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A SySTEMic Solution: Elementary Teacher Preparation in STEM Expertise and Engineering Awareness

Louis S. Nadelson
Boise State University

Janet Callahan
Boise State University

Pat Pyke
Boise State University

Anne Hay
Boise State University

Cheryl Schrader
Boise State University

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Louis Nadelson, College of Education

Louis S. Nadelson is an Assistant Professor in the College of Education at Boise State University. His research agenda is motive by science education and includes aspects of conceptual change, inquiry, and pre-service and in-service teacher education. He has investigated learning for conceptual change and the impact of inquiry on modifying misconceptions. Dr. Nadelson earned a B.S. degree in Biological Science from Colorado State University, a B.A. with concentrations in computing, mathematics and physics from The Evergreen State University, a Secondary Teaching Certificate from University of Puget Sound, an M.S. Ed. in Educational Administration from Western Washington University and a Ph.D. (research-based, not theoretical) in Educational Psychology from the University of Nevada, Las Vegas.

Janet Callahan, Boise State University

Janet M. Callahan is the Associate Dean for Academic Affairs at the College of Engineering at Boise State University and a Professor in the Materials Science and Engineering Department. Dr. Callahan received her Ph.D. in Materials Science, her M.S. in Metallurgy and her B.S. in Chemical Engineering from the University of Connecticut. Her educational research interests include freshmen engineering programs, math success, K-12 STEM curriculum, and recruitment and retention issues in engineering.

Pat Pyke, Boise State University

Patricia A. Pyke is the Director of Education Research for the College of Engineering at Boise State University. She oversees research projects in freshman programs, math support, mentoring, K-12 STEM, and women's programs. She earned a B.S.E. degree in Mechanical Engineering from Duke University and a master's degree in journalism from the University of California, Berkeley.

Anne Hay, Boise State University

Anne Hay is the Coordinator of the Idaho SySTEMic Solution, a K-12 research project at Boise State University funded by the U.S. Department of Education. Ms. Hay has more than 25 years of teaching experience in K-12 through college programs, teaching German, English as a foreign language, biology, general science, life science, ecology and music. She received a B.A. and an MS in biology from Stanford University and a Teaching Credential from the University of California, Berkeley.

Cheryl Schrader, Boise State University

Cheryl B. Schrader is Dean of the College of Engineering and Professor of Electrical and Computer Engineering at Boise State University. Dean Schrader has an extensive record of publications and sponsored research in the systems, control and engineering education fields. Recent recognition related to this work includes the 2005 Presidential Award for Excellence in Science, Engineering and Mathematics Mentoring from the White House and the 2008 IEEE Education Society Hewlett-Packard/Harriett B. Rigas Award. Dean Schrader received her B.S. in Electrical Engineering from Valparaiso University, and her M.S. in Electrical Engineering and Ph.D. in Systems and Control, both from University of Notre Dame.

A SySTEMic Solution: Elementary Teacher Preparation in STEM Expertise and Engineering Awareness

Abstract

Research shows that most K-5 teachers are typically required to complete only minimal coursework in science and mathematics, which constrains their knowledge, efficacy, and confidence for teaching STEM (Science, Technology, Engineering and Math) content. Additionally, elementary teachers, like much of the general public, have limited comprehension about the relationship between STEM concepts and engineering fields and the kind of work and societal contributions made by engineers. Yet, elementary school is a critical time in which students develop foundational understanding of STEM concepts, career options, and inquiry learning.

To address students' STEM needs and limited teacher preparation, the *Idaho SySTEMic Solution* research project was implemented by the College of Education and College of Engineering at Boise State University, in partnership with the Meridian Joint School District and educational products and services company PCS Edventures! Funded by the U.S. Department of Education, the *Idaho SySTEMic Solution* is a STEM education initiative designed to advance achievement and confidence among elementary-age learners and their teachers. Phase I of the *Idaho SySTEMic Solution,* which is the subject of this report, focuses on teachers, with the goal of increasing their STEM content knowledge, instructional practices, awareness of engineering, and overall confidence for teaching STEM concepts. Phase I began with a three-day summer institute for 39 elementary teachers at seven schools representing socioeconomic diversity in the largest school district in Idaho.

