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# **AC 2012-5242: TEACHER TRAINING AND STUDENT INQUIRY AND SCIENCE LITERACY: LINKING TEACHER INTERVENTION TO STUDENTS' OUTCOMES IN STEM COURSES IN MIDDLE AND HIGH SCHOOL CLASSES**

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# **Teacher Training and Student Inquiry and Science Literacy: Linking Teacher Intervention to Students' Outcomes in STEM Courses in Middle and High School Classes**

## *Abstract*

Engineers and scientist utilize the principles and theories of science and mathematics to design, test, and manufacture products that are important to the future of a nation's citizenry. With the exception of biological sciences, however, the percentage of college students seeking degrees in math, science and engineering disciplines has been declining for the past two decades. Furthermore, fewer potential engineering majors are completing rigorous college preparatory programs and graduating in the top quarter of their high schools. This shortfall has raised concerns among leaders in science, technology, engineering, and mathematics, (STEM) fields. To meet the changing demands of the nation's science and engineering labor force, recognition of the importance of pre-college education intervention and implementation of challenging curricula that captures and sustains middle and high school students' achievement and interest in science and engineering is critical.

Current research reveals that one of the most important determinants of what students learn is the expertise and pedagogy of the teacher. Additionally, the current research on K-12 STEM student achievement is that students need direct instruction in science literacy including comprehension, science vocabulary, and science writing. This should be coupled with deliberate and guided practice in scientific experimentation. Accordingly, our research is focused on improving teacher quality in these important instructional areas and resulting middle and high school student learning in science, technology, engineering and math (STEM).

Our university has partnered with two large urban school districts to plan, deliver and sustain a targeted inservice teacher professional development and a middle and high school STEM student curriculum intervention. Recognizing that understanding informational text is a major problem in urban schools and a major barrier to science and achievement, we have worked at improving strategic instruction in science literacy for our teachers and their students in addition to foci on inquiry instruction with emphases on engineering problem solving and experimentation. Results of this teacher and student focused STEM educational intervention has revealed a dramatic increase in student interest in scientific experimentation, engineering problem solving and increased science literacy and achievement.

## Introduction

Engineers and scientist utilize the principles and theories of science and mathematics to design, test, and manufacture products that are important to the future of a nation's citizenry. With the exception of biological sciences, however, the percentage of college students seeking degrees in math, science and engineering disciplines has been declining for the past two decades. Furthermore, fewer potential engineering majors are completing rigorous college preparatory programs and graduating in the top quarter of their high schools. This shortfall has raised concerns among leaders in science, technology, engineering, and mathematics, (STEM) fields.

To meet the changing demands of the nation's science and engineering labor force, recognition of the importance of pre-college education intervention and implementation of challenging curricula that captures and sustains middle and high school students' achievement and interest in science and engineering is critical.

Current research reveals that one of the most important determinants of what students learn is the expertise and pedagogy of the teacher. This is of particular importance at the middle and high school levels. Accordingly, our research is focused on improving teacher quality and resulting middle and high school student learning in science, technology, engineering and math (STEM) via formation, nurturance, and sustaining an important targeted school-university urban educational partnership.

Our university has partnered with two large urban school districts to plan, deliver and sustain a targeted inservice teacher professional development and a middle and high school STEM curriculum intervention. The partnership goals are to assist inservice middle and high school science teachers in (1) designing and implementing integrated science and engineering curricula and (2) development of instructional methods and strategies that enable teachers to effectively: (a) teach challenging content and research skills in middle and high school as required by state/national science standards; (b) generate knowledge and transform practice in middle and high school STEM education, (c) cultivate a world-class STEM workforce, (d) expand students' scientific literacy, and (e) promote research that advances the frontiers of knowledge in STEM middle and high school classrooms.

We have engaged in this project for approximately 32 months. To date, we have trained fifty-three middle and high school STEM teachers who are now delivering the innovative STEM curriculum that they created during a professional development summer teacher academy in their middle and high school classrooms.

