Impact of Authentic, Mentored Research Experiences for Teachers on Pedagogy (Fundamental)

Dr. Elena Nicolescu Veety, North Carolina State University

Elena Veety received the Ph.D. degree in electrical engineering from North Carolina State University, Raleigh, NC, in 2011. Her research focused on liquid crystal polarization gratings for tunable optical filters and telecommunications applications. Since 2011, she has been a Teaching Assistant Professor of Electrical and Computer Engineering at North Carolina State University. Currently, she is the Education Director for the NSF Nanosystems Engineering Research Center for Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST).

Mr. James Edward Lamberth III, Enloe High School

James Lamberth received a BA in science education and a BS in chemistry from North Carolina State University in 2005. He currently teaches science at Enloe Magnet High School in Raleigh, North Carolina. He is an ASSIST RET (Research Experience for Teachers) fellow, and a Kenan Fellow. He is as an education outreach liaison to the NCSU ASSIST Center.

Mrs. Evelyn L. Baldwin, Wake STEM Early College High School

Evelyn Baldwin has a Master of Education degree and a Bachelor of Science In Science Education degree from North Carolina State University. She has been a public school science teacher for twenty-five years in the Wake County Public School System in Raleigh, North Carolina. She is a 2015 Kenan Fellow and a National Board for Professional Teaching certified teacher in Adolescent and Young Adulthood science. She is an Education Outreach Liason with the ASSIST center at NCSU where she works with classroom teachers and students in the summer Research Experience for Teachers Program and the Young Scholars Program. Additionally, Mrs. Baldwin sponsors a Junior Women in Science and Engineering club at Wake STEM Early College High School.

Impact of authentic, mentored, research experiences for teachers on pedagogy (Fundamental)

Introduction

Research experiences for teachers (RET) programs can provide K-12 teachers with valuable and impactful professional development opportunities, increase teachers' self-efficacy and allow them to gain further mastery in their subject so that they can better translate that knowledge to their students. At a fundamental level, these types of programs are abbreviated apprenticeships in which the teacher trains to become a scientist. After all, if teachers are expected to teach their students how to do science, then they themselves must know how to do science [1].

While RET programs exist at universities across the country, the exact structures of the programs and the nature of the actual research experience vary broadly, making analysis of the overall impacts of these programs difficult. An examination of the literature in this space yields several studies addressing the various impacts of RET programs on teachers and students [2] - [6]. However, the overall body of knowledge in this space is still somewhat limited considering the number of teachers who have participated in these programs. Currently, the National Science Foundation (NSF) reports 81 active RET sites [7]. These are three-year grants generally supporting 10 teachers per year, for a total of nearly 2500 teachers participating in RET programs solely based on active project grants.

This study attempts to build on the body of knowledge by analyzing how the authenticity and scientific rigor of the RET experience impacted teachers' pedagogy over four cohorts of middle and high-school teachers at an NSF funded Engineering Research Center.

Background: The RET Experience

RET sites within Engineering Research Centers (ERCs) have the potential to be very impactful, as they immerse K-12 teachers into a unique research environment. ERCs are multidisciplinary, systems-focused endeavors that integrate cutting-edge research, an industry and innovation ecosystem, and workforce development efforts within a diverse and inclusive community. Within this structure, teachers not only gain real-world technical skills to take back to the classroom, but they have an opportunity to experience how multidisciplinary, multi-institution, systems-driven research comes together towards a high-impact and relevant application.

The program described here takes place at one of these NSF ERCs, the ASSIST Center [8]. ASSIST sits at the interface of health and engineering, with a vision of creating self-powered, vigilant, wearable systems that will enable data-driven insights towards management of chronic conditions like diabetes, asthma, cardiovascular disease, and more. As part of its mission, the Center aims to train the next generation of scientists and engineers who will innovate at these cutting-edge, high-tech interfaces between disciplines. One of the ways we achieve this mission is by empowering K-12 teachers with the skills and resources they need to translate this exciting and imperative work to their students and build the pipeline of future scientists and engineers.

Through the RET program, teachers are immersed in the Center's research and innovation ecosystem, exploring a variety of topics including: wearable sensors, electronics, integration of sensors/electronics into textiles, energy harvesting modalities for battery-free operation, systems level design, data management, and human factors in engineering design.