To measure the results of the workshop, several data collection methods were utilized, for pre- and post-intervention assessment. Repeated measures analyses revealed significant teacher increase in confidence to teach STEM curriculum ($p < .01$), positive increase in engineering attitudes ($p < .01$) and increase in STEM teaching efficacy ($p < .01$) over the course of the three-day workshop. We attribute these changes to the content and context of the workshop instruction.

Introduction

Can three days of activities have a profound impact on how we perform in our professional capacity? It is a common expectation that K-12 teachers will engage in relatively brief professional development courses or workshops with the anticipation that the exposure to activities and content will improve their capacity to teach. Is this a realistic expectation? As most have experienced and would contend, learning takes time.[1] This is particularly true when learning content that is unrelated to prior knowledge.[1, 2] Maintaining this perspective would suggest that brief interventions are unlikely to achieve the desired goals of increased knowledge, comprehension, and retention of new or ambiguous content. However, research also shows that engaging in tasks that are relevant, novel, and applicable increase learner motivation which can lead to a greater probability that a relatively brief instructional intervention can result in significant learning.[1, 2] Capitalizing on the potential for learning associated with situations that are relevant, novel, and applicable, we developed a three-day workshop for elementary teachers to prepare them to teach inquiry based STEM curriculum using manipulatives, specifically PCS BrickLabs®, (Lego®-like building blocks). a tub of more than 5,000 plastic construction bricks and related curriculum.

Project Goals

We had several goals for the workshop. *The primary goal was to increase the capacity of our participating inservice elementary school teachers to teach STEM concepts*. Elementary school teachers are at the head of the STEM education pipeline. It is in elementary school that students build their foundation for STEM achievement and their subsequent potential for selecting STEM related careers.[3] Therefore, elevating teacher comfort and experience,[4] attitude toward,[5, 6] and efficacy for teaching STEM curriculum,[7-9] is critical for assuring students acquire fundamental knowledge and attitudes that are necessary for high levels of STEM achievement and increases in STEM career selection. This is perhaps most critical for engineering because of the challenges related to meeting the high demand for professionals in the associated fields.[10, 11]

The desire to increase the number of professionals entering STEM professions, and in particular engineering, motivated our *second goal – to impress upon the participants that engineering should be viewed as a creative process involving the application of science, technology, and mathematics in finding solutions to challenges affecting society, technology and environment worldwide.* Associated with this goal was an anticipated need to elevate the teachers' perceptions and awareness of engineering as a career. We predicted that the teachers would hold similar conceptions of engineering as the general public.[12] Holding constrained conceptions or misconceptions of engineering most likely hampers a teacher's ability or desire to encourage students to consider or pursue careers in engineering. Therefore, we determined it was fundamental for the workshop to address the participants' misconceptions and limited perceptions of engineers and engineering.

A third more specific goal was to prepare the participating inservice teachers to teach STEM curriculum using inquiry instruction and the PCS BrickLab® manipulatives. Inquiry has become a major emphasis in STEM curriculum and learning standards.[4, 13-15] However, most elementary teachers typically have had to complete only two college level courses in mathematics and two in science to meet the requirements for their certification.[16] Elementary teachers' limited exposure and engagement in STEM curriculum and instruction most likely constrains their understanding and awareness of the effective use of inquiry and manipulatives when teaching STEM. Therefore, preparing teachers to teach STEM content using inquiry and manipulatives may require a significant change in teacher education curriculum, or opportunities for teachers to gain understanding, preparation, and experience with inquiry and manipulatives through professional development. The immediacy of the needs of inservice teachers to effectively teach STEM curriculum supports the justification of our goal to enhance the abilities of our participants to successfully teach STEM using inquiry and manipulatives through a professional development opportunity.

These goals guided our development of the Idaho SySTEMic Solution. The Idaho SySTEMic Solution is a year-long project that began with a three-day workshop and has continued through the school year with extensive educational outreach and support. This report is limited specifically to the evaluation of the Phase I summer workshop. As we planned for the evaluation of our summer workshop it became apparent that the assessment of our goal attainment was not going to be immediately achieved. The assessment of the influence of the workshop on increasing the quality and quantity of STEM content being taught by the participating teachers is a longer term process. (We are currently in Phase II of SySTEMic where we are assessing teacher proficiency and confidence for teaching STEM topics using inquiry and project based learning.) For Phase I we were interested in assessing how our summer workshop might influence the participants' capacity for teaching STEM curriculum. This begged the question, how can we assess the influence of a short term intervention (three-day SySTEMic Solution workshop) on the participating teachers' perceptions, understanding, and willingness to teach STEM?

