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An Evaluation of a Research Experience Traineeship (RET) Program for Integrating Nanotechnology into Pre-College Curriculum

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Introduction

Nanotechnology has become a national focus throughout the United States with more than 24 billion USD of cumulative federal support towards nanotechnology research and development since 2001.[1] In the last 20 years, research and development in this space has led to a number of revolutions in electronics, photovoltaics, manufacturing, medicine and much more. One of the primary goals of this federal funding, as described by the inter-governmental body, the Committee on Technology Subcommittee on Nanoscale Science, Engineering, and Technology (NSET), has been to develop educational resources that will ultimately lead to a skilled workforce who will continually advance the state of the art of nanotechnology.

This study explores the impact of one summer's implementation of an NSF-funded Research Experiences for Teachers professional development K-12 program designed towards the end described by NSET. Specifically, the Research Experiences for Teacher Advancement in Nanotechnology (RETAIN) program at a large public Midwestern University was designed to provide 30 K-12 teachers (10 per year, primarily high school level) from high-needs, urban school districts with research experiences and shared activities designed to increase their understanding of the challenges and demands of nanotechnology, as well as college and career opportunities in science, technology, engineering, and mathematics (STEM) fields. In addition to these research experiences, our multi-disciplinary team sought to lead participants in the creation of 15 hands-on inquiry-based teaching modules (5 per year) that integrate multiple STEM disciplines, convey scientific-process skills, and align with Indiana Academic Standards[2] and the Next Generation Science Standards[3].

We frame this study as research evaluation, as our initial focus was on evaluating programmatic outcomes with the intention of improving the program itself through a cyclical process of research to practice[4]. In this paper, our scope extends to the broader scholarly community: here we build on our evaluation results, with the aim of extending the body of knowledge pertaining to STEM professional development opportunities similar to this one.

Research Experiences for Teacher Advancement in Nanotechnology (RETAIN) Overview

The primary objectives of this RET site included the following:

- Provide 30 high school teachers (10 per year) from high-needs, urban school districts with research experiences and shared activities designed to increase their understanding of the challenges and demands of nanotechnology, collaborative research, and college/career opportunities in STEM fields.
- Lead participants in the creation of 15 hands-on, inquiry-based teaching modules (5 per year) which integrate multiple STEM disciplines, convey scientific-process skills, and align with Indiana State Standards and Next Generation Science Standards (NGSS)
- Introduce teaching modules and classroom assessment strategies into targeted school districts in an effort to cultivate a positive image of, and greater interest in, STEM fields among urban secondary students, many of whom are from underrepresented groups.

- Support the broader RET community by disseminating logistics, schedules, outcomes, deliverables, best practices, and evaluation procedures via the RETAIN website

To meet these objectives, our team developed an immersive 6-week summer experience. The primary component of the teachers' experiences within this summer professional development opportunity included conducting scientific, nanotechnology-related research in labs at a large public Midwestern University under the guidance of individual faculty mentors. Research topics included but were not limited to the design of artificial biomembrane-mimicking systems for cell substrate applications; integrated wireless sensor systems; nano-batteries and characterization; and fabrication and testing of paper-based lithium ion batteries. The main deliverable from this experience was an abstract and research poster that teachers presented during a session at the university. Yet, beyond this, 9 of 10 teachers from the summer of 2015 presented at a local academic conference, and several teachers not only contributed to research in these topics, but also have been or will be featured as co-authors or acknowledged as contributors in peer-reviewed publications.

In addition, during their summer experience, teachers participated in two graduate-level courses, each meeting twice a week. One course focused on careers in nanotechnology while the other focused on pedagogy and module/lesson development. In 2015, the main deliverable for the Nanotechnology Careers Course was a Career Module created by three groups of teachers based on the 2014 National Nanotechnology Initiative Strategic Plan and data from national, state and local workforce development entities to help depict the career opportunities in nanotechnology and the academic and skills attainment that their own students would need in preparation for those careers. The main deliverable for the pedagogy and lesson plan development course was for students to produce five lesson plans centered on their various teaching content areas (biology, earth/space science, chemistry, physics, engineering technology, etc.) which incorporated a nanotechnology-based theme.

