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i-STEM Summer Institute: An Integrated Approach to Teacher Professional Development in STEM

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Abstract

The importance of STEM education to societal developments provides justification for assuring K–12 teachers are prepared to teach the related content. Inservice teacher professional development is critical to achieving the goal of enhanced student knowledge of STEM. Combining the need for increased capacity to teach STEM and the extant literature on teacher development, we created a four-day residential summer institute for 230 grade 4–9 teachers. The institute was designed to enhance the participants' content knowledge, use of inquiry for instruction, and efficacy for teaching STEM. A combination of content strands, plenary sessions, field trips and planning time were augmented by the provision of the resources necessary to implement the curriculum the participants learned. Pre- and post-test results of the participants' comfort, pedagogical discontentment, inquiry implementation, perceived efficacy, and content knowledge in the context of STEM revealed significant changes (p < 01). In addition, pre- and post-test results indicate the participants' perceptions and conceptions of STEM achieved substantial gains. Our report provides the details, outcomes, and potential implications for STEM education.

Introduction

The importance of STEM education to our national prosperity and global competitiveness was recently reinforced by the Obama administration's support for *Change the Equation*. *Change the Equation* is a multi-entity initiative formed in response to the rapidly increasing number of STEM related careers and the potential lack of preparation by many Americans to be employed in these positions. Further, there is a need to enssure our public is prepared to be part of the discussion surrounding an array of STEM related decisions. To address these issues, many are calling for increased emphasis on STEM education in K–12, as early and sustained preparation in STEM provides the foundation essential for further learning, competencies, and literacies (National Research Council, 2007). Enhancing the quality and quantity of K–12 STEM education is inextricably linked to the continued professional development of K–12 teachers. The need to enhance teacher capacity for teaching STEM and the gathering of empirical data to establish its effectiveness was the impetus behind our *i-STEM* summer institute professional development and research initiative.

The *i-STEM* project is a collaborative effort between business, industry, government, K–12, and higher education. Although the organization is working on a number of initiatives, including policy, research, communication and collaborations, the group has concentrated its resources on professional development opportunities for K–12 educators. Our report focuses on the structure and outcomes of an intensive four-day *i-STEM* residential professional development institute designed to increase grade 4–9 teacher preparation to teach STEM content. The summer institute was structured based on a needs assessment survey of grade 4–9 teachers, the extant literature, and our desire to use evidence based practices demonstrated to enhance teacher preparation and effectiveness.

Our research sought to determine how the structure and content of the summer institute influenced the participants' comfort with teaching STEM, efficacy for teaching STEM, content knowledge of STEM, inquiry implementation in STEM, and perceptions of STEM education. These parameters in part have been gathered previously for specific areas of math or science education, but there is no study we are aware of in which these variables have been attended to and assessed in the context of enhancing inservice teacher preparation to teach STEM. Therefore, our project provides a unique contribution to the literature because of our focus on STEM education and our adaptation and use of an array of assessments to measure the impact on our participants' perceptions of teaching STEM and knowledge of the related content.

Before we present our research and results, we discuss the relevant literature establishing the context for our study. Following the presentation of our study findings we discuss the related implications and directions for future research. We conclude with a discussion of study limitations and some closing remarks of our study's contributions to the field of teacher professional development in STEM education.

Review of Literature

Affective Variables and Teacher Effectiveness

The link between learning and affective variables such as confidence, anxiety, and efficacy has been well established (Riggs & Enochs, 1990; Sternberg & Williams, 2009; Tschannen-Moran, Woolfolk Hoy, & Hoy, 1998) particularly when implementing innovation (Guskey, 1988). There is evidence to suggest that there is a similar association between affective variables and teacher effectiveness (Darling-Hammond & Bransford, 2005). For example, when teachers are not comfortable with teaching a topic, such as the conceptually challenging content associated with many STEM themes, they tend to avoid teaching the topic, or teach the subject superficially (Bursal & Paznokas, 2006; NRC, 2007). The documented link between teacher comfort and teacher effectiveness as measured by student learning (Appleton, 1995) suggests that a lack of teacher comfort with STEM content can have a deleterious impact on student learning and perceptions of STEM (Beilock, Gunderson, Ramirez, & Levine, 2010). The link between teachers' comfort, their motivation to teach, and student learning in STEM provides good reason for attending to comfort and related variables (e.g., efficacy) in professional development directed at enhancing teacher capacity to teach STEM content and curriculum.

Logically, there is justification for positing that teacher comfort levels are directly linked to their levels of pedagogical contentment or discontentment (Sowell & Southerland, 2006). The argument suggests that if teachers are discontent with their pedagogy, they will not feel comfortable teaching the content. Hence, they will not be effective teachers. The association between teachers' comfort and contentment with their pedagogy validates the creation and offering of professional development designed to enhance pedagogical contentment for teaching STEM. Increases in teacher comfort and pedagogical contentment in STEM are likely to lead to an increase in teacher competencies and effectiveness in STEM, providing justification for attending to teacher discontentment in professional development in STEM. However, it is essential to determine the nature of the pedagogical discontentment toward STEM prior to offering professional development, in order to determine whether the intervention effectively increases teacher comfort and contentment in teaching STEM.