Variables Contributing to Teacher Effectiveness

To address this question we conducted a search of the literature to determine what factors have been found to be related to elementary teachers' effectiveness in teaching STEM content. Our search revealed a report by Parker and Heywood[17] espousing a relationship between the increase in understanding of science content and an increased knowledge of how to teach science. This suggests that an assessment of changes in STEM knowledge may be an effective indicator of teacher preparation to teach STEM. However, after discussing the use of direct measures of content knowledge we determined that the variations of STEM content and level of sophistication across grade levels[13] could potentially lead to variations in teacher attention to specific STEM content of interest or pertinence. Additionally, it would have been unrealistic, not to mention time-consuming and stressful for teachers, to administer exam style tests to assess teacher knowledge of mathematics and various science disciplines. Therefore, the potential confound due to variations in teacher attention toward subject knowledge and the complexity of trying to measure such knowledge justified the elimination of the assessment of any specific content knowledge as an appropriate or effective indicator for the effectiveness of our workshop for elevating teacher capacity to teach STEM content. This motivated us to identify variables that were ubiquitous to teachers and content, and reliable indicators of teaching quality and quantity.

Our continued search of the literature led us to a number of dispositional indicators that have been identified as being significantly related to the effective teaching of STEM. Efficacy in teaching has been reported to be a significant indicator variable related to teacher effectiveness and student success.[7, 8] Teaching efficacy has been linked to the amount of time teachers invest in teaching, their enthusiasm levels, and motivation to teach. Efficacy beliefs are of particular importance for success within the STEM domains.[18] This suggests we need to attend to the efficacy beliefs of elementary teachers to increase their chances for successfully teaching STEM related content. [19] We contend that an assessment of teacher efficacy is an appropriate measure for gathering evidence necessary to evaluate the effectiveness of professional development in elevating abilities to teach STEM content.

Similar to efficacy, teacher confidence for teaching STEM has been reported to be an important predictor of STEM teaching ability.[20, 21] Confidence is reported to be related to knowledge, such that low knowledge levels correlate to low confidence levels.[22] Jarrett asserts that teacher confidence for teaching STEM related concepts is influenced by a number of experiences with differential contributions. Jarrett reports that the greatest influences on teacher confidence for teaching STEM concepts emerges from their elementary education STEM experiences and exposure to STEM content in teacher education curriculum. The high influence of teacher education curriculum on confidence suggests that additional course work and professional development in STEM content can positively and significantly influence confidence for teaching STEM curriculum.[23] The relationship between teacher effectiveness, content knowledge, and confidence for teaching[24] provides justification for using a measure of teacher confidence to evaluate the effectiveness of professional development.

A general attitude toward STEM content has been found to predict the quality and quantity of teacher STEM instruction.[5, 6] Appleton[25] asserts that teachers with negative attitudes toward STEM content tend to avoid teaching STEM related content. Further, Tonsun[26] contends that attitudes toward STEM are potentially more influential on teaching STEM than subject knowledge. Similarly, Yilmaz-Tuzun[27] reports preservice teachers' STEM attitudes are significantly positively correlated with their STEM knowledge and confidence for teaching. Confidence has a compound effect because, as Deemer[28] details, the transfer of teacher attitude to their students which suggests a poor attitude toward STEM may be initiated and enhanced by teachers. Therefore, if teachers carry negative attitudes toward STEM content, they are likely to avoid teaching STEM concepts, probably will not feel comfortable teaching STEM topics, hold low efficacy for teaching STEM, and may transfer the negative attitudes to their students. Since attitudes toward STEM are an important indicator of quality and quantity of teacher STEM instruction, there is justification to assessing this construct with elementary teachers.

A National Academy of Engineering report[12] conveys that a majority of the public has well defined, yet uninformed, attitudes toward engineering. We argue that engineering is representative of applied science, mathematics, and technology. Therefore, a measure of attitude toward engineering is likely to be closely aligned with a more general attitude toward STEM. We claim that elementary teachers' engineering opinions and perceptions are likely to be consistent with the general public. Since public opinions toward engineering are reported to be uninformed, we argue that clarification of the work and traits of engineers is likely to positively shift attitudes. Further, we posit shifting elementary teachers' engineering attitudes (our proxy for attitudes toward STEM) will be joined by shifts in their efficacy and confidence for teaching STEM. Therefore, we contend there is justification for considering an assessment of elementary teachers' attitudes toward engineering as a comparable measure of their attitudes toward STEM.