Study Overview

In this multi-methods research evaluation, we sought to understand the impact of this professional development opportunity on teachers' understanding of nanotechnology and STEM, as well as their commitment to inquiry-based teaching practices. In addition, we attempted to identify the impact of the teachers' integration of nanotechnology into their classrooms on their students' attitudes towards STEM fields (namely, science, mathematics, engineering and technology), students' perceptions of their 21st Century Learning skills, and career interests. We utilized both survey and observational data to address these objectives, as indicated in Table 1.

We addressed each of the questions shown in Table 1 sequentially and in separate phases. In the first phase, we looked in-depth at survey responses from all teachers who participated in this six-week nanotechnology summer research program in 2015 and who then integrated nanotechnology into the classroom over the 2015-2016 academic school year. Second, we report observational data from five teachers' nano-lessons by using a modified version of the Science Teacher Inquiry Rubric (STIR).[5] Third, using the Student Attitudes toward STEM (S-STEM) survey,[6] we present changes in these teachers' students' attitudes towards STEM, as well as changes in students' perceptions of their own 21st century skills. Lastly, we report changes in students' reported interests in 12 STEM careers.

Table 1. Overview of Research Evaluation Questions and Methods

Research Evaluation Questions	Method	Participant
Q1. To what extent does the RETAIN program influence participants' understanding and perceptions of nanotechnology?	Pre/post survey	Teachers
Q2. When delivering their nano-lessons, to what extent did teachers utilize a student-centered and inquiry-based pedagogy in their classrooms?	Classroom observations	Teachers
Q3. To what extent do the students of RET participants demonstrate improved attitudes towards STEM after experiencing a nano-lesson or series of lessons?	Pre/post S-STEM	Students
Q4. To what extent do the students of RET participants report changes in their career interests and academic pathways?	Pre/post S-STEM	Students

Participant Overview

During the summer of 2015, ten high school teachers (nine female and one male) from the local university's urban school districts spent six weeks on the university campus involved in various areas of nanotechnology research. In the subsequent school year, they integrated some aspect of nanotechnology into their course. Six of the teachers had five years or less of teaching experience and four of the teachers had six to ten years of previous teaching experience. Participants were primarily female (n = 9). Teachers taught courses in astronomy, biology, biomedical sciences (through Project Lead the Way), chemistry, and physics. One course was in K8, whereas all other courses were K9-12. Three participants self-identified as African American, five as white or Caucasian, and two as multi-racial.

Phase 1: Nanotechnology Careers & Perceptions Survey

In Phase 1, we addressed the question, "To what extent does the RETAIN program influence participants' understanding and perceptions of nanotechnology?" To address this question, our team developed two constructs, each with four items set on a 5-point Likert-type scale where 1 corresponded with Strongly Disagree, 5 with Strongly Agree, and 2 through 4 represented middle points along the 5-point distribution. The first construct, ***Nano-careers***, was designed to gauge teachers' self-reported understanding of nanotechnology careers, whereas the second construct, ***Nano-potential***, was designed to gauge their perceptions of the future potential of nanotechnology. We combined pre and post survey responses when computing Cronbach's alpha for each construct and found that each had good to excellent internal consistency reliability[7] ($\alpha_{\text{Nano-careers}} = .937$; $\alpha_{\text{Nano-Potential}} = .810$). Table 2 provides an overview of responses before teachers' participation in the RETAIN program and approximately one year later, after teachers had completed the RETAIN program and integrated nanotechnology into their classes.