Recognizing the possibility that teacher pedagogical discontentment can be contextual or process specific, Southerland and colleagues (in press) developed a scale that specifically assesses teachers' discontentment with science teaching. The researchers anticipate their survey will be used as a tool for assessing teacher perceptions of their pedagogical discontentment before and after professional development. The authors posit that the scale can be used to expose shifts in teachers' pedagogical contentment due to engagement in well-crafted and well-implemented professional development focused on enhancing teaching and learning in science. Although the scale was specifically designed to assess science educators, the constructs (e.g., teaching to all students, assessment) and the corresponding items transcend science education and are to be considered elements important to all aspects of STEM teaching (National Council of Teachers of Mathematics, 2005; NRC, 2000). The likely association between teachers' perceptions of their effectiveness and need for continuing education (Cochran-Smith & Zeichner, 2005) provide warrant for exploring how professional development might be structured to influence teacher contentment with their pedagogy. Further, the array of outcomes from investigations of the influence of professional development on teachers (Nadelson et al., 2010; Lawless & Pellegrino, 2007) suggests more research in this area is needed. Therefore, when creating and implementing teacher professional development on STEM teaching and learning, there is justification for focusing on content and processes that are predicted to influence teacher pedagogical discontentment. Additionally, there is warrant for the pre and post assessment of the pedagogical discontentment of teachers engaging in the professional development to determine the effectiveness of the program on enhancing teacher perceptions of their practice.

Instructional Perceptions and Preparation

The works of Brophy and Good (1986, 1997) have revealed a direct association between the instructional approach of the teacher and student achievement, which suggests that students are more likely to learn from teachers with higher levels of instructional competency. The teacher-student association provides the impetus to address teachers' instructional competencies as a critical component of professional development. Although some instructional competencies are domain specific, such as teaching a lesson that attends to students' prior content or subject matter knowledge, other instructional activities may be domain general, such as teaching how to evaluate the quality, source, and credibility of evidence (Gess-Newsome & Lederman, 2001). One of the areas of instruction in the STEM curriculum that continues to receive increased emphasis is the teaching of scientific inquiry (National Research Council [NRC], 1997, 2000). Effectively teaching inquiry is challenging and this requires experience and reflection (Nadelson, 2009).

The documented effectiveness of scientific inquiry as an approach to learning (Nadelson & Williams, in press) provides support for using these methods to increase student learning in STEM. Scientific inquiry is viewed as an effective method because it places students in authentic learning activities by engaging them in the roles experienced by STEM professionals (Nadelson, 2009; NRC, 2000). However, many teachers are likely to lack experience with authentic scientific research, which may lead them to hold constrained perceptions of inquiry (NRC, 2000, 2007; Silverstein, Dubner, Miller, Giled, & Loike, 2009). The predictably limited number of opportunities for many K–12 teachers to engage in authentic scientific research experiences (long-term) suggests that teachers typically base their perceptions of inquiry on their coursework experience or professional development (Anderson, 2007; NRC, 2000). The potential issue with this situation is illuminated by the research of Buck and colleagues (2009) which found that the vast majority of STEM labs typically engage college students at the lowest levels of inquiry (Schwab, 1962). The results of the study by Buck and associates suggests that the college level coursework taken by many K–12 teachers may reinforce a constrained perspective of inquiry and inadequately prepare the teachers for implementing higher levels of scientific inquiry in their teaching.

The anticipated lack of teachers' exposure to higher levels of inquiry in their academic preparation and the corresponding lack of exposure to authentic inquiry models validate our development and implementation of professional development focused on engaging teachers in a range of scientific inquiry experiences. Professional development in scientific inquiry is arguably even more critical when teachers are considering unfamiliar content such as the concepts typically associated with teaching and learning STEM. The assessment of the effectiveness of professional development focused on using scientific inquiry to teach STEM is essential for determining the impact upon teachers' perceptions and conceptions of using inquiry for instruction.

Content Knowledge

There is a mixture of evidence linking teachers' subject matter (content) knowledge to their classroom practice and their students' achievement (Ball, 1988; Lederman, Gess-Newsome & Latz, 1994; Wilson, Floden, & Ferrini-Mundy, 2001). The variety of outcomes in studies examining teacher content knowledge and student learning provide merit for continued investigation of the relationship. There is certainly face validity to the notion that teachers' level of understanding and knowledge of subject matter is linked to their ability to effectively teach the content. The relationship between teachers' content knowledge and their effectiveness (as measured by student achievement) may be attributed to the established association between content knowledge and comfort, confidence, and instructional abilities within the domain (Appleton, 1995; Shallcross, Spink, Stephenson, & Warwick, 2002).

Given that the preparation to teach STEM of most K–8 certified teachers typically consists of no more than two semesters of college level math and two semesters of science (Fulp, 2002), it is essential to provide on-going opportunities for these educators to increase their subject matter knowledge (NRC, 2007). Professional development can be implemented to increase teacher subject matter knowledge through many forms, such as workshops, courses, and presentations (Hewson, 2007). Regardless of the format, effective professional development should be designed to provide opportunities for educators to increase their knowledge and understanding of STEM content (NRC, 2007).

Applying the notion that increased content knowledge can increase teacher effectiveness, and due to the limited STEM subject matter knowledge of many K–9 teachers, we designed a summer professional development institute targeting these teachers. It is critical to address the STEM content knowledge of elementary level teachers because of the expectation that they will teach all subject areas and have limited preparation in STEM domains (Fulp, 2002). The need becomes even more critical at the middle school level, where teachers specialize in subject areas and yet may have the same preparation as an elementary teacher in STEM. Further, middle school has been identified as a critical juncture in which student motivation and performance is susceptible to decline (Speering & Rennie, 1996; Zacheria & Calabrese Barton, 2003), suggesting that teachers need to be at full capacity to enssure the highest levels of student engagement and achievement in STEM learning.

The potential link between elementary and middle school teachers' knowledge of STEM subject matter and their effectiveness in teaching STEM is justification for providing professional development designed to increase content knowledge of STEM. To determine the effectiveness of meeting the goal of increased content knowledge, it is critical to assess the participating teachers' content knowledge of STEM within the domains they are learning.