The Project

Personnel from the College of Education and College of Engineering at Boise State University, a metropolitan university in the western United States, and PCS Edventures!, a company based in Idaho that supplies learning solutions worldwide, collaborated to address issues of teacher preparedness for teaching inquiry based STEM curriculum using manipulatives for instruction. The result of this collaborative effort was the creation and implementation of the Idaho SySTEMic Solution. Our initiative addressed the STEM needs of 39 elementary school teachers (grades first through fifth). The project focused on using BrickLab® manipulatives for teaching inquiry based STEM curriculum. The course began with a three-day summer workshop (Phase I) and continued through the school year with on-site support and Internet based educational modules (Phase II). This current study reports on the outcome of the Phase I three-day summer workshop. Again the goals of this initiative were: increase participants' preparation for teaching STEM content; increase participants' knowledge of STEM careers and in particular engineering; and increase participants' understanding of how to teach using inquiry and manipulatives.

Research Questions

The three research questions that guided our research were:

1. *What were the relationships between years of teaching experience, levels of education, reported comfort with teaching STEM, knowledge of STEM, levels of efficacy for teaching STEM, confidence for teaching STEM, and attitudes toward engineering, of the participants' prior to the Idaho SySTEMic Solution Workshop?*

2. *Did the participants' experience changes in their levels of efficacy for teaching STEM, confidence for teaching STEM, and their attitudes toward engineering during the Idaho SySTEMic Solution three-day workshop?*

3. *What were the participants' perspectives of the workshop? In particular what did they find to be helpful for preparing them to teach inquiry based STEM curriculum using manipulatives?*

Hypotheses

We hypothesized that the participating teachers would experience increases in their confidence, knowledge, and efficacy for teaching STEM due to engagement in our workshop. The workshop provided extensive hands-on activities and experiences using manipulatives that could easily be transferred to the teaching of inquiry based mathematics and science. We anticipated that the participants would realize they had higher than anticipated levels of understanding and skills needed to effectively teach inquiry based STEM using manipulatives which would lead to increases in their efficacy and confidence for teaching STEM.

Methodology: Participants

A cadre of 39 participants (teachers) was recruited from several elementary schools within the suburban Meridian district, which serves a range of social economic status student populations. Due to attrition and a lack of participation in both our pre- and post-tests our final study sample was composed of 36 participants. The demographics are presented in Table 1.

Table 1

Participant Demographics with Averages and Standard Deviations Where Appropriate

Measure	M (SD)
Male	3
Female	33
Age	40.5 (10.8)
Average Years of Experience	13.0 (8.7)
Bachelor Degree	23
Master Degree	13
First Grade	7
Second Grade	12
Third Grade	4
Fourth Grade	7
Fifth Grade	6

Methodology: Instruments

In our study we utilized four instruments: a demographics survey, a survey of confidence for teaching STEM, a survey of efficacy for teaching STEM, and an assessment of perceptions of engineering.

Our demographics scale was used to gather a range of personal characteristic data such as age, gender, ethnicity, and education. We also gathered professional data such as years of teaching, years in the present position, grade level of instruction, and experience participating in prior STEM professional development initiatives. We also included two items which asked participants to rate their comfort and knowledge levels for teaching STEM topics on a five point Likert scale.

Our confidence for teaching STEM survey was adapted from the *Teaching Confidence Scale*.[9] The 32 item *Teaching Confidence Scale* assesses teachers' confidence using responses on a six point Likert scale with "1" representing "Strongly Disagree" to "6" which represented "Strongly Agree." The *Teaching Confidence Scale* includes some STEM items asking participants to rate their confidence to "*teach science as a co-inquirer with students*" and to "*connect mathematics to literature*." However, the instrument has a more comprehensive perspective of teaching that was not pertinent to our STEM focus. Therefore, we modified items such as "*select appropriate literature for thematic teaching*" to "*select appropriate resources for science and mathematics teaching*." Our goal was to maintain the structure and general theme of the *Teaching Confidence Scale* while redirecting the focus of the items toward STEM content. Woolfolk Hoy has established the content validity of the *Teaching Confidence Scale* and has reported on internal reliability Cronbach's alpha of .95.