The importance of teacher involvement

This STEM K-12 research is focused on teacher training as a precursor to curricular change for students in STEM because the integration of societally relevant engineering technologies into science and health curriculum requires the full involvement and understanding of teachers for true impact on students to occur.<sup>6</sup> Accordingly, teacher training/professional development, and mentoring assistance have been demonstrated to be critical prerequisites for the effective application of research in secondary classrooms.<sup>7,8</sup> We have chosen to focus on teacher training in STEM education rather than solely on students' STEM education because several studies indicate that when teachers are directly involved in the planned integration of research into K-12 curriculum, they are consistently able to engage students in meaningful educational experiences and to allow more time for high level individualized instruction.<sup>9,10</sup>

Integrating societally relevant engineering and science technologies research into traditional science and health curriculum

Two major educational movements have converged that guide this teacher training effort. These movements have a profound impact on approaches to teaching and decisions involving academic resources. (1) State and national educational officials have prescribed content standards for

major subject areas and have aligned high-stakes testing to these standards; and (2) increased requirement for science and health subject infusion to support content goals and improve engagement in curriculum for students. These movements inspire us to conduct this teacher training and curricular research, by infusing inservice teacher training and curricular intervention into traditional middle and high school science and health curricula and measuring change across teacher and student groups.

Combining health and science research focused specifically on urban risk factors with current health and science teacher training and curriculum is a significant endeavor that has multiple benefits for the middle and high school teachers and students who participate in the program. By exploring and learning about the research at the four participating USC research centers and the participating societally-focused engineering technology laboratories at USC, middle and high school teachers and students will collaboratively learn how scientists help us address important questions that are ethnically and culturally relevant to advancing academically successful, healthy, and sustainable urban societies.

An emphasis on science and health, and the technology associated with these subjects is consistent with the goals for school reform in our state.<sup>12</sup> Hence, our teacher training is focused on the interdisciplinary nature of health and science education to develop content area literacy through a student-centered curriculum, thereby promoting teachers' and students' understanding and application of engineering, health, and science research in their classrooms. The major policy and planning documents that influence our state's schools acknowledge that good health is a basic precursor to academic success. A common theme is the need for schools to take an active role in developing and promoting the physical, mental, emotional, and social understanding of the environment and health of students. Because the environment and health have interrelated impacts on students, health and environmental-related engineering technologies can be used to capture teachers' and students' STEM interest, demonstrate the personal relevance of science and engineering, and enhance development of knowledge and skills in related curricular areas.

Historically, schools have resisted allocating resources to health and science education and associated teacher inservice efforts, because evidence of benefits was insufficient.<sup>13</sup> Today, however, the benefits of STEM education and integrated school health/science/literacy curricular approaches are clear. This is particularly evident for minority populations who have been the focus of outreach efforts and teacher and child-related research in our university's participating research centers and laboratories.

#### STEM content literacy and engaging instruction for English learners

Our state and county have the greatest number of minority students in the country whose primary language is not English (over 1.5 million, 25% of total school population). Under No Child Left Behind,<sup>14</sup> schools must ensure that English Learners (ELs) show significant yearly progress in developing English skills as well as meeting grade level standards in all academic content areas. According to the latest report card on the implementation of NCLB, our area schools are falling short of meeting the academic needs of English Learners.<sup>15</sup> Students struggle to develop the cognitive academic language proficiency (CALP) necessary to comprehend content-area texts particularly in STEM areas. Chall, Jacobs, and Baldwin<sup>16</sup> noted that this breakdown in academic achievement in STEM content areas is particularly significant in middle and high school.

Content-area texts contain a large number of content-specific vocabulary words and concepts that are beyond the students' English language abilities. Students need to be taught how to read content-area texts as well as to develop the academic language and discourse associated with each content area, particularly as they proceed through cognitively demanding curricula in middle and high school. The STEM literacy focus of our teacher training and curricular intervention addresses content area literacy needs for students while they are at greatest risk for failure (in middle and high school) and alleviate difficulties associated with the STEM vocabulary and reading comprehension skills.

Furthermore, scientists and engineers utilize the principles and theories of science and mathematics to design, test, manufacture and sustain technologies that are important to the advancement, health, safety and quality of life of a nation's citizenry. With the exception of the biological sciences, however, the percentage of college students seeking degrees in science and engineering disciplines has been in decline for the past two decades. To meet the demands of the nation's labor force, recognition of the importance of pre-college education and implementation of challenging curricula that captures and sustains K-12 students' interest in science and engineering is critical. Current research reveals that one of the most important determinants of what students learn is the content expertise and pedagogy of the teacher. Accordingly, we have designed a compelling inservice teacher-training program to address this challenge.