Our Research

Considering the influence of affective variables on teacher effectiveness, instructional perceptions and preparation in scientific inquiry, and the potential relationship between teacher content knowledge and student achievement, we designed and implemented this teacher professional development research project. Our goal was to increase the participating teachers' comfort, efficacy, and perceptions of their effectiveness to teach STEM by attending to their subject matter knowledge, inquiry instruction preparation, and understanding of how people learn. To assess our achievement of this goal we developed a research protocol: using a pre-experimental design (Creswell, 2009) we pre- and post-tested the participants on a range of variables, examining the outcomes for significant changes.

Our Research Questions

We used the following questions to guide our research:

- *What were the relationships between the assessed levels of comfort with teaching STEM, efficacy for teaching STEM, pedagogical discontentment, and implementation of inquiry instruction?*
- *Were there any relationships between the participants' personal characteristics and their comfort with teaching STEM, perceptions of efficacy for teaching STEM, pedagogical discontentment, and implementation of inquiry instruction?*
- *Were there significant changes in the participants' levels of comfort with teaching STEM, perceptions of efficacy for teaching STEM, pedagogical discontentment, and implementation of inquiry instruction?*
- *Were there significant changes in the participant's content knowledge?*
- *What were the participants' perceptions of STEM education and their implementation of STEM in their educational settings, and did these perceptions change from pre- to post-institute?*

Participants

Our research participants were educators who voluntarily registered for the i-STEM summer institute. A call with open registration was issued to educators throughout the state. Although the program specifically targeted educators in grades 4–9, the participants were expected to register as part of a team, which we left up to participants' discretion to define. As a result we had educators representing a broad spectrum of K–12 education. We had 239 preregister for the institute; however, only 229 attended the four-day gathering. Further, while over 180 of our participants completed our post-survey, only about half of the participants completed all surveys pre and post using the same unique identifier. Therefore, our demographics and post-institute analysis are based on the 123 participants who completed all surveys, pre and post, using the same unique self-selected five digit code.

Our participants were on average 42.21 (S = 10.69) years old, had been teaching an average of 12.35 (S = 9.39) years, and had taken an average of 4.28 (S = 1.58) college level science classes and an average of 4.01 (S = 1.61) college level mathematics classes. Females made up 80% of the participants, while 84.2% of the participants were from urban or suburban communities. Teachers from K–5 or K–6 schools made up 39% of the participants, with middle school teachers representing 28%, high school teachers representing 7.5%, and the remaining 25.5% coming from K–8, K–12, and alternative schools. The majority (58.9%) of the participants majored in elementary education, with the remainder holding degrees in various domains, most of which were related to STEM, including instructional technology and health education. Thus, the participants in our study were widely diversified, which is consistent with the populations of teachers found in most primary and secondary schools.

Data Collection Instruments

Demographics. To assess our participants' professional characteristics, we developed a demographics instrument based on the information we determined to be salient to our research questions. Included were standard items such as age, gender, and ethnicity. In addition, we included the items necessary to determine the grade level our participants taught, their college majors, the configuration of their schools and community settings, and the number of college level math and science courses they had completed.

In our demographics survey, we included a single item in which we asked participants to rate their comfort with teaching a STEM curriculum on a 10 point scale with 1 representing "Very Uncomfortable" to 10 representing "Very Comfortable." Items similar to these have been used in prior research and have generated data that were highly correlated with the outcomes from instruments used to measure the same construct or variable with established reliability and validity (Nadelson & Sinatra, 2009).

Perceptions and practices of STEM teaching. To determine the participants' perceptions and practices of STEM teaching we developed a six-item free response survey. We wanted to collect data that would allow us to establish how the participants defined STEM, how they collaborated to teach STEM, their motivation to teach STEM, their engagement in STEM professional development, the nature of their implementation of STEM curriculum, and the influence access to resources had on their decisions to teach STEM. These questions were generated by a committee assembled to develop the i-STEM summer institute. The items were grounded in the extensive discussions of the potential barriers to teaching STEM and the related activities and topics of the institute that were chosen to address these hindrances. Items asked participants to respond to questions such as, "How do you define STEM?" and "How do you collaborate with others when teaching STEM content?" and "What kind of social/professional networking do you engage in to gain support for teaching STEM content?" The participants were instructed to provide the detail necessary to allow us to fully understand their perspectives.

Pedagogical discontentment. To assess our participants' pedagogical discontentment in teaching STEM, we modified the 21-item Science Teachers' Pedagogical Discontentment Scale (STPDS) (Southerland, Nadelson, Sowell, Kahveci, Saka & Granger, under review). The intended use of this instrument is to determine the effectiveness of professional development for decreasing discontentment with teaching science. The STPDS asks takers to rate their level of pedagogical discontentment on a five-point Likert scale, reacting to items such as *"Teaching science to students of lower ability levels."* The scale ranges from "1" representing *"no discontentment"* to "5" representing *"very high discontentment."* The STPDS does have six subscales, which can be examined separately or aggregately. We modified the scale by replacing the word "science" with "STEM" to create items such as, *"Teaching STEM to students of lower ability levels."* Many of the items, such as *"Monitoring student understanding through alternative forms of assessment"* required no modification. Southerland and colleagues established the validity of the instrument through interviews with science teachers and feedback from teacher professional development experts. The reliability of the instrument was established to have a .93 Cronbach's alpha with the subscales Cronbach's alphas ranging from .77 to .89, which indicates a good to high level of instrument reliability.

