

## **Research Experiences For Teachers: Linking Research to Teacher Practice and Student Achievement in Engineering and Computer Science**

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# **Research Experiences For Teachers: Linking Research to Teacher Practice and Student Achievement in Engineering and Computer Science**

## **Abstract**

Research identifies a national urgency to improve teacher performance and student achievement in science and engineering. This paper responds to this need and presents the results of a six year Research Experience for Teachers (RET) programs funded by the National Science Foundation in which engineering faculty collaborate with middle and high school teachers and their students. The Advanced Content in Computational Engineering and Science Standards for Teachers Research Experience for Teachers (ACCESS 4 Teachers RET) program is our newest program and is a comprehensive teacher professional development program in which middle school teachers participate in an intensive summer research experience in computer science and engineering labs, build curriculum based on the laboratory research content that they learn, participate in lesson study, and implement new curriculum in their middle and high school classrooms. This paper contains a combined report of results of both the ACCESS 4 Teachers RET program and our former RET programs. The two programs have the combined intent of bringing innovative computer science and engineering research to middle and high school students and improving student achievement through scientific inquiry, engaging students in computational thinking, and engineering design. The programs' design includes a summer intensive experience in which teachers fully participate in a computer science or engineering laboratory research and engage in an inquiry focused content-to-pedagogy teacher professional development workshop, building curriculum from their lab research experience with foci on scientific experimentation and improving students' science achievement and literacy. The programs are aligned with Common Core Math Standards and Next Generation Science Standards and addresses the research question:

- What is the impact of an intensive research-based teacher professional development program on teacher and student performance?

Fifty-three teachers and their 7,420 students have participated in the ACCESS 4 Teachers RET and our previous Societally Relevant Engineering Technologies (SRET) programs combined. This paper combines both of our RET programs. Assessment metrics used to measure the impact of the programs are: a teacher instructional performance metric, the Science Teaching Efficacy Beliefs Instrument- revised, a science qualitative reading inventory, grade and content specific concept inventories, and a motivation for science questionnaire. Program results are: the RET teachers had a mean science teaching efficacy higher than the national average. The mean score on teacher performance rating was higher than the state's average rating. The RET teachers had a significant performance gain pre to post program. Results also indicate that students made significant gains during their curricular intervention resulting from their teachers' participation in the RET programs. Students gained science and engineering knowledge, increased their science interest and motivation, and demonstrated gains in science literacy as well.

## **Introduction and program need**

There is a growing national concern over decreases in science achievement in middle and high school. Paired with it are challenges associated with workforce declines in STEM-related careers. In response, in a recent PCAST report<sup>1</sup> recommendations for recruitment of science and engineering students and corresponding recommendations for increased attention to strategic STEM-related instruction and teacher professional development have emerged. A significant challenge facing urban science teachers is a low sense of self-efficacy in teaching STEM content.<sup>2</sup> Additionally, a recent large-scale study of teachers revealed that secondary teachers indicated a strong need for help in the areas of English Language Development (ELD) and content teaching in science, and that a weakness of existing professional development was in the lack of attention to English learners (EL) and the lack of long-term follow up.<sup>3</sup> This suggests a significant need for professional development of the type offered in these RET programs so that all students can benefit, particularly ELs. Intervening with teachers via lesson study and using high quality research in developing middle and high school curricula is an important way of positively impacting student outcomes. These points are essential for strategic intervention connected to professional development for teachers and are precisely the focus of the SRET RET and ACCESS 4 Teachers RET programs.

A major reason posited for poor student achievement in science relates to teachers' preparedness. Stigler and colleagues<sup>4</sup> found that US teachers were quite ill prepared to teach science compared to other nations. In particular, middle school teachers have been found to be unprepared due to their limited science content knowledge and their inability to apply math to science content.<sup>5</sup> Researchers hypothesize that this is because the majority of middle school teachers are "generalists" in that they often hold elementary multiple subject credentials and achieve their secondary credentials by exam rather than by studying scientific subject matter. With the implementation of the Next Generation Science Standards, which have both contemporary engineering and science at their core, increasing both middle and high school teachers' content knowledge is critical.

While there are many skills needed to teach science effectively, deep interconnected subject matter knowledge is crucial in secondary schools.<sup>6</sup> Scholars argue that in-service science teachers, particularly in middle and high schools, fall short in their understanding the depth of contemporary science content they are required to teach.<sup>7,8</sup> For example, Parker et al.<sup>9</sup> found that, while high school teachers were most likely to have deep science content knowledge, middle school teachers' science knowledge was limited. Only 13% of studied high school teachers had low levels of science knowledge as opposed to 63% of middle school teachers. In contrast, 56% of high school teachers showed high levels of science content knowledge in comparison to 23% of middle school teachers. The RET programs focus on addressing the content area needs of both middle and high school teachers by immersing them in science- math pairs in cutting-edge computer science and engineering labs and guiding them in curricular development using their research experiences as content using a lesson study approach.

