69 percent to 89 percent)
- Considering students' prior understanding when planning curriculum and instruction (89 percent to 94 percent)
- Making connections between science/mathematics and other disciplines (83 percent to 94 percent)
- Using cooperative learning groups (76 percent to 94 percent)
- Using hands-on activities (86 percent to 94 percent)
- Engaging students in inquiry-oriented activities (57 percent to 100 percent)
- Having students prepare project/laboratory/research reports (14 percent to 83 percent)
- Using computers (56 percent to 78 percent)
- Engaging students in applying science/math in a variety of contexts (52 percent to 89 percent)
- Using performance-based assessment (76 percent to 94 percent)
- Using portfolios (41 percent to 78 percent)
- Leading a class using investigative strategies (69 percent to 83 percent)
- Managing a class of students engaged in hands-on/project-based work (69 percent to 89 percent)
- Helping students take responsibility for their own learning (66 percent to 100 percent)
- Using strategies that encourage participation of females and

minorities in science/math (64 percent to 100 percent)
- Encouraging students' interest in science/mathematics (86 percent to 100 percent)
- Recognizing and responding to student diversity (76 percent to 94 percent)

Frequency of Use of Instructional Practices consists of teacher-reported frequency of use of specific instructional practices. NUMERACY program participants reported more frequent use of all strategies at the end of the program:

- Demonstrating a mathematics-related principle or phenomenon (69 percent to 94 percent)
- Teaching mathematics using real-world contexts (83 percent to 94 percent)
- Arranging seating to facilitate student discussion (71 percent to 100 percent)
- Using open-ended questions (90 percent to 100 percent)
- Requiring students to provide evidence to support their claims (79 percent to 89 percent)
- Encouraging students to explain concepts to one another (72 percent to 89 percent)
- Encouraging students to consider alternative explanations (69 percent to 94 percent)
- Allowing students to work at their own pace (86 percent to 89 percent)
- Helping students see connections between math/science and other disciplines (62 percent to 89 percent)
- Using formative assessment (83 percent to 94 percent)
- Embedding assessment in regular class activities (86 percent to 100 percent)
- Reading and commenting on reflections students have written in notebooks or journals (31 percent to 78 percent)

Student Activities are the activities that students are engaged in within the classroom. NUMERACY participants were asked questions regarding the frequency of use of various student activities. Findings in regards to the frequency of use of effective student activities from baseline to end of program revealed an increase in all areas of this construct for UTC program participants.

Frequent Use – Participants reported more frequent use for the following student activities by end of the program:

- Participating in student-led discussions (48 percent to 72 percent)
- Participating in discussions with the teacher to further mathematics understanding (83 percent to 94 percent)
- Working in cooperative learning groups (83 percent to 89 percent)
- Making formal presentations to the class (14 percent to 28 percent)
- Reading other (non-textbook) mathematics-related materials in class (48 percent to 88 percent)
- Working on solving a real-world problem (52 percent to 94 percent)

- Sharing student ideas or solve problems with each other in small groups (59 percent to 89 percent)
- Engaging in hands-on science/math activities (90 percent to 100 percent)
- Following specific instructions in an activity or investigation (62 percent to 94 percent)
- Designing or implementing his or her own investigation (17 percent to 33 percent)
- Working on models or simulations (31 percent to 44 percent)
- Working on extended mathematics investigations or projects (7 percent to 28 percent)
- Recording, representing, and/or analyzing data (28 percent to 72 percent)
- Writing reflections in a notebook or journal (38 percent to 78 percent)
- Working on portfolios (7 percent to 33 percent)
- Taking tests requiring open-ended responses (35 percent to 59 percent)
- Participating in field work (3 percent to 17 percent)

Principal Perceptions are the impressions that participants have about their administrator's perceptions of the teaching and learning of science/math. Participants in the UTC program had positive views on support from their leadership from baseline to end of program in most areas.

Areas of Increased Agreement – Teachers agreed their principal provided encouragement and/or support in the following areas:

- Encouraging the implementation of current national standards in science/math education (86 percent to 94 percent)
- Providing materials/equipment for science/math (52 percent to 67 percent)
- Encouraging innovative practice (79 percent to 89 percent)
- Accepting the noise that comes with an active classroom (59 percent to 78 percent)
- Acting as a buffer between teachers and external pressures (48 percent to 56 percent)

Parental Support was reported to be very low by participants in the UTC program. Most participants indicated that few parents volunteer to assist with class activities (94 percent), donate money or materials (94 percent), voice support for various instructional strategies (100 percent), or attend parent-teacher conferences (94 percent), and/or PTA or math/science nights (100 percent).