Inquiry implementation. To assess our participants' instructional practices with inquiry implementation, we used a modified version of the Inquiry Science Implementation Scale (ISIS) (Brandon, Young, Pottenger, & Taum, 2009). The instrument instructs users to respond to the prompt, *"When you teach science, how frequently do you:"* for each of the 22 items. The items include statements such as, *"demonstrate the use of a new instrument?"* and *"ask students to make predictions about an experiment?"* Participants rate their perception of their implementation on a five-point Likert scale ranging from "1" representing *"never"* to "5" representing *"always."* We modified this scale by adjusting the stem prompt to read *"When you teach STEM, how frequently do you:"* but did not change the scale questions. The instrument has established validity and a Cronbach's alpha reliability of .89, which was established using samples of inservice teachers.

Efficacy for teaching STEM. To assess our participants' perceptions of their effectiveness for teaching STEM, we modified the *Science Teaching Efficacy Belief Instrument* (STEBI) (Riggs & Enochs, 1990). This 25-item instrument uses forward and reversed phrased items to assess teachers' perceptions of their efficacy for teaching science. Participants rate their beliefs on a five point Likert scale ranging from "1" representing *"Strongly Disagree"* to "5" representing *"Strongly Agree"* responding to items such as, *"I am continually finding better ways to teach science"* or reversed phrased items such as, *"I am not very effective in monitoring science experiments."* We made modifications to some of the STEBI items to reflect a more general focus on STEM, rewriting items such as, *"Increased teacher effort in teaching science produces little change in some student's science achievement"* to read *"Increased teacher effort in teaching STEM content produces little change in some student's STEM learning achievement."* The modified version of the instrument was used with elementary level teachers and achieved an internal reliability alpha of .85 (Nadelson, Callahan, Pyke, Hay,& Schrader, 2010) indicating a good level of instrument reliability.

Data Collection Process

All data collection took place on-line using a web-based survey site. The participants were instructed to use the *"same last five digits of any phone number"* as a unique code for all surveys so that their responses could be tracked. Prior to the summer institute all participants were sent an e-mail requesting they complete the surveys before they arrived at the summer institute and the URL link to the surveys. We developed the surveys so that they had to be taken in sequence and concluded with a completion verification page which the participants were instructed to print and bring with them to the institute at registration to document they completed the pre-surveys. We had computers available at registration for those who had not completed the surveys to do so on site prior to the start of the institute.

The participants were post-tested in a similar fashion. A link to the survey sites was sent to all participants with a request to complete the surveys within two weeks after the close of the summer institute. Over the next four weeks, reminders to complete the surveys were emailed out to the participants. We provided the extended timeline to complete the post-institute surveys to increase the likelihood that the participants took time to provide accurate and complete answers.

Pre and post testing of the participants' content knowledge took place in their content strands with the tests administered by their content strand providers. Again the participants were instructed to use the same last five digits of any phone number they could remember as a unique identification code. To assure matching of pre and post survey results, we gathered demographic data pre and post to allow for another level of pairing data by the self selected five digit code.

The Summer Institute

We planned our intensive four-day residential summer institute to have about 32 hours of instruction, 4 hours of planning, 6 hours of networking, and unstructured time for socializing. The instruction was composed of a combination of plenary lectures, panels, and presentations and 20 hours' content/domain specific strands exploring some theme integrating STEM (e.g., energy, space, the human body, placer mining, mathematical thinking, materials science, and others). Between the two institute locations we offered 14 strands. The strands varied widely in content and were selected from applications submitted by individuals or organizations wanting to conduct a workshop to strategically represent a spectrum of STEM topics. Consistent to all content strands was a focus on inquiry, integrating STEM curriculum, integrating the content into the current 4–9 curriculum, effective STEM pedagogy and best practices, using the instructional materials that were introduced in the strands, and assessment of student learning.

As mentioned previously, all grade 4–9 teachers in the state were encouraged to apply to be participants in the summer institute, and were expected to register as part of a team. The idea was to establish the participants in professional learning communities that would continue to support the development and implementation following the summer institute. Our thought was the team would also be effective for sustaining participant engagement in discussion and reflection on teaching STEM curricula.

The institute was supported by a grant and matching funds that allowed us to cover the cost for meals and lodging, travel, two continuing education college credits, no more than about $300 worth of content strand related instructional materials, and a stipend for attending the conference for each of the educators attending the summer institute. We also financed the time and expenses of the strand providers and conference presenters.

The contents of the 20-hour themed strands were dependent on the proposals submitted by the individuals or organizations applying to be strand providers, and were selected according to the perceived potential to fulfill our established standards of quality and content. Once selected, the providers submitted a syllabus, a classroom "kit" of up to $300 of supplies needed to implement the strand curriculum that was distributed to each of the strand participants, and a pre/post test of content/subject knowledge covered in the strands. Each strand had about 15–20 participants and met daily for approximately 5 hours evenly divided between morning and afternoon. During this time the participants explored the content through lab activities, field trips, and presentations.

Results

We began our analysis by determining the reliability of our instruments. We calculated the Cronbach's alpha for each measure using the pre-test scores ($N = 229$). For the inquiry implementation measure the alpha was .97, for the pedagogical discontentment survey the alpha was .93, and for the perceptions of efficacy for teaching STEM the alpha was .83. All reliability scores were at the good to high levels of acceptability, indicating we could proceed with our analysis under the assumption that the instruments we used to gather our data performed consistently.