## **Programs scope**

The RET programs are programs in which computer science and engineering faculty collaborate with middle and high school teachers and their students. The RET is a comprehensive teacher professional development in which middle and high school teachers participate in an intensive summer research experience in university computer science and engineering labs, build grades 6-12 curriculum based on the laboratory research content that they learn in the labs, and implement the new curriculum in their classrooms. The programs have the combined intent of bringing contemporary, innovative engineering research to middle and high school students and improving student achievement and interest in science and engineering through scientific inquiry.

### **Key activities**

The RET programs' design and associated activities included a five-week summer intensive experience in which four days per week (9am-4pm) middle and high school teachers fully participated in engineering laboratory research and then one day per week teachers engage in an inquiry focused content-to-pedagogy teacher professional development workshop, building curriculum from their lab research experience with foci on scientific experimentation and improving students' science achievement and literacy. Following the summer intensive research and curriculum building experience, the teachers used the curriculum that they built in their classrooms and engaged in fall and spring semester follow-up. Through this, they engaged in lesson study, studying videotapes of their lessons with one another and engineering faculty with the goal of improving their instructional practices. This follow-up combined lesson study, a proven form of teacher self-study guided by experts, and science literacy professional development. The RET is aligned with Common Core Math and English Language Arts content standards and the national Next Generation Science Standards, which focus on bringing engineering problem solving to America's K-12 classrooms.

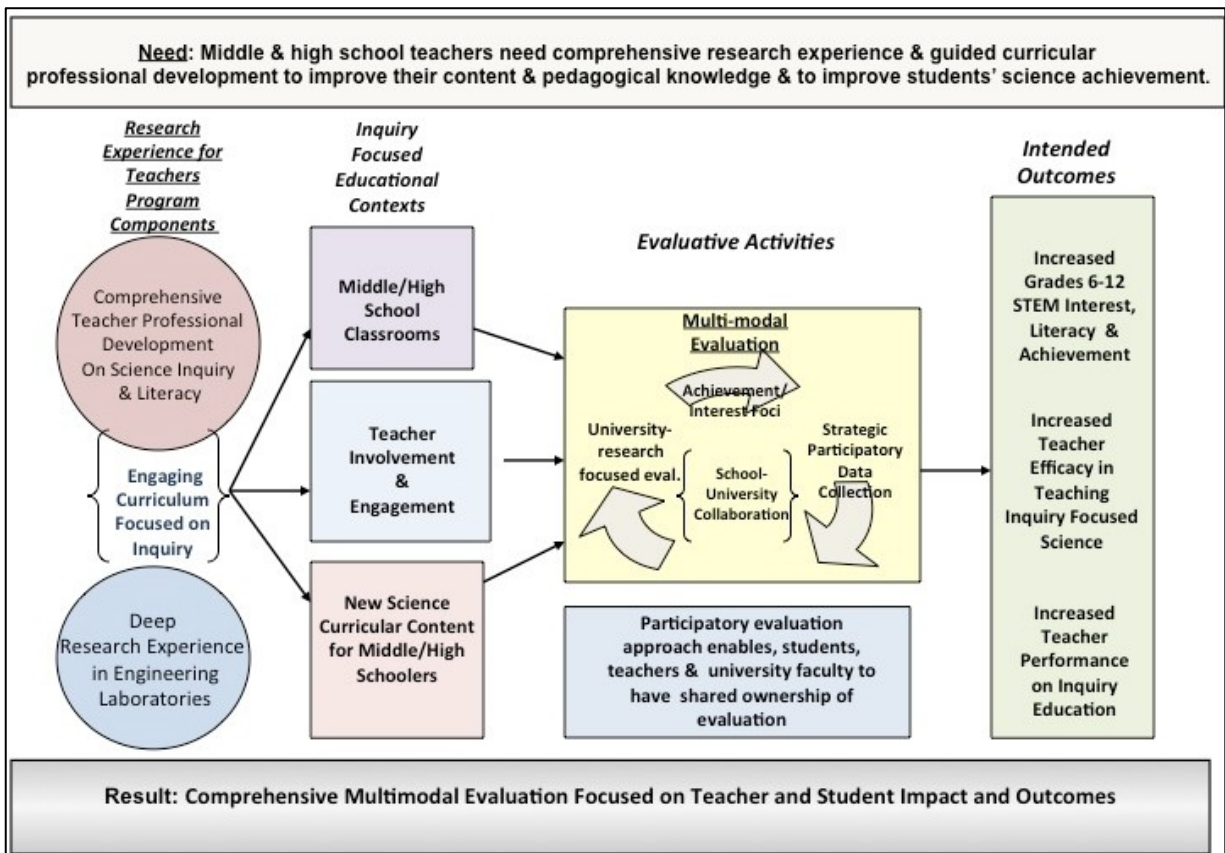
The programs' outcome goals are:

- To increase teachers' knowledge of computationally-focused science and engineering technologies.
- To increase middle and high school teachers' disciplinary pedagogic competence in computer science, engineering, and applied math through a comprehensive professional development program that includes targeted lab-based research experience focused on computer science (CS) and engineering aligned with Next Generation Science Standards (NGSS), Common Core Math Standards (CCMS), and advanced lesson study
- To build and maintain long-term collaborative partnerships between middle and high school teachers and the research community that positively impact student achievement and career paths.

These programs have served middle and high school teachers and their students in urban settings. To date, we have served 53 middle and high school teachers and their 7,420 students (combined in six years; 2010-2015). Accordingly, the programs had both broad-based and deep impact on teachers and students.

### **Impact focused assessment and results**

The RET employs a carefully crafted, outcomes focused approach that is aligned with a teacher performance to student outcomes assessment logic model. Figure 1 (below) illustrates the links between teacher performance and student outcomes in the model.



This logic model indicates how each of the program components relates to the intended outcome goals of the RET.

Aligned with this logic model, five assessment metrics were used to measure the impact of the SRET/ACCESS 4 Teachers RET programs. Two impact measures were used for teachers and three impact measures were used for students. A description of each measure and associated results follow.

### Teacher assessments

- *Teacher Instructional Performance Metric:* This assessment is a rubric scored observational measure of science teacher instructional performance aligned to the state's teacher performance assessment entitled the Teacher Performance Observational Rubric (TPOR).<sup>10</sup> Reliability of this instrument is .79 (Cohen's coefficient alpha, NOTE: a score above .70 is considered a statistically reliable instrument). RET participating teachers were

observed and their teaching performance was scored based on their instructional performance and practice and compared to a statewide sample of the state's science teachers.

- *Science Teaching Efficacy Beliefs Instrument-Revised* (STEBI-R secondary)<sup>11</sup>: This assessment is a teacher metric and is a measure that assesses teachers' efficacy in teaching science to middle school and high schoolers (in other words their belief that they are a science teacher that can improve students' achievement. The instrument includes personal science teaching efficacy (PSTE) and science teaching outcome expectation (the outcomes that they expect from their students, STO). The measure was administered with the teachers before they were in the RET and after they completed it to and compared to non-participant science teachers that match the participant teachers socio-demographically (using state and national data) to measure impacts of the programs on participating teachers. Reliability of this instrument is .89 (Cohen's coefficient alpha).<sup>12</sup>

### **Student assessments**

- *Science Qualitative Reading Inventory*: This assessment is an inventory of science vocabulary, reading comprehension, and science writing achievement and is matched to grade level science content and vocabulary in grades 6-12 science content. Range of reliability of this instrument is .79-.83 (Cohen's coefficient alpha). Students whose teachers participated in the RET program were compared to those whose teachers did not participate in an RET. Science literacy is an achievement measure and is directly correlated to other science achievement metrics (including standardized statewide achievement tests,  $r=.397$ ,  $p<.01$ ) because ability to read and understand science textbooks is critical to understanding science concepts and procedures (including experimentation.) The science reading inventory was administered at the start of the year after the teachers completed the SRET/ACCESS 4 Teachers RET experience and then at the end of the year to measure the gains in students' science literacy as a function of the teachers' improved teaching from participating in the RET experience. During the SRET/ACCESS 4 Teachers RET experience, the teachers received deliberate professional development on how to effectively use science texts with students to improve their science literacy. As such, we measured the impact of this teacher professional development component.
- *Grade and Content Specific Concept Inventories*: These inventories measure grade leveled concepts critical to scientific understanding in middle and high school that are aligned with the grades 6-12 science content standards (and in some cases, the math standards as well). These measures have been designed with the teachers and are reflective of SRET/ACCESS 4 Teachers RET created unit content. They also are aligned with best practices in item response theory (IRT).<sup>13</sup> These inventories are achievement measures of concepts directly aligned with the curriculum (lessons) that the teachers created and implemented resulting from the SRET RET experience. These inventories were administered with students before and after the SRET RET lessons to measure achievement gains in science.
- *Motivation for Science Questionnaire*: This questionnaire measures students' interest, motivation, and engagement in science. Reliability of this instrument is .79 (Cohen's coefficient alpha). Motivation and achievement are directly correlated. Additional motivation and interest in science correlate with students' effort in science coursework and eventual career interest in science fields.