Professional Development (PD) Experiences is an area of the survey where participants indicate their impressions of the ability of the PD program to increase their skills. NUMERACY participants reported positive impressions of the impact of the PD at the end of the program in regards to impact on content knowledge (67 percent), as well as the impact on understanding how students learn (67 percent), and ability to implement high-quality science/math instructional materials (67 percent).

FINDINGS FROM CONTENT ASSESSMENT

The UTC program developed and administered a 25-item, objectively scored assessment for use in the evaluation. An analysis of program submitted data indicated there was no significant growth from baseline (86 percent correct) to end of the program (88 percent correct) in teacher mathematics content knowledge assessed.

CONCLUDING OBSERVATIONS FOR PROGRAM

The University of Tennessee – Chattanooga NUMERACY professional development program did not completely address the components of the Core Conceptual Framework (e.g., content focus, active participation, duration, and coherence) in the grant proposal as part of their planned focus. As a result of this approach, as well as the format of the delivery of the program, the program failed to have an overall positive impact on teacher quality. In fact, data submitted in regards to teacher quality revealed a significant decrease in use of effective mathematics instructional practices across the program.

Teacher survey findings were mostly positive for the UTC mathematics program. In their self-reports, participants indicated increased use of all effective strategies for teaching mathematics (e.g., arranging seating for discussion, alternative explanations, connections between mathematics/science and other disciplines, formative assessments). Further, participant's felt more prepared to implement effective mathematics teaching in their self-reports. For example, the use of development of student conceptual understanding, use of hands-on, inquiry, computers, diversity, and helping students take responsibility for their own learning were all areas more participants reported feeling prepared to use. Unfortunately, participants' perceived preparedness and reported frequency of use did not translate into significant gains in implemented practice in classroom observations.

Across the program, participants in the UTC program also reported more negative instructional influences on their teaching. It is unclear if this was coincidental or if there was something taking place with the program that had a negative influence. Teacher perceptions of administrative support were mixed and parental support was reported as very little with 94-100 percent agreement by end of program. In regards to participant impressions of the PD program, the majority of UTC participants (67 percent) reported that they felt the program had more impact than previous PD experiences on their ability to understand how children think about/learn science and/or mathematics, mathematics content knowledge, and their ability to implement effective mathematics instruction. Overall, participants in the UTC program experienced decline across the year in their ability to deliver effective instruction as evidenced in program submitted recordings of participants' teaching. Therefore, it is difficult to make any conclusions about the effectiveness of this program. The NUMERACY teachers did report some positive change in teacher beliefs and use of strategies, though it is unclear exactly why these apparent shifts did not translate into change in practice.

Program Narrative
University of Tennessee–Chattanooga (UTC)
Wigal and Cowan, PIs

PROGRAM SETTING AND PARTICIPANTS

The Technology/Engineering + Literacy = MATH Understanding (TELMU) program at the University of Tennessee–Chattanooga was a partnership between the College of Engineering and the College of Education to deliver a grade 6-9 mathematics focused program including the integration of literacy. The professional development program included 120 contact hours for 40 teacher participants. UTC partnered with six LEA's (Grundy, Sequatchie, Hamilton, Bledsoe, Meigs, and Richard City) for this program. There were 10 summer workshop days conducted, along with three Saturday sessions combined with 16-hours of online work. The goals of this project included enabling participants to expand their pedagogical content knowledge in two areas:

1. The power of learning through experience, including effective ways of using applications to learn math.
2. The role of vocabulary and metacognition in developing mathematical reasoning, conceptual understanding, and problem solving ability.

The objectives of the TELMU program included enabling teachers to:

1. Expand their mathematics content knowledge, especially in the areas of rational number sense, linear models, vocabulary, and understanding of key grades 6-9 concepts, so they have the foundations for teaching these competencies effectively.
2. Engage in realistic STEM projects and become familiar with materials in their supply kits, and later implement similar projects in their own classrooms.
3. Increase their ability to use mathematical knowledge and concepts to solve contextual STEM problems, learn the value of such problems for developing mathematical competence, rehearse effective ways to use this pedagogical approach, and develop the confidence to use similar activities in their own classrooms.
4. Understand and be able to apply key metacognitive literacy strategies to support the development of their students' ability to solve quantitative problems in context.