Our first research question asked: *What were the relationships between the assessed levels of comfort with teaching STEM, percep-*

	Perceptions of STEM Teaching Efficacy	Inquiry Implementation	Pedagogical Discontentment	Comfort With Teaching Stem
Perceptions of STEM Teaching Efficacy	--	.51**	-.27**	.41**
Inquiry Implementation		--	-.02	.17
Pedagogical Discontentment			--	-.35**
Comfort With Teaching Stem				--

* $p < .05$, ** $p < .01$

Table 1. Correlations between Study Measures

tions of efficacy for teaching STEM, pedagogical discontentment, and implementation of inquiry instruction? To answer this question we conducted a correlational analysis using the pre-test scores for comfort with teaching STEM, perceptions of efficacy for teaching STEM, pedagogical discontentment, and inquiry implementation (see Table 1). We used the pre-test scores because the summer institute was designed to attend to these variables, and thus the post-test values may be less representative of the ecology of K–12 teacher perceptions, comfort, discontentment and inquiry implementation. Additionally, we anticipated that the individual differences of teachers needs would likely result in differential shifts in our measures.

Our results revealed significant ($p < .01$) positive relationships between our participants' perceptions of their STEM teaching efficacy, inquiry implementation, and comfort with teaching STEM, such that when levels of efficacy increased so did levels of inquiry implementation and comfort with teaching STEM. We also found a significant ($p < .01$) negative relationship between the participants' perceptions of their STEM teaching efficacy and pedagogical discontentment, such that when levels of efficacy increased levels of pedagogical discontentment decreased. Our analysis exposed one other significant ($p< .01$) relationship between pedagogical discontentment and comfort with teaching STEM, which was negative, such that as levels of pedagogical discontentment increased the levels of comfort decreased. No relationships were found between inquiry implementation, pedagogical discontentment, and comfort teaching STEM.

Our second research question asked: *Were there any relationships between the participants' personal characteristics and their comfort with teaching STEM, perceptions of efficacy for teaching STEM, pedagogical discontentment, and implementation of inquiry instruction?* To answer this question we conducted a combination of correlation analysis (for ordinal or ratio data) and cross tabs (for nominal data) to determine any relationships. Our analysis revealed a significant correlation between comfort with teaching STEM and the number of college level science courses ($r = .21$, $p < .05$) and the number of college level mathematics courses ($r= .22$, $p < .05$). The found relationship indicates that as the participants took more college level science or math courses the experience increased their comfort level for teaching STEM. We also found a significant correlation between the number of college level science courses and pedagogical discontentment ($r = -.24$, $p < .01$), such that as participants took more science courses their pedagogical discontentment decreased. We found no other significant associations between personal characteristics and our measured variables.

Our third research question asked: *Were there significant changes in the participants' levels of comfort with teaching STEM, efficacy for teaching STEM, pedagogical discontentment, and implementation of inquiry instruction?* To conduct this analysis we conditioned our data matching all pre-test scores to post-test scores on the five-digit phone code that was provided by each of the participants on all measures. As mentioned previously, 229 of our participants completed the pre-tests and over 180 partici-

Measure	Pre M	Pre SD	Post M	Post SD	t-test t	Sig.(2 tail) p
Comfort Teaching STEM *(10 point scale)*	5.62	2.45	7.89	1.55	10.94	<.01
Pedagogical Discontentment *(5 point scale)*	2.09	.63	1.78	.53	-6.26	<.01
Inquiry Implementation *(5 point scale)*	3.62	.82	4.01	.57	5.72	<.01
Efficacy for Teaching STEM *(5 point scale)*	3.45	.35	3.67	.36	6.27	<.01

Table 2. Means, Standard Deviations, T-Test Scores, and Level of Significance for the Study Measures

pants completed the post tests, but after conditioning to match pre-post institute scores of all measures, our sample size was reduced to 124 participants. Following the data conditioning we conducted a series of pair samples t-test, using pre and post-test scores. Our analysis revealed significant increases in perceptions of inquiry implementation ($p < .01$), comfort with teaching STEM ($p < .01$), and perceptions of efficacy for teaching STEM ($p < .01$), and significant decreases in pedagogical discontentment ($p < .01$). The means, standard deviations, t-test scores, and p-values are presented in Table 2. Recall that for our measures we used a 5-point Likert scale, with the exception of our comfort measure for which we used a 10-point scale.

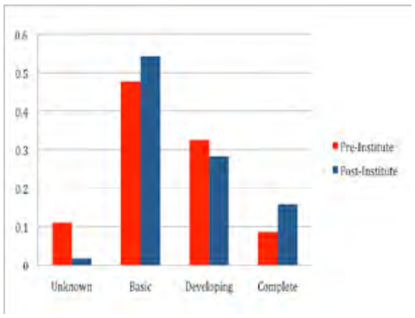
In addition to the changes in the participants as a whole, we also analyzed our data to determine whether there was a change differential based on the level of science or math classes our participants had previously taken. To determine this relationship, we conducted a correlational analysis using number of college level mathematics and science courses and pre-test post-test differences for our measures of inquiry implementation, perceptions of efficacy for teaching STEM, comfort teaching STEM, and pedagogical discontentment for teaching STEM. Our analysis failed to reveal any relationships or differential effects based on the number of college level mathematics or science courses and the change in inquiry implementation, perceptions of efficacy for teaching STEM, comfort teaching STEM, and pedagogical discontentment for teaching STEM

Our fourth research question asked: *Were there significant changes in the participants' content knowledge?* To answer this question, we examined the pre-test and post-test content knowledge tests from each of the strands. Although it would have been valuable to compare the change in the participants' content knowledge between strands, there were too many inconsistencies between the content knowledge assessments. We exposed variations in the subject matter covered in the content between strands; the format of the content knowledge assessments; the depth of the content knowledge being taught and examined; and the alignment of the content assessment with the strand curriculum. These variations signified that comparison of content tests between strands would have been fraught with fidelity issues and would have produced meaningless results. Therefore, we examined the pre-post content knowledge assessments only within the context of the strands in which the assessment took place.