Table 2. Nanotechnology Careers & Perceptions Survey Results (Pre and Post)

Construct (internal consistency reliability) and Construct items	Pre		Post	
	Mean	**STDEV**	**Mean**	**STDEV**
Nano-Careers (α = .937)	**2.05**	**0.93**	**3.90**	**0.29**
I understand the career opportunities in nanotechnology.	2.00	0.94	4.10	0.32
I am knowledgeable concerning the requirements for admission to a nanotechnology program.	1.90	0.99	3.90	0.32
I am aware of opportunities for majoring in nanotechnology at [the university].	2.40	1.17	3.90	0.74
I am knowledgeable about various nanotechnology majors available to students.	1.90	0.99	3.70	0.95
Nano-Potential (α = .810)	**3.88**	**0.62**	**4.00**	**0.33**
Nanotechnologists are innovative.	4.30	0.67	4.30	0.48
I like the scope and variety of work that is conducted using nanotechnology.	3.80	0.79	4.20	0.42
Nanotechnology plays an important role in solving society's problems.	3.70	0.67	3.80	0.63
Nanotechnology has contributed greatly to fixing problems in the world.	3.70	0.67	3.70	0.48

An inspection of the histogram of responses to each construct indicated that the data were approximately non-normal. Due to this and the small sample size, we performed Wilcoxon Signed Rank Tests[8], the non-parametric alternative to paired t-tests, to identify whether participants' responses significantly changed for each construct as a result of their participation in the RETAIN program. For the Nano-Careers construct, this test revealed a significant increase in participants' understanding of nanotechnology careers, $z = -2.710$, $p < .01$, with a large effect size[9] ($r = .61$). Specifically, median responses to the Nano-Careers construct increased from pre-program ($Md = 2.00$) to post-program ($Md = 3.88$). In contrast, participants' perceptions of nanotechnology's potential did not change significantly, $z = -.656$, $p = .512$, with a small effect size[9] ($r = .15$). While median responses to the Nano-Potential construct did not change between pre- and post-program ($Md = 4.00$), a closer inspection revealed that five participants' mean responses showed a positive change, four showed a negative change, and one did not change.

Phase 2: Teachers' use of student-centered and inquiry-based pedagogy

In this second phase, we addressed the question, "When delivering their nano-lessons, to what extent did teachers utilize a student-centered and inquiry-based pedagogy in their classrooms?" RETAIN participants were tasked to create five nanotechnology based teaching lessons that corresponded with their teaching area (e.g., biology, chemistry, physics). To address this evaluation question, we report quantized observational data of these lessons. Specifically, our observations were conducted using a modified version of the Science Teacher Inquiry Rubric (STIR). The STIR rubric was developed based upon the National Science Education Standards' essential features of inquiry instruction.[10] STIR has been tested for validity for use as an observation tool with very good inter-rater reliability.[5]

The STIR rubric guides observers with respect to the following five curriculum features:

1. Learners are engaged by scientifically oriented questions.
2. Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
3. Learners formulate explanations and conclusions from evidence to address scientifically oriented questions.
4. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
5. Learners communicate and justify their proposed explanations.

The rubric is used to elucidate the extent to which teachers utilize a learner centered versus a teacher centered pedagogy with respect to each of these five curriculum features. Each of these features are evaluated with one question prompt on the rubric, with the exception of feature two which includes two question prompts, as shown in Appendix A. For each of these prompts, the observer marks one of five options. For our purposes, a "1" represented instruction that was entirely student-centered whereas a "4" indicated that the instruction was entirely teacher-centered. The observer may also indicate if the question prompt was not applicable to the lesson.

Five of the ten RETAIN teachers' nano-lessons were observed by three different scholars. These observers met to discuss the observation protocol prior to any classroom observations. Then, after each of these scholars observed the same lesson, they discussed their coding of the common observation and talked through any discrepancies. The coders next revisited their solo-observation-STIR scores and revised their coding in light of this group discussion. In this way, alignment was sought between observers, thereby enhancing the trustworthiness of the findings.