Our measure of efficacy for teaching STEM was inferred from participants' scores on the *Science Teaching Efficacy Belief Instrument* [STEBI]. [29] This 25 item instrument uses forward and reversed phrased items to assess teacher's 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 instrument was developed for use with elementary level teachers, and achieved an internal reliability alpha of .91 [29] There are two subscales of the STEBI, one assesses personal science teaching efficacy beliefs and the other assesses science teaching outcome expectancy.

We used the participants' attitudes toward engineering as a proxy for their perceptions of science as a career. To assess attitude toward engineering we developed an instrument based on the *Pittsburgh Freshman Engineering Attitudes Survey* [PFEAS].[30] This instrument uses a five point Likert scale ranging from "1" representing "Strongly Disagree" to "5" representing "Strongly Agree" to assess attitudes toward engineering. We modified the PFEAS from its original form retaining items that focused on general attitudes and perceptions of engineering, and eliminating items that were highly technical or focused specifically on pursuing a degree in engineering. We added some items based on conversations with engineers and educators. For example we used items such as, "*An engineer would enjoy taking math and science courses more than liberal arts courses*" and "*Engineering is an exact science*" to form two subscales. Our final instrument contained 30 items evenly distributed on the dispositions toward engineering and attitudes toward careers in engineering subscales. The validity and reliability of the PFEAS has been previously established, and we anticipated that our modifications had little influence on the psychometrics of the scale.

We used a standard workshop evaluation form to gather participant impressions of the three days of activities. Ten items using a five point Likert scale were used to assess participants' perspectives of the format, setting, logistics, and content of the workshop. Two additional free response items asked participants to provide feedback regarding the "*pluses, minuses, and interesting*" aspects of the workshop and the "*muddy and marvy moments*" they experienced. Our goal was to gather salient information related to the workshop that the participants deemed as effective or ineffective for preparing them to use manipulatives for teaching inquiry based STEM curriculum.

Procedure: Workshop Intervention

In the Idaho SySTEMic Solution workshop intervention we utilized a combination of lecture, small group discussion, hands-on activities, and individual assignments. Instructors and presenters included PCS Edventures! and Boise State staff, as well as the Meridian superintendent and other regional education leaders. The workshop opened with engineering faculty and research staff giving a presentation on engineering, its creative aspects, ways that engineering affects everyday life, and engineering education overall. This set the stage for workshop participants and instructors to be able to tie BrickLab® lessons not only to science, math and technology, but also to engineering. The PCS BrickLab® curriculum is rich with engineering connections, such as building skyscrapers, bridges and structures, solar and wind energy, and manufacturing and systems. The primary focus of the workshop was preparing the teachers to use the BrickLab® manipulatives to teach inquiry based STEM curriculum. Our intent was to make the participants as familiar as possible with the resources and process of implementing inquiry based curriculum using the BrickLab® manipulatives to teach STEM curriculum. The participants also attended lectures intended to prepare them for inquiry instruction, curriculum development, assessment, aligning the use of the manipulatives with state and local learning standards, and classrooms management when using BrickLab® manipulatives.

The primary outcome goal of the workshop was to make sure that the participants were comfortable and prepared to use the manipulatives (*Bricklabs®*) to teach age/developmentally appropriate inquiry based STEM curriculum. On day one of the workshop participants were supplied with activity books for their particular grade level, which provided them with a foundation and resource for further development. PCS provided numerous examples and a framework for aligning the curriculum to the specific learning standards of the school district. Alignment became an important aspect of the participants' curriculum development and planning, as teachers were encouraged to continue refining and expanding the alignment of the curriculum. On day two and three of the workshop the participants engaged in a series of hand-on labs, lectures, and curriculum planning activities aimed at increasing their capacity to effectively teach inquiry based STEM curriculum using the BrickLab® manipulatives. We structured the workshop to balance theory, practice, and preparation. Our intent was to make the participants familiar with the resources and process of implementing inquiry based curriculum, using manipulatives as a significant resource to teach STEM curriculum.

Procedure: Data Collection

All data collection took place using the Zoomerang survey web site, with the exception of the workshop evaluation survey. Using a series of Web pages we lock-stepped the participants thought our Zoomerang based consent form, demographics measure, and three study instruments. Each survey required participants to provide the same unique five digit code, which was used to organize the data and conduct pre and post repeated measures comparative analysis.