Overall, comparisons of the pre and post strand content knowledge tests by strand revealed significant increases in the teachers' knowledge and understanding of the STEM concepts explored in each of the strands. For example, in the *STEM and the Human Body* strand the average pre-test score for the 13 participants was about 36% correct (on the 25-item test) and about 99.6% correct post test, a significant increase ($t = 11.27$, $p < .01$). These results trend throughout the institute strands, indicating that the participants experienced significant gains in their STEM content knowledge due to their engagement in the summer institute.

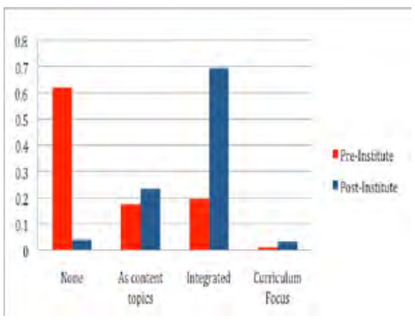
Our fifth research question asked: *What were the participants' perceptions of STEM education and their implementation of STEM in their educational settings, and did these per-*

How would you define - STEM?



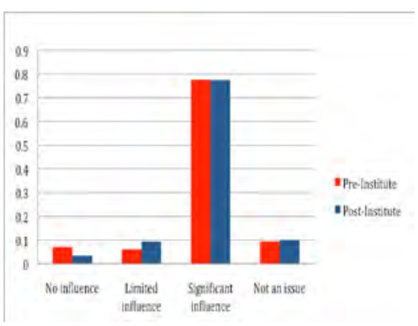
Unknown	I am not familiar with STEM.
Basic	Science, technology, engineering, math education
Developing	Science, Technology, Engineering, and Math. An integration of these elements together in any of these classes/content areas.
Complete	The focus of STEM education is: science, technology, engineering, and math. It is an approach to instruction that melds the four into techniques and presentations which capture student interest and motivation. It connects today's world with tomorrow's leaders via teachers who are versed and eager to encourage students in the four domains through their natural curiosity of the world. I hope.

Describe your implementation of STEM curriculum.



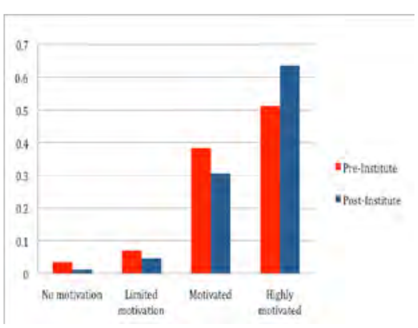
None	I'm just learning what the STEM curriculum is, so I haven't implemented it yet.
As content topics	Very basic math of measurement, genetics, etc., and basic computer technology.
Integrated	I use STEM curriculum for labs and demonstrations to show my students real world applications of what they are learning.
Curriculum Focus	Working at a math and science magnet, I try to integrate science and mathematics throughout the curriculum.

How does access to education/instructional resources influence your teaching of STEM?



No influence	It doesn't.
Limited influence	Very little. It is all new to us.
Significant influence	When a teacher has access to those resources, teaching is more educational. The students learn and remember more with hands-on material.
Not an issue	We seem to always have enough resources at hand.

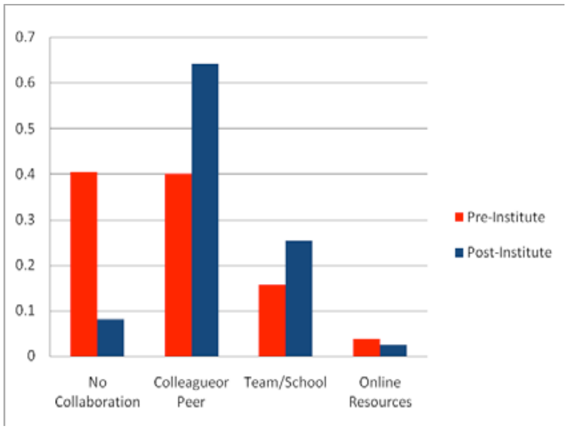
Please describe your level of motivation for teaching STEM.



No motivation	Very low. I am only certified to teach life sciences, so have a weak background in physical science, chemistry and math.
Limited motivation	My level of motivation for teaching Stem is minimal. Due to lack of understanding of what it entails.
Motivated	I think it is important to use STEM to better prepare children for a future where STEM concepts are so critical - motivated.
Highly motivated	VERY Excited! I would like to implement cross-curriculum in my classroom using the STEM areas of study.

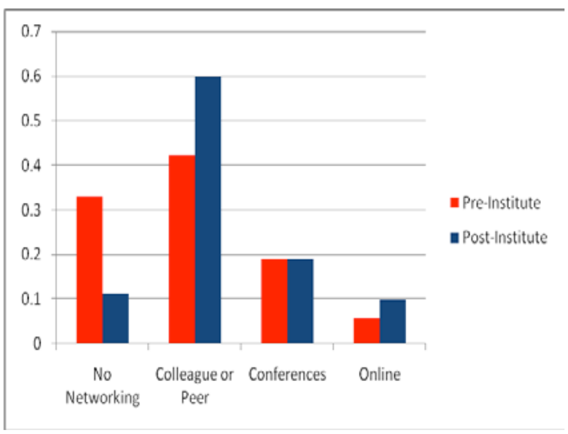
Figure 1. The responses to four (of the six) free response items ranked according to the quality for both pre (red) and post (blue) institute.

How do you collaborate with others when teaching STEM content?



No Collaboration	At this point, I do not.
Colleague or Peer	I work with the other science and math teachers of my students to coordinate instruction and content.
Team/School	Weekly meetings discussing standards and developing meaningful hands on lessons
Online Resources	Online using email and shared online courses

What kind of social/professional networking do you engage in to gain support for teaching STEM content?