Often, a teacher's lesson would include multiple components. For example, one teacher began class by prompting students to think about prior learning. Then students worked in teams of two to four on one of two activities: they either finished a poster which included a literature review or they utilized YouTube videos to answer pre-determined questions. Hence, the observer coded these two course components separately. When quantizing the results, we took the average of the two course components. If one component was marked as "not applicable" and the other component was marked with a score, we only report the component that had a score, thereby ignoring the "n/a". Table 3 provides an overview of these quantized results.

Table 3. STIR Observation Quantized Results

Feature No. Feature Description	**Mean**	**SD**
1. Learners are engaged by scientifically oriented questions.	3.2	0.3
2. Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.	2.7	1.0
3. Learners formulate explanations and conclusions from evidence to address scientifically oriented questions.	2.7	1.0
4. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.	2.6	0.8
5. Learners communicate and justify their proposed explanations.	3.3	0.7

Note: A "1" depicts entirely student-centered pedagogy whereas "4" depicts entirely teacher-centered pedagogy

One potential misconception from Table 3 is that a score closer to one is necessarily better. In contrast, we hoped to rather see observations marked around the mid-point at 2.5. This would indicate that teachers navigated between teacher-centered and student-centered pedagogy. Such instructional strategies empower students to learn while not leaving them to fend for themselves, so to speak. In other words, here teachers let students grapple with uncertainty while still facilitating their learning as would a coach or a guide. Such pedagogy is supported by developmental theorists who follow Vygotskian and social constructivist traditions.[11]

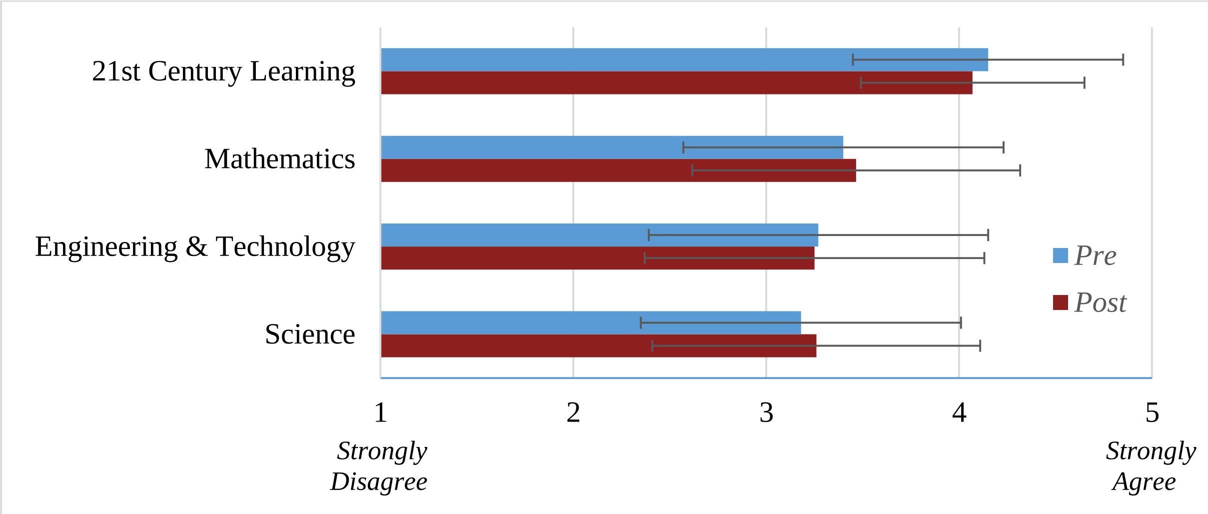
On average, the RETAIN teachers tended towards a more teacher-centered pedagogy. In other words, most often teachers specified a problem statement or scientific question for students to engage with ($\mu = 3.2$). While still slightly teacher-centered (on average), they were less directive as to what evidence students should collect ($\mu = 2.7$), how students should analyze that evidence ($\mu = 2.7$), and how students should explain their findings ($\mu = 2.6$). Interestingly, however, teachers tended to specify how the answer should be scoped rather rigidly ($\mu = 3.3$). We posit that teachers tended towards a more teacher-centered pedagogy with *some* inquiry-based learning in the middle of the lesson in order to quickly move through the lesson. While they may have touched on a nano-topic, often they moved quickly onto other course components that they needed to allocate more times towards for state testing. Therefore, teachers did not have learners engage in a holistic scientific procedure, which may take multiple lessons or even weeks, which would then provide greater potential for more student-centered than teacher-centered approaches.