During the program teachers create and implement lesson plans that integrate the information they have learned from their RET experience into the classroom, focusing on the Engineering Design Process used in the Center research environment. Giving teachers the hands-on experience of working in a university lab environment enables them to bring relatable, relevant problems to their students. Experiences lead to excellent lessons that spark students' interest and help promote the value of STEM fields to future undergraduates. This program encourages teachers to integrate their new knowledge and engineering design expertise into lessons that encompass the NGSS (Next Generation Science Standards) crosscutting concepts. Every teacher in the program experiences wearable system design elements that demonstrate patterns, cause and effect, scale proportion and quantity, systems and system models, energy and matter, structure and function, and stability and change [9].

Currently in its 7th year, the ASSIST program at NC State University has hosted 6 cohorts of summer RETs for a total of 64 participants. The participants included teachers from a variety of disciplines at both the middle and high school level. All teachers participated in a 5-week summer program, which provided a $5,000 stipend. During the program they received training in both technical and professional skills as well as overall exposure to the Center's research. Teachers were instructed by ASSIST Center faculty and given the opportunity to conduct experiments in active lab environments, while also working in teams to design a functioning wearable system.

This study represents one of the Center's efforts to examine and understand the practical impacts of its RET programs on teachers, and by extension their students. While our pre and post-surveys from this program have indicated positive outcomes including overall teacher satisfaction and improved self-efficacy, the aim here is not teacher perception, but rather understanding how the research experience impacts the lessons that are presented in the classroom.

Research Question/Hypothesis

The fundamental research question of this study is: ***Does an independent in-lab research experience for an RET have an effect on the overall quality, content, depth of technical understanding, teaching strategy, and originality of their lesson plans?*** Specifically, we hypothesize that adding the authentic research experience involving an independent project conducted in a lab under the direction of a Center faculty member and graduate student, will lead to more technically rigorous and original lesson plans, and may lead to teachers adopting more student-centered teaching strategies. This is under the assumption that professional development activities and other aspects of the RET program are kept as uniform as possible for all participants.

Methods

For the purpose of this study, we look at the past 4 cohorts of teachers (2015-2018). We omit the two years prior to 2015, since the program was still under development leading to a lack of uniformity in the program's implementation, activities, and expectations. The four cohorts that are part of this study include a total of 41 teachers: 16 in 2015, 16 in 2016, 5 in 2017, and 4 in 2018. We separated the cohorts into 2 experimental groups. Group A includes the larger cohorts from 2015 and 2016 and Group B includes the smaller cohorts from 2017 and 2018. Group A consisted of 32 teachers, 53% High School and 47% Middle School. Group B consisted of 9 teachers, 89% High School and 11% Middle School. The teachers' subject area expertise included Science, Math, Career and Technical Education (CTE), English, History, Health/PE, and Special Education). Figure 1 shows the percentage of teachers by primary subject area taught.

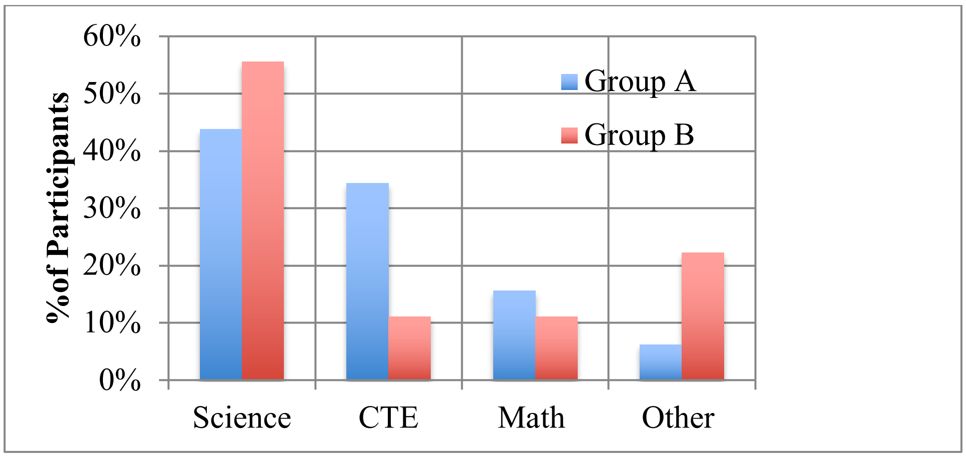

Figure 1: Percentage of participants by subject area taught. The "other" category includes English, History, Health/PE, and Special Education.