All participants were pre-tested and post-tested. We pre-tested participants one week before the workshop. During our workshop registration, we identified any participants who had not completed the pre-testing. We provided those participants who had not completed the surveys with immediate access to a computer so that they were able to complete their pretest surveys prior to the start of the workshop. We conducted an immediate post-tested at the end of the third day of the workshop in a campus computer lab using the same webpage interfaced Zoomerang survey links. Participants were reminded to use the same five digit code when completing the post test surveys.

In the closing session of the workshop we distributed the paper form of the workshop evaluation. We did not consider it was necessary to link the data from the evaluations to any of the other study instruments. Therefore, we did not request the participants to use their five-digit codes when completing the workshop evaluations.

Results

We began our analysis by calculating the internal reliability of our instruments using the pretest scores. The Cronbach's alpha of our confidence for teaching STEM measure was found to be .95, indicating a high level of internal reliability. The Cronbach's alpha of our efficacy for teaching STEM measure was found to be .85, revealing a good level of instrument internal reliability. The Cronbach's alpha of our attitude toward engineering measure was found to be .71 indicting an acceptable level of internal reliability. Our results were fairly consistent with the reports of internal reliability from the authors of the instruments, suggesting they performed as expected.

Our first research question asked: *What were the participants' pre-workshop relationships between years of teaching experience, levels of education, reported comfort with teaching STEM, knowledge of STEM, levels of efficacy for teaching STEM, confidence for teaching STEM, and attitudes toward engineering?* We began answering this question with a calculation of the correlations between our pretest measures, our demographics measures, and our teacher comfort and knowledge for teaching STEM content measures (see Table 2).

Table 2

Correlations of Pre-Workshop Measures, Demographics and Comfort and Knowledge of STEM (n = 36)

Variable	1	2	3	4	5	6	7	8	9
1. Age	--	.14	.72**	-.01	.19	.12	.05	.34*	-.14
2. Education Level		--	.18	.15	.18	.29	.02	.07	.10
3. Years teaching:			--	-.04	.24	.10	.20	.39*	-.04
4. Grade(s) primarily Taught				--	-.18	-.17	-.03	-.18	-.20
5. Comfort Teaching STEM					--	.86**	.39*	.63**	.04
6. Knowledge of STEM						--	.38*	.55**	.03
7. Efficacy Teaching STEM							--	.43**	-.09
8. Confidence Teaching STEM								--	.07
9. Engineering Attitude									--

* $p < .05$; ** $p < .01$

Our correlation analysis revealed a significant link between years of teaching experience and confidence in teaching STEM p < .05, such that as experience increased so did confidence for teaching STEM. Interestingly, experience was not correlated with comfort, efficacy, or knowledge for teaching STEM. Age was also found to be correlated with confidence for teaching STEM p < .05, which may represent a spurious relationship since age and years of experience were highly correlated p < .01.

Comfort with teaching STEM content was found to be positively correlated with knowledge of STEM content ($p < .01$), with efficacy for teaching STEM ($p < .05$) and confidence teaching STEM ($p < .01$). Similarly, knowledge of STEM content was positively correlated with efficacy for teaching STEM ($p < .05$) and confidence teaching STEM ($p < .01$). Given the high correlation between comfort with STEM and knowledge of STEM ($r = .86$, $p < .01$) it is expected they would have similar relationships with the other measures. These findings are consistent with prior research.

Our participants' confidence for teaching STEM was found to be significantly positively correlated with their efficacy for teaching STEM ($p < .01$). It may be argued that efficacy and confidence are proximal assessments of the same construct. However, these two measures only share about 18.5% of the variance, which suggests that even though there appears to be overlap in the outcomes, the instruments appear to be measuring different perspectives of teaching STEM content.

Overall, years of experience and age were predictors of our participants' confidence for teaching STEM. In addition, comfort with STEM, knowledge of STEM, efficacy for teaching STEM and confidence with STEM were all found to be positively correlated. Participants' levels of education, grade level primarily taught, and attitudes toward engineering were not found to be significantly correlated with any other measures.

Our second research question asked: *Were there changes in the participants' levels of efficacy for teaching STEM, confidence for teaching STEM, and their attitudes toward engineering after the three day SySTEMic initiative workshop?* To answer this question we conducted a paired samples t-test of the pre-test and post-test composite scores of our three study measures (see Table 3 for means and standard deviations). Our analysis revealed significant increases in participants' efficacy for teaching STEM, $t(35) = 7.88$, $p < .01$, confidence for teaching STEM, $t(35) = 3.59$, $p < .01$, and attitudes toward engineering, $t(35) = 7.40$, $p < .01$. Our results revealed a significant and positive influence on the participants' efficacy, confidence, and attitude toward engineering, resulting from our three-day workshop.