No Networking	I never have before.
Colleague or Peer	Working with other teachers in the school and district you work in, and working with people in the community who have jobs and or background in these areas.
Conferences & Classes	I attend i-STEM and other learning opportunities like Out of the Rock [Extremely awesome class].
Online	I receive the NCTM magazine online.

Figure 2. The responses to our items assessing collaboration and networking practices to prepare and implement STEM curriculum pre (red) and post (blue) institute.

ceptions change from pre to post institute? To answer this question we initially classified the items of our *Perceptions and Practices in STEM Education* instrument into two groups, one containing items in which responses were classified as ordinal and the other in which the responses were considered nominal. We then created a coding scheme through a post-hoc content analysis (Creswell, 2009) of the responses to items. Our post-hoc coding of each of the items revealed variations in responses and at the same time exposed classifiable consistencies. Recognizing the item specific response variations and potential to capitalize on the observed consistencies, we developed a series of rubrics to rank and categorize the responses for each of the instrument items. Our goal with this analysis was not to conduct a quantitative analysis of the results but rather to expose trends and shifts in the responses.

Ordinal response group. For the ordinal group of items, we structured our classification rubrics such that "0" represented very low-quality explanation, no knowledge, or no engagement responses such as "I don't know" or "Nothing". Responses were ranked as a "1" if the participant answers conveyed minimal quality explanation, low knowledge, or low engagement. We ranked responses as a "2" if the participants' replies communicated moderate explanation quality, moderate knowledge, or moderate engagement. Participant responses were ranked as "3" if they conveyed high-quality explanations, high levels of knowledge, or high levels of engagement. The results of our ranking for pre- and post-institute are presented in

Figure 1 along with examples of responses that corresponded to each level of our rating rubric.

The outcome of our analysis of our ordinal item group revealed that the participants' post-institute responses tended to shift toward higher quality explanations, increased knowledge levels, and increased levels of engagement when compared to the pre-institute responses. The exception was the item asking the participants to detail how access to resources influenced their ability to implement STEM curriculum, which did not seem to experience shifts in responses. The largest shifts in response were exposed for the items requesting participants to describe their collaboration and to detail their implementation of STEM curriculum.

Although we were able to detect increases in the quality of explanation, knowledge, or engagement of the responses for three of the four items, the post-test responses to some items tended to remain predominantly at the lower end of the spectrum. For example, the responses to the items assessing how the participants defined STEM was revealed to essentially shift only one level on our rubric. Our results indicate that the participants experienced a differential development in their explanations, knowledge, and engagement in STEM education.

Nominal response group. The two items that we classified to be associated with nominal responses assessed the nature of our participants' collaboration and networking practices as they engage in STEM teaching. We again conducted a post-hoc analysis of the responses to form a response classification rubric used to categorize the nature of our participants' conveyed collaboration and networking practices. We found considerable overlap in our participants' methods of networking to gain support to prepare to teach STEM and for collaborating when they teach STEM. Thus, we formed four categories to reflect the predominant methods participants indicated that they used to collaborate or network. These methods included no collaboration or networking, person to person, group interactions, and internet based. As we coded our participants' responses we encountered situations in which participants responded with more than one mode of collaboration. In these situations, we choose to classify the responses using the mode that dominated the response. The classification groupings, corresponding examples, and the categorization result pre- and post-institute are presented in Figure 2.

Our analysis revealed substantial shifts from no networking or collaboration to colleague or peer collaboration or team collaborations. However, there was little change in the use of conference and online resources to network to gain support for teaching STEM, and little change in the use of online resources for networking to teach STEM. Overall, there was a trend toward increased engagement in collaboration and networking, with substantially more participants detailing ways of working with others post-institute when compared to their pre-institute responses.

Discussion

The goal of this project was to provide a professional development opportunity for teachers to enhance their STEM content/subject matter knowledge, their comfort with teaching STEM, perceptions of efficacy for teaching STEM, pedagogical contentment related to teaching STEM, and use of inquiry for teaching STEM. The anticipated relationships between these constructs and variables provided the justification for developing, implementing, and assessing professional development opportunities that attend to affective and cognitive elements that influence teacher effectiveness for teaching STEM (Appleton, 1995; Darling-Hammond & Bransford, 2005; NRC, 2007) which we applied in the context of teaching STEM.

Our results revealed perceptions of efficacy for teaching STEM to be related to comfort with teaching STEM, pedagogical discontentment with teaching STEM, and inquiry implementation. This association provides warrant for addressing a wide range of affective and pedagogical constructs when working to increase teacher efficacy for teaching STEM. We posit that the focus of our summer institute on increasing the participants' comfort with teaching STEM, pedagogical contentment with STEM, and knowledge of how to implement inquiry to teach STEM led to increased teacher efficacy within the domain. Our results provide further support for considering the complex interactions among variables that can influence teachers' perceptions of efficacy.

It is interesting to note that even though inquiry implementation, pedagogical contentment, and comfort were associated with efficacy, they were not found to be significantly associated with each other. The lack of relationships among these variables and the significant association with efficacy provides further support for the multifaceted nature of teacher efficacy, and reinforces the need to address a wide range of variables to assure growth in teachers' perceptions of their effectiveness. Further examination of the variables related to efficacy for teaching STEM reveals multiple aspects pertaining to pedagogy and affective states that are arguably unrelated to each other but associated with teachers' perceptions of their effectiveness (Guskey, 1988; Tschannen-Moran, Woolfolk Hoy, & Hoy, 1998). The association of efficacy perception with measures of comfort, implementing inquiry, and pedagogical discontentment, and the lack of a detectable association between these variables, is certainly an area worthy of deeper examination, particularly in the context of inservice teachers involved in professional development to teach STEM.