Both groups received similar training in terms of technical skills, professional skills, group engineering design project, and overall exposure to the Center's research. However, Group B had the opportunity to engage in an authentic independent research project under the mentorship of one of the Center's faculty, while Group A had a broad introduction to a wider variety of research activities. Due to time constraints, some of the tours and research-related hands-on activities had to be omitted to allow time for the research experience. In essence, this led to a more in-depth authentic research experience (Group B), as opposed to a more superficial exploration of a broader range of research topics (Group A).

The reason for this difference in experience was logistical. With a large cohort (16 teachers), it was not feasible to assign each teacher to an individual faculty member's lab. Instead, the various researchers brought presentations, demonstrations, and workshops to the group. The smaller cohorts allowed us the flexibility to place each teacher in a lab for three days every week to get a more in-depth and authentic research experience.

The sample schedules in the table below illustrate the similarities and differences in the research experience between the two sets of cohorts:

Table 1: Comparison of schedule of activities for the two groups of teachers

Schedule	**Group A: Large Cohorts (2015-2016)**	**Group B: Small Cohorts (2017-2018)**
Week 1	• Introduction to ASSIST Center • Teaching the Engineering Design Process • Introductions to One Health Initiative, Ideation, Arduino Programming • ***Tour: College of Textiles***	• Introduction to ASSIST Center • Teaching the Engineering Design Process • Introductions to One Health Initiative, Ideation, Arduino Programming • ***Independent Research in ASSIST Lab***
Week 2	• Week-long professional development retreat	• ***Mon-Wed: Independent Research Project Work*** • Professional Development Activities including Lesson Plan Development
Week 3	• ASSIST Research Highlights: Hands-on workshops, tours, and presentations from two ASSIST Labs focusing on: Energy Harvesting, and Wearable Devices. • Work on Group Engineering Design Project. Focus on Criteria and Constraints, Ideation, and background research.	• ***Mon-Wed: Independent Research Project Work*** • ASSIST Research Highlight: Energy Harvesting • Work on Group Engineering Design Project. Focus on Criteria and Constraints, Ideation, and background research.
Week 4	• Arduino programming and circuits training • Work on Group Engineering Design Project: First Prototype Due • Research Highlight: Low power wearable sensors.	• ***Mon-Wed: Independent Research Project Work*** • Arduino programming and circuits training • Work on Group Engineering Design Project: First Prototype Due
Week 5	• Complete Group Engineering Design Project. • ***Tour of ASSIST Industry Member and environmental testing labs.***	• ***Mon-Wed: Independent Research Project Work*** • Complete Group Engineering Design Project.
Final Deliverables	• 2 Lesson Plans • Group Engineering Design Project: Prototype and Poster Presentation • 1 Classroom Demo based on ASSIST research	• 2 Lesson Plans • Group Engineering Design Project: Prototype and Poster Presentation • Independent Research Project Poster Presentation

Each participant was asked to develop two lesson plans for their classrooms based on the research experience. Group A had an 81% submission rate for lesson plans (52 lessons) and group B had a 78% submission rate (14 lessons). All identifying information on the 66 submitted lessons was redacted to ensure impartial analysis. Lessons were assigned a key that would enable the identification of their original cohort after all lesson plans were read and analyzed for content. Two individuals with expertise in STEM education read, analyzed, and rated every lesson based on the following criteria:

1. 5-point Likert Scale Evaluation of Lesson: Overall Quality, Originality, and Level of Scientific Rigor.
2. Qualitative analysis of research themes addressed and teaching strategies employed.
3. Quantitative measures including: duration of lesson (# of class periods) and whether standards and assessments are included.

Several steps were taken in the data collection process to address construct validity as well as reliability of the data. First, in order to remove researcher bias, all lesson plans were redacted to remove date, author, and school information. The lesson plan's grade level however was intentionally retained to aid the researchers in assessing each lesson plan in the context of its intended grade level. This step helps to avoid confounding the students' age group with the Scientific Rigor, which is the construct we are intending to assess. Thus, in terms of level of scientific rigor, researchers considered the technical detail, scientific accuracy, and depth of technical content covered in the lesson as they relate to the grade-level appropriate standards (NGSS or state standards). In terms of overall quality, lessons were judged on characteristics including: completeness, quality/clarity of writing, whether standards and appropriate assessments were included, and whether the lesson was 'ready to teach' (i.e. could another teacher with a similar background take the lesson as-is and present it without major modification). In terms of originality, researchers judged to what extent the concepts and activities explored in the lesson were unique or original, as opposed to a re-hashing of activities/concepts that either: (i) were introduced to the teachers as part of the RET program, or (ii) are commonly used/well known activities for that grade level.