PROGRAM ALIGNMENT WITH CORE CONCEPTUAL FRAMEWORK

The proposed UTC program aligned with some aspects of the five components of the Core Conceptual framework, with a focus on mathematics **content knowledge** delivered through co-teaching of activities by engineering and education faculty who model best practice (e.g., TeachEngineering website). TeachEnginnering lessons were used which are hands-on and relevant to student lives. Some Project Lead the Way curriculum was adapted and these activities will also be

used. An interactive, activity-based, approach was used including integration of key literacy strategies and active participation in quantitative experiments and activities. **Active learning** was a focus, including the use of experiments and analyzing and reporting results. Participants were engaged in working on teams for ten project-based lessons in the summer workshop. It is not clear what percentage of time of the overall professional development program was devoted to active learning.

Coherence was addressed through a purposeful focus on addressing existing teacher beliefs. There were indirect connections to state standards. However, the TELMU program did not address local/school level alignment between program objectives and school/district level needs. The **duration** of the program included 120-hours of contact with participants, which is consistent with the framework. This was achieved through an 80-hour summer institute, combined with 16-hours of web-based work and 24-hours of Saturday sessions (three total). **Collective participation** was not clear, as the proposal stated the program would include at least one mathematics and science teacher from each of the participating schools.

FINDINGS FROM OBSERVATIONS

The submission rate for teacher-provided videos for the UTC program was less than desirable, as only seven participants submitted all three videos. There were 23 participants who submitted at least one video. Overall, results showed no significant growth in any of the four constructs (e.g., design of lesson, implementation of lesson, classroom culture, and mathematics content) related to desired change in teacher practice and content knowledge across the program.

At baseline, UTC TELMU program participants were characterized as being at the "elements of effective instruction" stage on the design of lesson construct (score of 2.26), increasing somewhat, but not significantly, by the end of program (2.29). The design of lesson construct examines the extent of planning, organization, resources, equity, collaboration, flow, assessments, and sense making that takes place in the lesson delivery.

UTC TELMU program participants began the program with an implementation of lesson score of 2.59 ("elements of effective instruction") and improved this slightly to 2.78 ("elements of effective instruction") by the end of program, which was determined to not be statistically significant. The implementation of lesson construct examines level of investigative mathematics/science in the lesson, quality of classroom management strategies, pace of the lesson, ability to modify instruction based upon student understanding, teacher questioning strategies, and formative assessments.

Teachers in the TELMU program began the program a mathematics content knowledge overall mean score of 2.78 ("elements of effective instruction"). Again, teachers made some improvements across the program, realizing an improved mean score of 3.06 ("beginning stages of effective instruction") by the end of the program, though this was determined to not be statistically significant. This means that some of the time during observations, mathematics content delivered was significant and worthwhile and appropriate for the developmental needs of students. Teacher-provided content was accurate, and some connections to real-world contexts were used. Participants did not incorporate abstraction, theory building, and connections to other disciplines in observed lessons.

Classroom culture was the final area without significant improvement for UTC participants. At baseline, the mean score for teachers in the program was 2.64, which grew slightly to a mean of 2.95 ("elements of effective instruction") by the end of the program. Implementation of strategies, including collaborative learning, centering instruction on student generated questions, and ideas and intellectual rigor, were not evident through observations. Active participation of all students was not observed as being encouraged and respected in a consistent manner.

FINDINGS FROM SURVEYS

An examination of pre/post survey data for UTC TELMU participants revealed mixed findings related to teacher opinions, frequency of use in instructional practices, student activities, instructional influences, teacher preparedness, principal perceptions, parental support, and professional development experiences.

Teacher opinions for UTC participants demonstrated both growth and decline in various areas of the construct.

Areas of Increased Agreement – More teachers agreed with the following items after the program:

- Teachers collaborated to share ideas more (64 percent to 68 percent)
- Teachers have necessary supplies and/materials for mathematics (42 percent to 50 percent)
- Teachers have time to collaborate with peers (50 percent to 68 percent)
- The school mathematics program is supported by local organizations, institutions (25 percent to 67 percent)
- Planned to use performance-based assessment (50 percent to 58 percent)
- Importance of developing student's conceptual understanding of mathematics (75 percent to 83 percent)
- Importance of having students prepare project/laboratory/research reports (17 percent to 33 percent)
- Importance of having students use computers (17 percent to 50 percent)

Areas of Increased Disagreement – Fewer teachers agreed with the following items after the program:

- Teachers in the school share a common vision of effective science/math instruction (25 percent to 33 percent)
- Importance of connecting math/science to other disciplines (25 percent to 33 percent)
- Importance of having students participate in appropriate hands-on activities (25 percent to 50 percent)
- Importance of having students participate in inquiry-oriented activities (42 percent to 67 percent)
- Importance of engaging students in applications of science/math

in a variety of contexts (25 percent to 33 percent)
- Importance of using performance based assessment (58 percent to 67 percent)

Instructional Influences were a second area of focus in the survey. The UTC TELMU participants reported mixed experiences with variables in this area at the end of the program.