Phase 3: RET Students' Attitudes towards STEM

In this third phase, we addressed the question, "To what extent do the students of RET participants demonstrate improved attitudes towards STEM after experiencing a nano-lesson or series of lessons?" The S-STEM survey was designed for K-12 students. The survey invites students to provide information about their attitudes toward science, technology, engineering and math subjects, postsecondary pathways, and career interests. The first four sections of the survey have items that load onto one four constructs. Each construct contains a series of items set on a 5-point Likert-type scale ranging from *strongly disagree* (1) to *strongly agree* (5). The four construct included the following (for construct items, see Appendix B):

1. **Math**: Mathematics self-efficacy, interests, and perceptions of its future value
2. **Science**: Science self-efficacy, interests, and perceptions of its future value
3. **Engineering/Technology**: Engineering/technology self-efficacy, interests, and future value
4. **21st Century Learning**: Confidence in communication, collaboration, self-directed learning

RETAIN participants were asked to give the S-STEM survey to students as a pre-test and post-test. As teachers were on the semester system, like universities, they receive a new set of students each semester. Hence, RETAIN teachers were asked to give the S-STEM survey as a pre-test in August (beginning of the Fall semester) or January (beginning of the Spring semester) and to give the S-STEM survey again as a post-test in December (end of the Fall semester) or May (end of Spring semester). Four teachers had students complete both the pre/post S-STEM survey at one of these times. In total, we received 155 complete pre/post responses, although one teacher provided students with a condensed survey. Specifically, these students only received all of the items on the math construct. Figure 1 provides an overview of the average responses to the constructs: for missing data, cases were excluded pairwise (e.g., for individual constructs) rather than listwise.



Construct	n	Pre			Post		
		μ	σ	α	μ	σ	α
21st Century Learning	116	4.15	.58	.93	4.07	.70	.96
Mathematics	145	3.40	.85	.91	3.47	.83	.90
Engineering & Technology	113	3.27	.88	.92	3.25	.88	.93
Science	118	3.18	.88	.90	3.26	.82	.91

Figure 1. RET Students' STEM Attitudes (pre/post)

As Figure 1 shows, all responses were positive. The most positive post-course responses were to the 21st Century Learning construct ($\mu = 4.07$), followed by Mathematics ($\mu = 3.47$), Science ($\mu = 3.26$), and Engineering & Technology ($\mu = 3.25$). The Shapiro-Wilks coefficients of the difference scores indicated that the data were approximately non-normal. Hence, Wilcoxon Signed Rank Tests were conducted to evaluate the impact of the intervention on students' responses to each construct. Despite the slight increase in students *average* responses to the Mathematics construct, this test revealed an overall decrease in students' Mathematics responses from pre ($Md = 3.62$) to post ($Md = 3.50$), $z = -2.29$, $p < .05$, with a small effect size[9] ($r = .19$). No other significant changes were found.

Phase 4: RET Students' Future Career Interests

In this fourth and final phase, we addressed the question, "To what extent do the students of RET participants report changes in their career interests and academic pathways?" In addition to the survey constructs described in Part 3, the "Your Future" section of the S-STEM asks students to identify their interest in specific STEM fields. Students responded to items set on a 4-point Likert-type scale ranging from *Not at all interested* (1) to *Very interested* (4). Appendix C provides an overview of the full item descriptions, which included example careers to contextualize responses.

