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A Seven-Year Study of Middle and High School Teachers Participating in Research Experiences For Teachers Programs: Exploring the Relationship Between Teacher Performance and Student Achievement

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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 seven-years of 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. One program (3 years) 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 classrooms. The second program (4 years) is a high school teacher RET program with similar components. This paper reports the results of both of the RET programs. The two programs had the combined intent of bringing innovative computer science and engineering research to middle and high school teachers and their students and improving teacher performance, while simultaneously improving student achievement through scientific inquiry, engaging students in computational thinking, and engineering design. The programs' design included a summer intensive experience in which teachers fully participated in a computer science or engineering laboratory research and engaged 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 were both aligned with Common Core Math Standards and Next Generation Science Standards and addressed the research question: What is the impact of an intensive research-based teacher professional development program on teacher and student performance?

In total, seventy teachers and their 10,398 students participated in the two RET programs combined. Assessment metrics used to determine the impact of the two RET programs were: 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. The combined program results were the following. The RET teachers had a mean science teaching efficacy significantly higher than the national average. The mean score on teacher performance rating was also significantly higher than the state's average rating. The RET teachers also had a significant performance gain pre-to-post program. Student related results indicated gains as well. Specifically, the participating teachers' students made significant gains during their curricular intervention resulting from their teachers' participation in the RET programs. The students gained science and engineering knowledge, increased their science interest and motivation, and demonstrated gains in science literacy as well. These results indicate that research experience for teachers programs benefit both the teachers and the students that they teach.

Introduction and program need

[Portions of this paper in the review of the literature and research design have been reprinted from the 2016 ASEE Poster Session Papers, which provide preliminary material for the reader.][1]

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[2] 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.[3] Additionally, a recent large-scale study of teachers revealed that secondary teachers indicated a strong need for help in the area teaching in science, and that a weakness of existing professional development was in the lack of attention to the needs of English learners (EL) and the lack of long-term follow up.[4] This suggests a significant need for professional development of the type offered in these RET programs so that all students can benefit. 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, which are represented in this manuscript.

A major reason posited for poor student achievement in science relates to teachers' preparedness in science. Stigler and colleagues[5] 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.[6] 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 (NGSS), 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 and now engineering effectively, deep interconnected subject matter knowledge is crucial in secondary schools.[7] Researchers argue that in-service science teachers, particularly in middle and high schools, fall short in their understanding the depth of contemporary science content and its tied to engineering they are now required to teach.[8,9] For example, Parker et al.[10] 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 which are the subject of this manuscript 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 applied to a lesson study approach.

Programs scope

These RETs are programs in which computer science and engineering faculty collaborate with middle and high school teachers and their students. The RETs are comprehensive teacher professional development opportunities in which middle and high school teachers participate in intensive summer research experiences 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 align it with NGSS standards, and implement the new curriculum in their classrooms. The programs have the combined intent of bringing contemporary, innovative engineering and computer science research to middle and high school students, thereby 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 (9:00 AM-4:00PM) middle and high school teachers fully participate 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, engineering design, NSGG standards and improving students' science achievement and literacy. Following the summer intensive research and curriculum building experience, the teachers use the curriculum that they build in their classrooms and engage in Fall and Spring semester follow-up. Through this, they engage 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 is a proven form of teacher self-study guided by experts, and science literacy professional development. The RETs are aligned with the national Next Generation Science Standards, which focus on bringing engineering problem solving to America's K-12 classrooms.

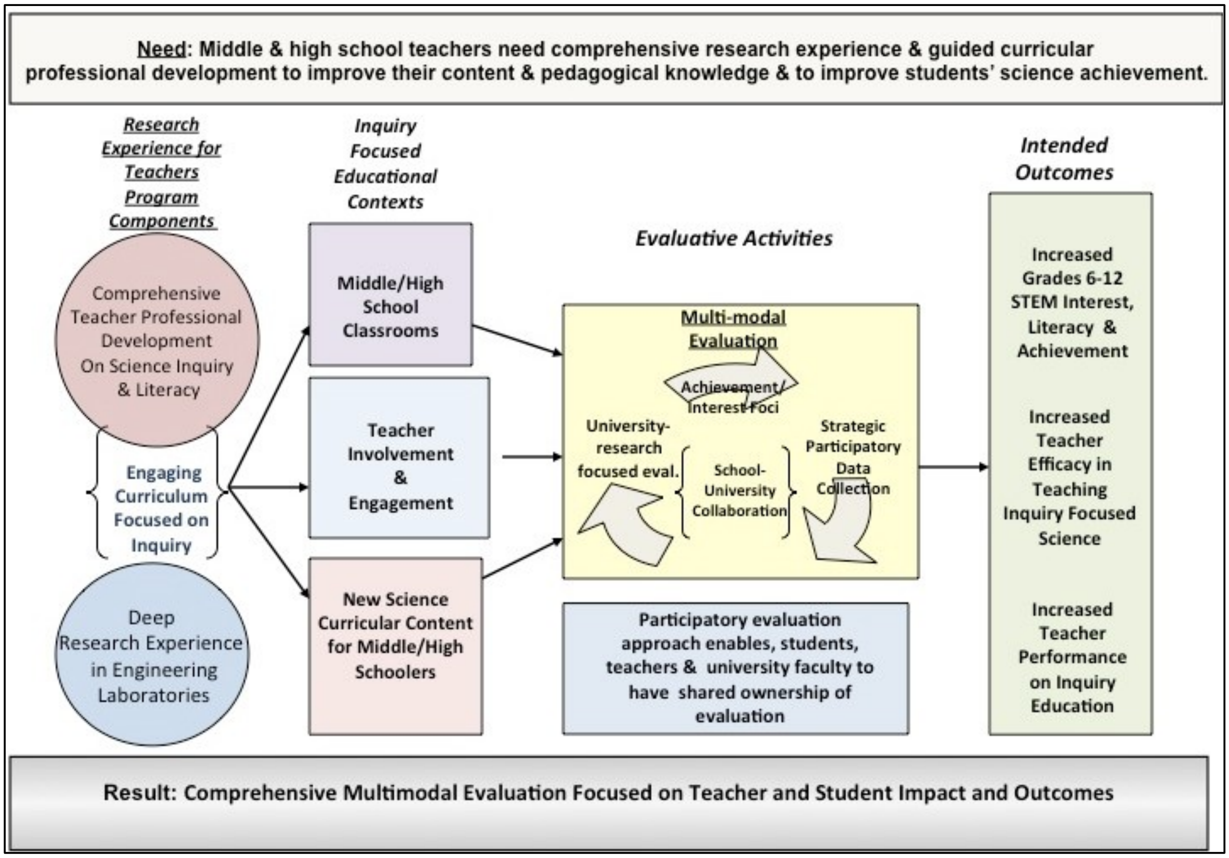
The programs' outcome goals are:

- 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) 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 70 middle and high school teachers and their 10,398 students (combined in seven years; 2010-2016). Accordingly, the programs have 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 aligns teacher performance with student outcomes assessment logic model. Figure 1 (below) illustrates the links between teacher performance and student outcomes in the professional development model.



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

Aligned with this logic model, five assessment metrics are used to measure the combined impact of the SRET/ACCESS 4 Teachers RET programs. Two impact measures are used for teachers and three impact measures are used for students. A description of each measure and associated results across the seven program years 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).[11] Reliability of this instrument is .79 (Cohen's coefficient alpha, NOTE: a score above .70 is considered a statistically reliable instrument). RET participating teachers are observed and their teaching performance is scored based on their instructional performance and practice and compared to a statewide sample of the state's secondary science teachers.
- *Science Teaching Efficacy Beliefs Instrument-Revised* (STEBI-R secondary)[12]: This assessment is a teacher metric and is a measure that assesses teachers' efficacy in teaching science to middle school and high school students (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, STOE). The measure is administered with the teachers before they enroll in the RET and after they complete it and teachers are compared to non-participant science teachers that match the participant teachers' socio-demographic characteristics (using state and national data) to measure impacts of the RET programs on participating teachers teaching efficacy. Reliability of this instrument is .89 (Cohen's coefficient alpha).[13]

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. The range of reliability of this instrument is .79-.83 (Cohen's coefficient alpha). Students whose teachers participate in the RET program are compared to those whose teachers do 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 contemporary science concepts and procedures (including experimentation.) The science reading inventory is administered at the start of the year after the teachers complete 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 receive deliberate professional development on how to effectively use science texts with students to improve their science literacy. As such, we measure 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 grades 6-12 NGSS 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 align with best practices in item response theory (IRT).[14] These inventories are achievement measures of concepts directly aligned with the curriculum (lessons) that the teachers create and implement resulting from the SRET/ACCESS 4 Teachers RET experience. These inventories are administered with students before and after the SRET/ACCESS 4 Teachers RET lessons to measure achievement gains in science, computer science, and engineering.

- *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 and engineering correlate with students' effort in science coursework and eventual career interest in science and engineering fields.

Results (2010-16)

The STEBI-R measures teachers' science teaching efficacy. Using seven 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 programs 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 3.68 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 for this manuscript, we have compared teacher instructional performance using a standardized teacher observational metric, the TPOR (for in-service 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 in-service teachers across the state. The mean score on our teacher performance rating (TPOR) for RET participants was 3.97 (partial comparison). The statewide average in single subject science PACT-R rating is 2.89. Our teachers had a 32.7 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 intent is that statistical comparisons to state and national averages reveals promising SRET/ACCESS 4 Teachers RET 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 seven years of combined teacher research and professional development.

Table 1: Teacher Results 2010-2016

Metric	Post – Program Subscale Ave.	Nat'l Subscale Ave.	RET % Total Gains
Teacher Performance (TPOR/ PACT)	3.97	2.89	**32.7**
Science Teaching Efficacy	3.68	2.47	**21.5**

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 are designed to target science literacy, and we use 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.) Summative results are presented in Table 2 (2010-2016).

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.[15]

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 2010-2016).

Table 2: Student Results (2010-2016)

Metric	Pre-pgm. % Score	Post –pgm. % Score	% Gains
Science Knowledge *(conceptual understanding)*	57.3	92.6	**35.3**
Science Literacy	51.9	87.3	**35.4**
Science Interest & Motivation *(sum)*	54.2	89.3	**35.1**

These multi-year 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. The students 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 two RET programs across time.

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