Encourages Effective Instruction – The following influences were perceived as having a more positive relationship on teaching mathematics effectively by the end of the program:

- State and/or district curriculum frameworks (36 percent to 57 percent)
- State and/or district testing polices and practices (33 percent to 43 percent)
- Access to computers (42 percent to 57 percent)
- Funds for equipment and supplies (50 percent to 71 percent)
- Time to work with other teachers (58 percent to 71 percent)
- Time for professional development (50 percent to 57 percent)
- Public attitudes toward reform (25 percent to 43 percent)

Inhibits Effective Instruction – The following influences were perceived as having a more negative relationship on teaching mathematics effectively by the end of the program:

- Quality of available materials (27 percent to 43 percent)
- System of managing instructional resources at district or school level (50 percent to 57 percent)
- Importance of mathematics/science within the school (25 percent to 43 percent)
- Consistency of science/math reform efforts with other school/district reforms (50 percent to 57 percent)

Teacher Preparedness comprised the third construct of the survey. Participants in the TELMU program experienced gains in most areas of perceived preparedness across the program, as indicated by a greater percentage of teachers indicating that they were fairly well or well prepared in the following construct areas:

- Providing concrete experiences before abstract concepts (81 percent to 100 percent)
- Developing student conceptual understanding (91 percent to 100 percent)
- Using hands-on activities (91 percent to 100 percent)
- Engaging students in inquiry-oriented activities (73 percent to 100 percent)
- Having students prepare project/laboratory/research reports (55 percent to 100 percent)
- Using computers (82 percent to 100 percent)
- Engaging students in applying science/math in a variety of contexts (82 percent to 100 percent)

- Using performance based assessments (90 percent to 100 percent)
- Leading a class using investigative strategies (73 percent to 75 percent)
- Helping students take responsibility for their own learning (82 percent to 100 percent)
- Recognizing and responding to student diversity (82 percent to 100 percent)
- Using strategies that encourage participation of females and minorities in science/math (73 percent to 100 percent)

Decline in Preparation – In two areas TELMU participants' felt less prepared following participation in the program: use of cooperative learning groups (9 percent to 25 percent) and managing a class of students engaged in hands-on/project-based work (9 percent to 25 percent).

Frequency of Use of Instructional Practices consists of teacher-reported frequency of use of specific instructional practices. TELMU program participants reported more frequent use of most strategies by the end of the program:

- Introducing content through formal presentations (82 percent to 86 percent)
- Teaching mathematics in real-world contexts (67 percent to 75 percent)
- Encouraging students to explain concepts to one another (82 percent to 86 percent)
- Encouraging students to consider alternative explanations (82 percent to 86 percent)
- Helping students see connections between math/science and other disciplines (73 percent to 86 percent)
- Using formative assessment (64 percent to 86 percent)
- Embedding assessment in regular class activities (82 percent to 86 percent)

Decline in Frequency of Use – A greater percentage of TELMU participants reported less frequent use of the following effective instructional practices across the program: arranging seating to facilitate student discussion (18 percent to 29 percent), using open-ended questions (18 percent to 29 percent), and allowing students to work at their own pace (18 percent to 29 percent).

Student Activities are the activities that students are engaged in within the classroom. TELMU participants were asked questions regarding the frequency of use of various student activities. Findings in regards to the frequency of use of effective student activities from baseline to end of program revealed an increase of use of strategies in most of the areas of this construct.

Frequent Use – Participants reported more frequent use for these student activities by end of the program:

- Participating in discussions with the teacher to further understanding (82 percent to 86 percent)
- Making formal presentations to the class (9 percent to 43 percent)
- Reading other (non-textbook) science/math related materials in class (0 percent to 57 percent)

- Working on solving a real-world problem (82 percent to 86 percent)
- Engaging in hands-on science/math activities (55 percent to 72 percent)
- Following specific instructions in an activity or investigation (55 percent to 86 percent)
- Designing or implementing his or her own investigation (27 percent to 43 percent)
- Working on models or simulations (27 percent to 43 percent)
- Recording, representing, and/or analyzing data (9 percent to 57 percent)
- Writing reflections in a notebook or journal (18 percent to 57 percent)
- Working on portfolios (9 percent to 43 percent)
- Taking tests requiring open-ended responses (36 percent to 86 percent)
- Participating in field work (0 percent to 43 percent)

Decreased Use – More teachers reported less frequent use of some effective student activities by the end of the program:

- Working in cooperative learning groups (27 percent to 29 percent)
- Sharing student ideas or solve problems with each other in small groups (20 percent to 29 percent)
- Taking short-answer tests (30 percent to 43 percent)

Principal Perceptions are the impressions that participants have about their administrator's support for the teaching and learning of science/mathematics. Participants in the TTU program had very positive views of their leadership.