#### The teacher and associated student STEM intervention

The described teacher training and student curriculum intervention program is a multiphase program using a quasi-experimental research design with six major components: (1) a multiphase Summer Teacher Academy professional development model in middle and high school STEM education; (2) a quasi-experimental approach to middle and high school STEM teacher training and associated curriculum intervention with control classrooms, a multi-classroom needs assessment, and a summative and formative impact-based intervention evaluation; (3) collaboration between University content area expert researchers and a teacher training leadership team of teachers who became the teacher trainers for the professional development model; (4) a planned dissemination and sustainability effort for the professional development and curriculum implementation; and (5) national web-based teacher professional development dissemination potential. Seven *specific structures* (described below) have been utilized to allow for organized implementation of the 4-phase, 2-year teacher training and curricular intervention program.

#### Program design deliberation

This multi-phase teacher-training program uses a quasi-experimental design. There are three phases to the program with ten specifically delineated tasks. The narrative that follows briefly describes each phase of the research approach and its associated tasks. The first four months of the program (**Phase I**- a pre intervention phase) was devoted to designing the teacher training and associated student curricular content, convening the two research teams, the Teacher Training Leadership Team (TTLT) and the Content Expert Scientific Advisory Team (CESAT), and initial teacher professional development. Specifically, the following three tasks occurred in **Phase I** of the curriculum intervention.

In consultation with the CESAT, the TTLT of five teachers from the local urban school districts and university faculty developed a comprehensive inservice teacher training program, and 6-10 grade level-specific integrated curricular units of study that incorporated engineering problem solving that teachers implemented aligned to statewide curricular standards in middle and high school science, using research conducted at our university's national research centers and laboratories as content. The TTLT and CESAT collaboratively developed an interactive web-based teacher resource community of practice that allowed teachers to share lessons, how they incorporated the engineering problem solving process in to their lessons, and discussed successes and challenges to their instructional practices. The TTLT planned the first Summer Teacher Training Academy for teachers who work in the school districts. During **Phase II** of the program, the following specific tasks occurred: The first Summer Teacher Training Academy occurred on our university's campus. This was a four-week long summer academy with content specific academic year follow-up with the TTLT and CESAT on the middle and high school campuses during the fall curricular implementation. Content of the Teacher Academy included curriculum review, implementation of part one of James Stigler's<sup>15</sup> lesson study, use of problem based learning in the classroom, and use of question generation strategies (QGS) and question answer relationship (QAR) strategies to understand and use scientific informational text. During **Phase III**, curricular revisions associated with the first year of operation Part II of professional development, and the task of sustainability planning took place. In **Phase IV**, dissemination of the teacher training modules and curriculum took place.

Over the 2-year, 4-phase program period, the collaborative effort directly supported approximately 53 middle and high school teachers and their approximately 5,000 students in a sequential, in-depth, technology-mediated teacher professional development program and problem-based curricular intervention that included a total of approximately 140 hours of teacher professional development per year.

The instructional materials developed by the TTLT were succinctly aligned to content standards across science and health subject, embedded engineering program solving and targeted strategies for understanding informational text in science in the middle and high school curriculum, included a teacher training modular technology component. It is available for replication and dissemination in secondary schools nationally via the website facilitated by our program. This inservice teacher training research program has seven unique and innovative enabling structures that are essential to making the teacher training and curricular intervention feasible and measuring its impact, as follows.

#### Details of the teacher professional development

The research team of teacher leaders and university faculty planned the professional development for the teachers and the associated curricular intervention. As previously described, fifty-three participated in training on the integration of research about societally relevant engineering technologies in middle and high school science and health curricula. The vehicle for preparing the teachers was a **Summer Teacher Training Academy (STTA)** serving as a training-of-trainers program with technology-mediated, school site follow-up professional development in middle and high school classrooms. Teacher academies have been recognized in the teacher education literature as a powerful and impactful way of comprehensively training and supporting teachers.<sup>18</sup> The five-teacher TTLT involved in the follow-up serves as trainers and

mentors to the other teachers throughout the program. An online training that was mediated by university faculty provided to all non-trainer participant teachers throughout the program as a follow-up to the summer curricular academy was implemented. This served as a means for teachers to share ideas, to engage in virtual lesson study, to support one another and to interact with the (TTLT) teacher trainers and university experts.