Table 4 provides an overview of participants' responses to these questions. On average, in the post-survey participants responded positively to the constructs Medicine ($M = 2.69$, $SD = 1.01$), Medical Science ($M = 2.57$, $SD = 1.04$), Biology and Zoology ($M = 2.34$, $SD = .99$), Veterinary Work ($M = 2.33$, $SD = .93$), Engineering ($M = 2.25$, $SD = .98$), Computer Science ($M = 2.18$, SD

= .99), Chemistry (*M* = 2.17, SD = .90), Physics (*M* = 2.16, SD = .85), Mathematics (*M* = 2.16, *SD* = .85), and Environmental Work (*M* = 2.08, *SD* = .85). The two lowest responses were to Earth Science (*M* = 1.98, *SD* = .81) and Energy (*M* = 1.97, *SD* = .85).

Table 4. RET Students' STEM Career Interests (pre/post)

Subject Area		**Pre**		**Post**		Z	Sig. (2-tailed)	*r*
	n	*M*	*SD*	*M*	*SD*			
Physics	147	2.19	0.87	2.16	0.85	-0.44	0.66	.04
Environmental Work	119	2.07	0.86	2.08	0.85	-0.21	0.84	.02
Biology and Zoology	119	2.34	0.98	2.34	0.99	-0.10	0.92	.01
Veterinary Work	112	2.20	0.95	2.33	0.93	-1.73	0.08	.16
Mathematics	115	2.06	0.93	2.16	0.92	-1.31	0.19	.12
Medicine	115	2.75	1.04	2.69	1.01	-0.56	0.58	.05
Earth Science	116	1.94	0.77	1.98	0.81	-0.64	0.52	.06
Computer Science	119	2.18	1.04	2.18	0.99	-0.06	0.96	.01
Medical Science	117	2.44	1.06	2.57	1.04	-2.06	0.04	.19
Chemistry	115	2.15	0.91	2.17	0.90	-0.35	0.73	.03
Energy	119	1.97	0.82	1.97	0.85	-0.09	0.93	.01
Engineering	118	2.33	1.00	2.25	0.98	-0.95	0.34	.09

As each of these subject areas was measured with only one question, Wilcoxon Signed Ranks Tests were conducted to evaluate the impact of the intervention on students' responses to each subject area. The Z-statistics and significance for each test are shown in Table 4. This test revealed an increase in students' interests in Medical Science, $z = -2.06$, $p < .05$, with a small effect size ($r = .19$). While no other significant changes were found, Veterinary Work and Mathematics also showed slight increases, as indicated by their small effect sizes.

Closing Discussion

For decades, the National Science Foundation and the developers of the National Science Standards have recognized that inquiry-based instruction holds significant promise for developing scientifically literate students.[5] These findings help us elucidate best practices for and barriers to realizing NSET's goal of developing a skilled workforce to advance nanotechnology, as well as areas for us to improve future iterations of the professional development opportunities we offer to K-12 teachers through this RETAIN program and related professional development camps.

The teachers' responses were positive for each of the Nanotechnology constructs post-course. However, we were surprised that teachers' perceptions of Nanotechnology's potential were not more positive. In a follow-up investigation of one teacher's experiences, we asked her specifically about this response. She indicated that a lot of what was shown to her seemed very theoretical: in other words, she felt that a lot of the innovative advances from nanotechnology were soon to be but had not yet been realized. This aligns with our observation of this teacher's class: she showed a video on DNA drug delivery to students, which featured a technology that was several years from becoming a reality. We hope to heighten future teachers' perceptions by showing a more holistic picture of the societal advancements realized by nanotechnology research and development in future RET offerings.