It is important to acknowledge that the data gathered is through the lens of the researchers who are reading and analyzing the lesson plans. In this case, the lesson plans were read by two individuals that have 13 and 25 years of teaching experience, are leaders in their respective departments, are familiar with the various applicable standards, and have a familiarity with the RET program and the types of activities/training provided therein. Both individuals read and rated every lesson plan. To ensure reliability, we compared the Likert scores in each category for both individuals and concluded that there were no statistically significant differences ($p>0.05$ observed in all categories) between the two researchers' scores.

Finally, it must be noted that while every lesson plan submitted from both Cohorts of teachers was analyzed, giving us a complete representation of our population, we cannot make any claims about the generalizability of these results to either a broader RET participant population, or a broader teacher population.

Results and Analysis

In terms of overall lesson quality, originality, and depth of scientific rigor on a 5-point Likert scale, with 1 being poor and 5 being excellent the average scores of the two groups are given in Table 2. Statistical analysis was performed on the scores with a significance level of 0.05, therefore a p-value of less than 0.05 suggests strong evidence against the null hypothesis, in this case that the two groups are equivalent. The calculated p-values (given in Table 2) indicate that, while the scores for Group B were overall higher in all categories, the only statistically significant difference appeared in the "Depth of Scientific Rigor" category. Thus, we conclude that a more authentic and scientifically rigorous research experience is likely to translate into a more scientifically rigorous lesson for the students. This supports the Feldman et al. general and fundamental premise, that to teach someone how to do science, one must first understand how to do science.

Table 2: Comparison of lesson plan originality, depth of scientific rigor, and overall quality across the two experimental groups on a 5-point Likert scale.

	Group A N=52	**Group B N=14**	**Statistical Significance**
Originality	3.50	3.75	p=0.2
Depth of Scientific Rigor	3.23	4.18	p =0.0002
Overall Quality	3.28	3.75	p=0.05

The lessons were also analyzed for presence of some key research and engineering themes relevant to the Center including: Energy Harvesting, Sensors, Nanotechnology, Wearable Technologies, One Health, Engineering Design Process, Programming and Hardware, etc. It is important to note that both groups were introduced to all of these topics in some way. Table 3 below shows the percentage of lessons in each group that contained these themes. The notable result here is that the more technical themes (Nanotechnology and Energy Harvesting) appeared in a significantly higher percentage of the Group B lesson plans. Meanwhile, the less technical topics that teachers have more familiarity with (i.e. Engineering Design Process, Sensors, and Wearables) appeared in higher percentages of the Group A lessons. This trend indicates that Group B, having had a more advanced research experience, felt more comfortable selecting advanced topics to share with their students.

Table 3: Percentage of lesson plans in each group that contained each of the listed themes.

Topics	**Group A N=52**	**Group B N=14**
Nanotechnology	2%	21%
Energy Harvesting	10%	14%
Engineering Design Process	41%	29%
Sensors	43%	36%
Programming and Hardware	28%	25%
Wearable Technologies	30%	21%
One Health Initiative	33%	32%
Other	6%	7%
None	7%	4%

Teaching strategies were identified in the lessons to determine whether teachers tended toward more teacher-centered strategies such as direct instruction/demonstration rather than student-centered approaches including Project Based Learning or Inquiry-Based lessons. Table 4 summarizes these results.

Table 4: Percentage of lessons in each group demonstrating various pedagogical strategies.

Strategies	**Group A N=52**	**Group B N=14**
One or 2 strategies observed	24%	32%
Multiple different strategies observed	76%	68%
Direct Instruction	74%	50%
Teacher Demonstration	23%	4%
Class Discussion	45%	64%
Group Work or Discussion	91%	93%
Experiment or Lab	50%	43%
Inquiry-Based	29%	25%
Project Based Learning (PBL)	32%	21%

This data indicates that both groups tended toward using multiple pedagogical strategies within their lessons. A majority of lessons showed a blended teaching style that combines aspects of both teacher-centered and learner-centered approaches. However, it is notable that Group B showed a significant decrease in the percentage of lesson plans that included Direct Instruction and Teacher Demonstration. Group B also tended towards more class discussion and group work. Finally, the percentage of lesson plans that included only Direct Instruction/Demonstration and Discussion (no Experiment, Inquiry, or PBL) decreased from 22% (Group A) to 18% (Group B). This seems to support the conclusion that a more rigorous research experience provided teachers with more in-depth knowledge, which in turn made them more comfortable moving away from strictly teacher-centered instruction towards learner-guided experiences.