Sequentially, a summer teacher-training academy (STTA) occurred in 2010 immediately after the program’s development (4 month period) and in year 2, summer 2011. Mornings in the academy were spent learning the science, the engineering problem-based learning pedagogical supports, and exploring the engineering technologies related to the program that are aligned with state and national science, health, and English language arts content standards. Teacher participants spent a portion of the morning academy time in the participating research centers and laboratories, observing scientists and engineers conducting research, and discussing both the research and the application of the technologies and engineering problem solving in classroom settings. University professors presented on key topic areas and unit specific module lessons that were used within the instructional units. Afternoons of the summer academy were spent working with university faculty and participating teachers to apply what was learned in the science, engineering, and health education content component to instructional practice. Problem-based learning approaches using inquiry focused pedagogical lesson design was used. Teachers also learned how to deliberately teach science literacy in their classroom. Specifically, the teachers were taught the question answer relationship (QAR) and the question generation strategies (QGS) approach to teaching students how to comprehend and use scientific informational text. These strategies embed questioning strategies into instructional practices allowing students means to dissect their text into meaningful units of information.

As academic year follow-up, teacher participants explored curriculum materials in tandem with the university experts for use in their classrooms. A major objective of the teacher professional development was to familiarize the teachers with engineering and technological innovation so that they may use it in their curricula. They used inquiry instruction, practiced articulation of the scientific method and its application to engineering problem solving as a primary means of introducing engineering to their classroom. Teachers learned and practiced instructional strategies for use in the classroom based on the science, engineering, and health education content connected to the societally relevant engineering technology research, thereby affecting an increase in students’ science and health literacy.

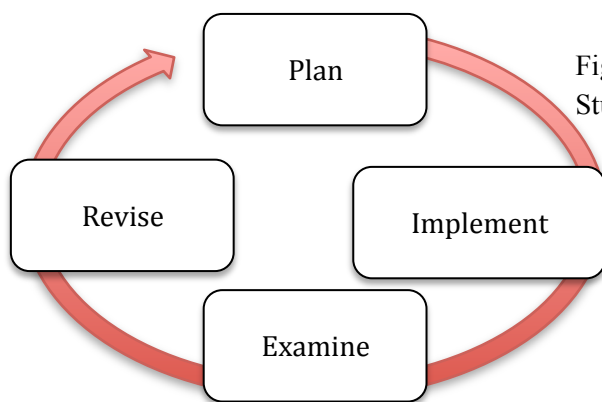


Figure 1: Lesson Study Cycle

#### Stigler’s Lesson Study teacher training model

Throughout the teacher training, the teachers used a research-based *lesson study* approach to build and study implementation of the curriculum in their respective middle and high school science and health classrooms. Lesson study, according to James Stigler,<sup>17</sup> refers to a professional development process whereby teachers closely

examine their lessons with a focus on addressing student need via data-driven decision-making, creating relevant curricula. Lesson study goes beyond collaboration to co-planning and observing actual lessons with a focus on student thinking. In the lesson study model, teachers learn together. Participants plan, observe, and refine "research lessons" designed to make real their long-term goals for student learning and development.<sup>17</sup> A key component of lesson study is observing and teaching of lessons, which are improved collaboratively. This compels teachers to examine their own practice in depth in the context of student learning, connects teachers with their students and their professional community, and inspires them to continue to improve. This model of teacher professional development has been applied widely and successfully in Japan and has recently been initiated by teachers across the US. For the purpose of the summer teacher training academy, participant teachers "studied" videotaped lesson exemplars using the lesson study cycle. Figure 1 (above) illustrates key components of the lesson study cycle and approach. Two major lesson structures were utilized for the curriculum planning and lesson study. These were the *learning cycles approach* and *inquiry-based learning*; both approaches are known powerful pedagogical teaching structures. Anderson and Krathwohl's<sup>19</sup> learning taxonomy was used to guide instructional objective creation and pedagogy development during the teachers' professional development experience. The teachers also utilized principles from Bransford's<sup>20</sup> *How People Learn* to develop scientific curricula that are theoretically aligned to strong learning principles.