Table 3

Pre-Test, Post-Test Means and Standard Deviations of our Three Study Measures (n = 36)

Measure	Mean (*SD*) Pre-Test	Mean (*SD*) Post-Test
Efficacy For Teaching STEM	89.77(*9.34*)	96.5(*9.57*)
Confidence for Teaching STEM	141.69(*16.41*)	150.31(*11.85*)
Attitude Toward Engineering	101.17(*5.47*)	110.51(*7.33*)

Our third research question asked: *What aspects of the workshop did the participants find to be particularly helpful for preparing them to teach using manipulatives in inquiry based STEM curriculum?* To determine the answer to this question we conducted a content analysis (Creswell & Plano Clark, 2007) of participants' answers to the selected response and free response items on the workshop evaluation.

Our analysis revealed that the participants felt that the hands-on activities and curriculum planning were the most valuable activities of the workshop. All participants strongly agreed that time spent working with the manipulatives was beneficial to their preparation for teaching STEM with the workshop associated resources (manipulatives and activity workbook). In contrast, only about two thirds of the participants agreed that the lectures were applicable to their preparation for teaching inquiry based STEM.

Analysis of the workshop evaluation written response item asking the participants what they thought was "*positive, negative, and interesting*" about the sessions again revealed that time spent interacting with the manipulatives was perceived as very positive and beneficial. This was reflected in responses to the item such as "*Getting some hands-on experience with the bricks*" and "*Hands-on; interactive* [*sessions*]." The participants also communicated positive perspectives toward the content from the lectures and presentations as reflected by passages such as, "*Project based learning philosophy – good stuff*" and "*Meeting and listening to the presenters*." The participants were positively influenced by the engineering presentations as revealed by passages such as, "*Helping see the range of things engineers are involved in*" and "*Engineering is not so scary; women can be good at math and science.*"

Most of the negative comments were related to the facilities issues (temperature of the room) and to the logistics of the workshop (time used for registration). However, two comments about lecture presentation indicated that some participants did not find them beneficial, "*Lecture a little long in the a.m.*" and "*Lecture style [I was] beginning [to] feel like I was back in college.*" A few negative comments focused on the noise associated with the use of the manipulatives such as, "*The noise with the* [*bricks*]." One negative comment that really stood out was, "*More time for discovery - I know we will get to do more later, but I know it will be hard to get those kids to quit*." This suggests that the time exploring with the manipulatives provided opportunity to learn more about how to use the manipulatives for teaching. However, some participants may not have had sufficient opportunity to gain the level of comfort with the classroom management necessary for using the bricks in their curriculum.

Participants responses to the "*muddy and marvy moments"* item centered on using the manipulatives, the activities they engaged in, the structures they built, and the corresponding vocabulary. This was reflected in comments such as, "*The task of building something and having you stand on it. And what does it mean to test something*" and "*Names for the versatile structure – post & lintel*." These comments reveal an increase in familiarity with inquiry, especially when it involved using manipulatives. Another major theme was the connection between the workshop and the participants' classrooms. This is evidence from the following passages, "*How this connects with the classroom*" and "*Activities that are able to be used*" and "*Classroom management hints*." Preparing teachers to teach inquiry-based STEM using manipulatives was the goal of our workshop and it appears we achieved that objective.

Discussion

The amount of STEM education required in most elementary teacher certification programs is minimal, which potentially explains why many of K-6 educators feel unprepared and lack confidence and efficacy for teaching STEM content.[7, 22, 23] To remedy this situation is it critical to provide elementary teachers with on-going professional development, meaningful resources, and appropriate support.[32] The goal of the Idaho SySTEMic Solution, which started with a three day workshop, was to increase the quantity and quality of inservice elementary teachers' inquiry-based STEM instruction using manipulatives through the use of a combination of hands-on activities, lectures, and related assignments.