## Results (2010-15)

The STEBI-R measures teachers' science teaching efficacy. Using six years of teaching efficacy data (a composite) and comparing to a national and state data set as comparative data, we have compared the science teaching efficacy of the RET participants to other national studies using  $z$  score adjusted data for multi-construct comparative accuracy. Mean scores for RET participants have been compared to non-RET groups. Table 1 illustrates the comparison of the teacher participants on the STEBI-R teacher measure compared to national measures on science teaching efficacy using the same instrument. The RET teachers had a mean science teaching efficacy of 3.74 and the national average (per other published studies) is 2.47. Table 1 also includes RET teacher participants' percentage gains from start to finish of their RET experience in science teaching efficacy (% gains are computed by denoting the sum score differences pre and post rather than 4-point mean gain).

For a second teacher assessment, we have compared teacher instructional performance using a standardized teacher observational metric, the TPOR (for inservice teachers), to the state's statewide averages. The TPOR is a measure aligned with that which is used to measure instructional performance in preservice and inservice teachers across the state. The mean score on our teacher performance rating (TPOR) for RET participants was 3.61 (partial comparison). The statewide average in single subject science PACT-R rating is 2.89. Our teachers had a 29.4 percent gain pre to post RET program (sum scores were used for this percentage gain statistic). Importantly, we recognize that many factors go into improving teacher performance, and that without controlled comparison, predictions of performance indicators are difficult, however our intention is that statistical comparisons to state and national averages reveals promising SRET RET/ACCESS 4 Teachers teacher results from the programs.

Full comparative results of the teacher impact metrics thus far are indicated in the table that follows (Tables 1). Results are presented as both means (or averages) and percentage gains during start to finish of the RET teacher "intervention" time period. These results are based on two years of combined teacher research and professional development.

Table 1: Teacher Results 2010-2015

<b>Metric</b>	<b>Post – Program Subscale Ave.</b>	<b>Nat'l Subscale Ave.</b>	<b>RET % Total Gains</b>
<b>Teacher Performance (TPOR/ PACT)</b>	3.61	2.89	29.4
<b>Science Teaching Efficacy</b>	3.74	2.47	23.7

These results indicate that the teachers made gains in performance and efficacy during the RET program and that the SRET/ACCESS 4 Teachers RET teacher participants out performed state and national averages on these two metrics.

In addition to conducting teacher performance and efficacy measures, we measured changes in student performance of the teachers who participated in the SRET/ACCESS 4 Teachers RET. Specifically, since one of the RET programs’ intentions are to increase science, technology, engineering and math (STEM) literacy, our curriculum interventions were designed to target science literacy, and we used this metric as a student comparison measure. As such, we designed, administered, and validated a qualitative reading measure for science literacy at both the high school and middle school levels that includes reading comprehension, reading vocabulary in science and writing in science. These data are subject specific and aligned with the newly developed national Common Core standards in English Language Arts by grade level, and the new Next Generation Science Standards, and represent subject specific literacy (e.g. physics literacy, biology literacy, life science literacy, or chemistry literacy.) Results are presented in Table 2 (2010-2015).

We also measured students’ motivation, interest and engagement in science. This was done via a motivation for science questionnaire, which is a four-point Likert-type instrument with 11 subscales adapted from Baker and Wigfield’s Motivation for Reading Questionnaire.<sup>14</sup>

Finally, with regard testing the conceptual knowledge gained from our curricular design that the teachers did during the summer SRET/ACCESS 4 Teachers RET, we designed and implemented a concept inventory as an achievement test for each teacher created “unit of study.” We have the following results for the student metrics in Table 2 (combined 2010-2015).

Table 2: Student Results (2010-2015)

<b>Metric</b>	<b>Pre-pgm. % Score</b>	<b>Post –pgm. % Score</b>	<b>% Gains</b>
<b>Science Knowledge</b> <i>(conceptual understanding)</i>	66.4	91.4	<b>20.5</b>
<b>Science Literacy</b>	52.3	85.2	<b>33.1</b>
<b>Science Interest &amp; Motivation</b> <i>(sum)</i>	51.8	87.3	<b>24.3</b>

These results indicate that the students (on average) made statistically significant ( $P < .05$  across measures) gains during their curricular intervention resulting from their teachers’ participation in the RET programs. They gained knowledge, increased their science interest and motivation, and demonstrated gains in science literacy as well.



The student and teacher focused SRET/ACCESS 4 Teachers RET program data have demonstrated that a teacher intervention results in student outcome gains. These gains are statistically significant, indicating success of the RET programs.

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