#### Instrumentation

Five assessment metrics were utilized to measure the impact of this teacher and student intervention program. All metrics were tested for reliability and validity using sound item response theory building blocks as guides. These included both teacher and middle and high school student metrics and were succinctly aligned with the program's intended outcomes of (a) increasing teacher performance, (b) increasing teaching efficacy and (c) increasing students' motivation for science, and improving science literacy.

##### Teacher Metrics:

- *Teacher Instructional Performance Metric*: This assessment tool is a rubric scored observational assessment of science teacher instructional performance and is aligned to California's teacher performance assessment: Performance Assessment of California's Teachers (PACT).
- *Science Teaching Efficacy Beliefs Instrument Revised (STEBI-R)*: This metric is a scale that assesses teachers' science teaching efficacy. It was administered as a pre and post-test to all teacher participants and is compared to non-participant science teachers that match the participant teachers' socio-demographics (national averages).

##### Student Metrics:

- *Science Qualitative Reading Inventory*: This assessment is an inventory of science vocabulary, reading comprehension, and science writing and is matched to grade level science content and vocabulary in grades 6-12 science content.
- *Grade and Content Specific Concept Inventories*: These inventories measure grade leveled concepts critical to scientific understanding in middle and high school.



- *Motivation for Science Questionnaire*: This questionnaire measures students’ interest, motivation, and engagement in science.

Results of these metrics are indicated in the two tables that follow (Tables 1 and 2). Results are presented as both means (or averages) and percentage gains during start to finish of the teacher and student intervention time period. These results are based on one to two years of teacher professional development and associated student intervention. Accordingly, these results are somewhat preliminary, as in most situations they do not yet represent longitudinal data collection and analyses.

Table 1: Teacher Results

<b>Metric</b>	<b>Post – Program Subscale Ave.</b>	<b>Nat’l Subscale Ave.</b>	<b>RET ITQ % Total Gains</b>
<b>Teacher Performance (PACT)</b>	3.19	2.89	<b>28.7</b>
<b>Science Teaching Efficacy</b>	3.22	2.47	<b>19.7</b>

These results indicate that the teachers made gains in performance and efficacy during the teacher professional development program and that the participants out performed state and national averages on these two metrics.

Table 2: Student Results

<b>Metric</b>	<b>Pre-pgm %</b>	<b>Post -pgm %</b>	<b>% Gains</b>
<b>Science Knowledge</b>	67.1	86.4	<b>19.3</b>
<b>Science Literacy</b>	51.6	87.8	<b>36.2</b>
<b>Science Interest &amp; Motivation</b>	62.5	83.93	<b>21.43</b>

These results indicate that the students (on average) made significant ( $P < .05$  across measures) gains during their curricular intervention. They gained knowledge, increased their science interest and motivation and gained in science literacy as well. These are true metrics of success for the program. Incidentally, we also documented changes in school district benchmark achievement testing in years one and two, with district benchmark assessments considered a pre-

intervention measure in year one because they were taken before the first summer academy and district benchmark achievement tests in year two considered a post test measure because they were administered after a year of intervention for teachers and students. Results revealed a 29.2 percent gain overall in these measures across grades 6-8.

#### Discussion, limitations, and conclusions

This project has great promise as both a student and teacher STEM intervention. We intend to increase sample size and explore additional student and teacher variables in the near future. Additionally, we intend to compare student and teacher measures across program years in the coming year using hierarchical linear modeling approach where students are nested in teachers' classrooms and schools. Due to the nature of the teacher intervention, it is difficult to include a large sample size in the project each year so multi-year comparisons have much to offer. Recognizing that teachers receive many interventions and professional trainings, we are not assuming that our teacher intervention "caused" changes in student or teacher performance, however in particular, our comparisons to national results in teacher performance and efficacy indicate that the intervention is a promising practice that extends far beyond typical teacher "workshops." Additionally, our science literacy gains, knowledge gains and district benchmark achievement tests in science gains were found to be quite dramatic in one year given the size of the middle school study population. In particular, deliberate instructional practice and anticipatory guidance on how to use questioning strategies and inquiry instruction with students have helped to improve both teacher performance and student learning. The results of this research inform the future of teacher training at both preservice and inservice levels. In reality it demonstrates that a few days of workshops are insufficient for changes in teacher performance and for student achievement to improve. Targeted follow-up is necessary and teacher lesson study and targeted dialogue around continuous improvement have proven to be helpful in eliciting teacher change and ultimately student success.

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