Consistent with previous research[22, 27] our results revealed relationships between our participating inservice teachers' knowledge of, confidence for, comfort with, and efficacy for teaching STEM content. It is reasonable to assume that if an individual has high levels of STEM knowledge then their comfort, confidence and efficacy would also be high. A lack of knowledge would make one unsure about their abilities, leading to a lack of confidence for teaching, a reduction in effectiveness, and an overall feeling of being uncomfortable teaching STEM concepts. It is interesting that confidence was positively correlated with experience but there was not a corresponding correlation with knowledge, comfort and efficacy. This suggests that experienced teachers may gain confidence in their abilities to teach a range of subjects because they have been successful over time, but the increase is not necessarily due to an increase in content knowledge. This supports our results, which suggest that teaching experience does not necessary lead to an increase in content knowledge, comfort teaching certain topics, or a greater feeling of effectiveness. Thus, knowledge is perhaps the most stable and difficult variable to alter when associated with comfort, confidence, and efficacy in teaching STEM content. Interestingly, no measures were associated with the participants' attitudes toward engineering (our proxy for attitude toward the STEM professions). We speculate that this is due to integration of engineering and STEM related careers into popular culture and the media which has lead to a positive shift in perceptions of STEM careers. We view this as a positive development. However, there is still work to be done since the shift has not been accompanied by increased time on task teaching most STEM content. Presumably, attitudes and perceptions toward STEM careers are shifting; consequently this measure may no longer be a meaningful and useful indicator of teacher confidence, knowledge, and efficacy for teaching STEM content.

The pre-test post-test analysis of our measures of confidence for teaching STEM, efficacy for teaching STEM, and attitude toward engineering, were all revealed to significantly increase. Recall, we used our attitudes toward engineering measure as a proxy for the teacher perspectives toward professions and professionals in the STEM domains. We attribute the increases to the content of the workshop which provided instruction on curriculum development, careers and activities of engineers, the research supporting hands-on learning, and the effective use of inquiry based instruction. Further, the time spent exploring and engaging in STEM content would increase knowledge, which in turn would influence confidence, efficacy, and attitudes toward engineering.[7] The lack of a detectable correlation between the participants' levels of education and their confidence and efficacy for teaching STEM, suggests that exposure to STEM content most likely does not occur in their preservice college coursework. Therefore, a greater knowledge of STEM content may have to come through other sources once the teachers are in service, such as summer workshops or professional development.

Workshop feedback reveals that experience with hands-on activities prepares teachers for using manipulatives in inquiry-based STEM content. Although the lecture content was developed to complement the hands-on activities, feedback indicates that integrating the two would most likely be more effective for increasing teacher efficacy, knowledge and confidence for teaching STEM content. In future workshop initiatives we plan to develop curriculum that integrates inquiry, hands-on learning, use of manipulatives, and STEM content with the content from the lectures. This will provide context and allow for the participants to engage in the curriculum in a manner that may result in even greater increases in STEM knowledge, confidence, and efficacy. In addition, a more interactive approach may allow us to accomplish the goals of increasing STEM knowledge while helping the participants develop greater levels of pedagogical content knowledge. Extensive evaluation of the teachers' year-long experiences, Phase II of this initial project, is under way; we expect it will amplify the results of the workshop.

Limitations and Conclusion

In the first cycle of our initiative implementation we limited our recruitment to seven elementary schools within the same school district. The rather constrained sample of elementary teachers from the same school district might be viewed as a limitation of our study. However, our intent was to determine if systemic change could take place, which required us to concentrate resources and attention on a manageable sample that could easily be monitored. In the second cycle of the initiative we plan to stay within the same schools to determine how expanding the program using experienced teachers might influence greater systemic changes. In future cycles of the initiative we plan to expand beyond the single school district and include middle school teachers.

Although our instruments had established reliability and validity, they were limited to scales provided with the selected response items. We were able to assess what the participants self reported, but we do not have evidence for why they selected their responses or specifically what they envisioned their responses to represent. The use of pre and post workshop interviews to gain a deeper understanding of participants' perspectives is an excellent direction for future research.

The *Idaho SySTEMic Solution* project was developed to increase first through fifth grade teachers' abilities to incorporate inquiry based STEM content using manipulatives. Participants' engagement in a three day workshop had a significant influence on their knowledge, confidence and efficacy to teach STEM content. The outcome of our project demonstrates the critical influence that professional development can have on teachers' mathematics and science teaching effectiveness. Applying our evidence to the systemic level indicates that continuing education is essential for increasing teachers' STEM teaching capacities which is anticipated to produce increases in student achievement and attitudes toward STEM curriculum.

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