Our analysis exposed a relationship between the number of college level math and science courses a participant had taken and his or her comfort with teaching STEM. We also detected a relationship between the number of science courses and pedagogical discontentment with STEM. These relationships reinforce the importance of attending to content or subject matter knowledge in efforts to increase teacher pedagogy associated with teaching STEM. In other words, as teachers learn more about science and math concepts, they feel more comfortable teaching STEM. Although this may seem obvious, there is continued debate regarding the impact more content knowledge has on teacher effectiveness (Darling-Hammond & Bransford, 2005), and yet our results indicate that comfort or contentment with teaching STEM is related to teachers' perceptions of their efficacy. However, the lack of associations with our measure of pedagogical discontentment, teacher perceptions of their efficacy, and implementing inquiry does raise questions regarding the influence content knowledge has on effective teaching. The relationship between coursework related to STEM and teacher perceptions of their preparation to teach the concepts is an association that warrants on-going investigation.

Our results revealed significant increases in our participants' comfort for teaching STEM, their perceptions of inquiry implementation, their perceived efficacy for teaching STEM, and a significant decrease in pedagogical discontentment. In addition, the participants also expressed significant increases in content/subject matter knowledge. These findings indicate that our professional development intervention was effective at modifying our participants' perceptions and conceptions of teaching of STEM, while increasing their STEM content/subject matter knowledge. The shift in perceptions of teaching STEM along with content/subject matter knowledge of STEM provides further support for the influence professional development can have on an array of variables related to teaching. The ability of our professional development intervention to significantly influence a wide range of variables may be attributed to the integrated structure of the institute, which was designed to attend to a wide range of educational needs and teacher preparation. The ability of a four-day intensive professional development intervention to bring about change in these variables provides the justification for offering these opportunities to teachers, for our data suggests the experience can be transformative in multiple ways.

The final finding indicated that the participants experienced shifts in their perceptions and conceptions of STEM education. The positive shift in perceptions and conceptions of STEM education was made evident by the increase in the quality of explanations, level of knowledge, and levels of engagement conveyed in the answers to the free response questions. The outcome of our analysis suggests that our professional development intervention influenced how the participants defined, planned for, and perceived how they implement STEM education. The substantial increase in the level of sophistication of the responses indicates the intervention was effective for increasing perceptions of engagement and knowledge of STEM. Perhaps the most promising result was the substantial increase in motivation for teaching STEM, which may be attributed to the participants' increased content/subject matter knowledge and perceptions of their ability to teach STEM.

The notable shift in the responses associated with the networking and collaboration to implement STEM curriculum items may be directly linked to the themes and structure of the conference that explicitly addressed teaming, planning, and engagement in collaborative activities. We posit that the structured planning time in the summer institute facilitated the transfer of knowledge of engagement in communication and collaborative processes to the context of STEM, suggesting that teachers benefit greatly when provided with opportunities to apply familiar processes in the context of innovations. Although the influence of the institute seems apparent, there may be nuanced influences of professional development activities that lead to substantial shifts in some perceptions and minor shifts in others. Exploration of the subtle and substantial influences of intensive professional development activities may be a fruitful direction for future research. Future exploration of teacher transfer of knowledge and skills to new contexts or implementations of innovations is critically important to gaining a greater understanding of these relationships.

The following summary of lessons learned from our summer institute may be beneficial to other professional development providers as they structure and implement continuing education opportunities for K–12 educators. Perhaps the most significant lesson learned was the importance of having the participants register and attend our professional development offering as teams. The collegiality apparent in the planning and the informal discussions that took place during the institute suggests that teams are an essential structure for enhancing the success of professional development endeavors. Further, we attribute the increase in teacher perceptions, preparation, and confidence to teach STEM to the wide variety of content presented in our summer institute, combined with the concentration on specific STEM strands, which together enhanced general knowledge of STEM. Thus, when structuring STEM continuing education opportunities for teachers based on our lesson learned, we recommend that professional development providers consider a wide range of experiences and content along with specific areas of concentration, as we perceive this will enhance a range of knowledge and affective variables associated with teacher preparation to teach STEM.

Limitations

Although we had a rather large sample for our analysis (N = 124), only a little over 50% of the participants' responses could be accounted for, leaving almost half of our participants out of our pre- to post-institute analysis. Although it is unlikely, we cannot be sure that the inclusion of the responses from the unaccounted-for participants would not have shifted the results of our data. A second limitation was the nature of the data collection. Even though most of our study instruments had established validity and reliability, our study was still constrained by the limitations associated with self-report and selected response data. However, our participants' responses appeared to be consistent with expected outcomes and the anticipated impact of the professional development, suggesting that the findings are likely representative of the influence of the intervention on the participants. The third limitation was the configuration of our study population. The participants in our study were a self-selected group with interests in improving their STEM education knowledge and teaching, and therefore may not be representative of the larger teacher population. Additional research with a broad selection of teachers with a wider range of interest in and motivation for increasing their STEM teaching capacity may be needed to fully substantiate our findings. The limitations of our study provide excellent contexts and directions for future investigation in this line of STEM education research.

Conclusion

As national STEM education initiatives develop and are promoted, such as Change the Equation, it is critical that the educational community respond to determine the most effective way to address the goals of these endeavors. The intention of our professional development summer institute was to build upon the extant literature on enhancing teacher capacity and effectiveness to teach STEM by attending to their content knowledge and affective perceptions in the context of STEM teaching and learning. Our results indicate significant gains in the participating teachers' perceived efficacy, comfort, contentment, and knowledge related to STEM education. These results support the effectiveness of our intervention in increasing teacher capacity to teach STEM and providing a model for others seeking to respond to calls for enhancing the quantity and quality of STEM education.

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