Areas of Increased Agreement – Teachers agreed their principal provided encouragement and/or support in the following areas:

- Encouraging selection of science/math content and instructional strategies to address individual students' learning (33 percent to 50 percent)
- Encouraging the implementation of current national standards in science/math education (67 percent to 75 percent)
- Providing materials/equipment for science/math (33 percent to 50 percent)
- Providing time for teachers to meet and share ideas (33 percent to 50 percent)
- Encouraging teachers to observe other exemplary teachers (33 percent to 50 percent)
- Acting as a buffer between teachers and external pressures (50 percent to 75 percent)

Parental Support was reported to be very low by participants in the TELMU program. In fact, 100 percent of participants indicated that few parents volunteer to assist with class activities, donate money for materials, voice support for various instructional strategies, or attend parent-teacher conferences, and/or PTA or math/science nights.

Professional Development (PD) Experiences is an area of the survey where participants indicate their impressions of the ability of the PD program to increase their skills. TELMU participants (50 percent) reported positive impressions of the impact of the PD at the end of the program in regards to impact on content knowledge (an increase from 33 percent at baseline). The impact on understanding how students learn, and ability to implement high-quality science/math instructional materials remained the same as baseline at the end of the program with only 50 percent agreeing there was an impact on them personally.

FINDINGS FROM CONTENT ASSESSMENT

The TELMU program did not follow the THEC requirements for development and administration of a 25-item, objectively scored assessment for use in the evaluation. Therefore, there are no program-level content assessment data available to report for this program.

CONCLUDING OBSERVATIONS FOR PROGRAM

The TELMU professional development program addressed some aspects of the components of the Core Conceptual Framework (e.g., content focus, active participation, duration, and coherence) in the grant proposal as part of their planned focus. Program outcomes indicate the TELMU intervention did not have a statistically significant impact on teacher quality (e.g., ability to implement the lessons, classroom culture, and math content knowledge).

Teacher reported opinions and perceptions of preparation, as well as frequency of use of strategies revealed some growth for participants in the UTC program. In their self-reports, participants indicated increased use of some effective strategies for teaching mathematics (e.g., use of real-world contexts, alternative explanations, connections between mathematics/science and other disciplines, formative assessments). Additionally, participant's felt more prepared to implement effective mathematics teaching in their self-reports. For example, the use of development of student conceptual understanding, use of hands-on, inquiry, computers, diversity, and helping students take responsibility for their own learning were all areas more participants reported feeling prepared to use. Unfortunately, participants' perceived preparedness did not translate into observable gains in implemented practice in classroom observations.

TELMU participants experienced positive growth in perceptions of instructional influences on promoting effective instruction. Specifically, TELMU teachers felt state and district curriculum frameworks, access to computers, funds for equipment and supplies, time to collaborate, time for professional development, and public attitudes toward reform all supported effective instruction. Instructional influences that negatively influenced instruction included quality of available instructional materials, district/school level management of instructional resources, importance school places on mathematics/science, and consistence of science/mathematics reform with other district reforms.

Teacher perceptions of administrative support were very positive. Agreement grew across the program regarding principal support of innovative instructional practices, provisions for materials

and equipment, making connections across disciplines, time for collaboration, the noise level of active classrooms, and the level of administrative buffering between teachers and external forces. However, parental support was reported as very little with 100 percent agreement on all constructs by end of program. In regards to participant impressions of the PD program, half of teacher participants (50 percent) reported that they felt the program had more impact than previous PD experiences on their ability to understand how children think about/learn science and/or mathematics content knowledge, as well as their ability to implement effective mathematics instruction. Overall, the ability to make conclusions regarding the success of this program is limited. There were no significant gains in teacher quality measures and content knowledge pre/post data were not submitted in appropriate format. Attitudinal data did show some growth in self-reported use of strategies and teacher perceived preparedness. Moreover, only half (50 percent) of participants felt the program had a great impact on their practice.

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