However, it must also be noted that a slight decrease in the experiment, inquiry-based, and PBL lessons was also recorded between group A and B. It is possible this result is related to the fact that teachers in Group B chose to write shorter lessons (36% of the lessons were for a single class period and 39% were for 2-4 class periods). Conversely, only 16% of lessons in Group A were single-class lessons and 24% were unit lessons lasting longer than 1 week. Longer, unit-style lessons, may be more easily suited to PBL and inquiry-style approaches.

A few final metrics for evaluation of the lesson plans included the presence of Next Generation Science Standards (NGSS) and/or North Carolina State Standards and appropriate assessments and rubrics. Teachers in both groups overwhelmingly included NGSS in their lessons (95% of Group A and 100% of Group B). In terms of rubrics and assessments, 75% of Group B and 64% of Group A included these. This result suggests that both groups of teachers had a good baseline understanding of how to write a complete and high-quality lesson plan that will fit in their required curriculum.

Conclusion

This study aimed to analyze how the authenticity and scientific rigor of the RET experience impacted teachers' pedagogy. The two experimental groups of teachers participating in the program received similar training in terms of technical skills, professional skills, and overall exposure to the Center's research. However, group B had the opportunity to engage in an authentic, scientifically rigorous, independent research project under the mentorship of one of the Center's faculty, while group A had a more superficial introduction to a wider variety of research activities. Teachers in both groups were asked to write two lesson plans based on their RET experience. These lesson plans were analyzed to determine in what ways the research experience impacted pedagogy.

Taken as a whole, the data seem to suggest that a more authentic research experience is likely to translate to more technical depth in the lesson plan. While no significant differences were seen in lesson plan originality and general quality, it is evident that the group that undertook a more rigorous research project ended up presenting a more scientifically rigorous lesson to their students. These teachers also tended away from strictly teacher-centric instruction, although a commensurate increase in completely student-centric pedagogy was not observed. It appears teachers in group B opted for blended learning styles and also lessons that were more focused, technical, and shorter in duration.

References:

[1] A. Feldman, K. Divoll, and A. Rogan‐Klyve, "Research education of new scientists: Implications for science teacher education," *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, vol. 46, no. 4, pp. 442-459, 2009.

[2] M. M. Pop, P. Dixon, and C. M. Grove, "Research Experiences for Teachers (RET): Motivation, Expectations, and Changes to Teaching Practices due to Professional Program Involvement," *Journal of Science Teacher Education*, vol. 21, no. 2, pp.127-147, 2010.

[3] S. Yavuz, "Who are the Science Teachers that Seek Professional Development in Research Experience for Teachers (RET's)? Implications for Teacher Professional Development," *Journal of Science Education and Technology*, vol. 22, no. 6, pp. 934-951, 2013.

[4] P. Enderle, et al, "Examining the influence of RETs on science teacher beliefs and practice," *Science Education*, vol. 98 no. 6, pp. 1077-1108, 2014.

[5] D. K. Capps, and B. A. Crawford, "Inquiry-Based Professional Development: What does it take to support teachers in learning about inquiry and nature of science?" *International Journal of Science Education*, vol. 35 no. 12, pp.1947-1978, 2013.

[6] M. R. Blanchard, and V. D. Sampson, "Fostering Impactful Research Experiences for Teachers (RETs)," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 14 no. 1, pp. 447-465, 2017.

[7] National Science Foundation, "Research Experiences for Teachers (RET) in Engineering and Computer Science ". [Online]. Available: https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505170. [Accessed: Feb. 1, 2019].

[8] The Center for Advanced Self-Powered Systems of Integrated Sensors and Technologies. [Online]. Available: https://assist.ncsu.edu. [Accessed: Feb 1, 2019].

[9] National Science Teachers Association, “Next Generation Science Standards, Crosscutting Concepts”. [Online]. Available: https://ngss.nsta.org/CrosscuttingConceptsFull.aspx. [Accessed: March 1, 2019].

.

.