In Phase 2, we found a tendency towards teacher-centered instruction rather than student-centered instruction. We think that this is because teachers did not have the luxury of integrating a full nano-lab, potentially due to time, resources, or outside curricular pressure. This led us to realize that the STIR may not be ideal for the purposes of our investigation. Specifically, there seems to be a misalignment between teachers' lessons and what the STIR is intended to measure, namely, a full scientific investigation. Furthermore, our observations also highlighted the challenge that high school STEM teachers' face in integrating nanotechnology into their classroom. While each of the classroom lessons that we observed included a nano-component, the teacher's primary focus corresponded with something students were expected to know per state mandates and with respect to state tests. More time spent on nanotechnology, especially a full nano-lab would, we think, detract from what the teachers were expected to cover.

Third, we did not find any changes in students' STEM self-efficacy as measured by the S-STEM constructs. Interestingly, many students appeared to show decreases on the Mathematics constructs. We are unsure of the ultimate causes of this findings. In a surprising contrast, students' showed slight increases in three specific career choices: Mathematics, Medical Science, and Veterinary Science. In addition, Medicine and Medical Science showed the largest interest in the students' post-responses. Roughly half of the RETAIN teachers conducted research in these spaces, so we hypothesize that these experiences, combined with the courses the teachers participated in, may have helped produce these results.

Future Work

While these results have been encouraging, we have also decided upon several changes that we intend to implement in this RET-site in the future. First, corresponding with Phase 1, this data does not provide a comprehensive overview of changes in teachers' nanotechnology content knowledge or their conceptualizations of this phenomena. Specifically, what the constructs we have utilized portray is teachers' self-reported understanding or perceptions. In the future, we hope to triangulate this data with other objective measures of teachers' understanding of nanotechnology. Specifically, with the subsequent RET cohorts, we intend to implement a content test and utilize concept mapping to understand changes in both teachers' content knowledge of fundamental nanotechnology concepts as well as their conceptualizations of nanotechnology.

Second, in addition to the limitations with the STIR described in the discussion, one core component of the rubric that we disliked was the emphasis on "data analysis" rather than design in any sense. As an example, one of the teachers had students design a nano-robot. Students could, but were not required to analyze any data. While on one hand we would posit that data analysis can and should be interwoven in with design, the STIR does not emphasize such design creativity in any sense. To overcome this limitation, in subsequent iterations of this RET site, we intend to utilize a broader, more nano-centric observational protocol.

Lastly, for Phases 3 and 4, we simply would like to see more teachers distribute the surveys to their students. Most of the responses came from one teacher's classroom. We hope to develop a better plan for collecting this data in the future. In addition, in this study we did not adjust the S-STEM in any manner. In the future, we hope to give students the eight nano-questions that we gave to teachers, and add a career question on nanotechnology.

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Appendix A: STIR Rubric (adapted from Beerer and Bodzin)[5]

Feature 1: Learners are engaged by scientifically oriented questions.				
Item: Teacher provides an opportunity for learners to engage with a scientifically oriented question.	Learner is prompted to formulate own questions or hypothesis to be tested.	Teacher suggests topic areas or provides samples to help learners formulate own questions or hypothesis.	Teacher offers learners lists of questions or hypotheses from which to select.	Teacher provides learners with specific stated (or implied) questions or hypotheses to be investigated.
Feature 2: Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.				
Item: Teacher engages learners in planning investigations to gather evidence in response to questions.	Learners develop procedures and protocols to independently plan and conduct a full investigation.	Teacher encourages learners to plan and conduct a full investigation, providing support and scaffolding with making decisions.	Teacher provides guidelines for learners to plan and conduct part of an investigation. Some choices are made by the learners.	Teacher provides the procedures and protocols for the students to conduct the investigation.
Item: Teacher helps learners give priority to evidence which allows them to draw conclusions and/or develop and evaluate explanations that address scientifically oriented questions.	Learners determine what constitutes evidence and develop procedures and protocols for gathering and analyzing relevant data (as appropriate).	Teacher directs learners to collect certain data, or only provides portion of needed data. Often provides protocols for data collection.	Teacher provides data and asks learners to analyze.	Teacher provides data and gives specific direction on how data is to be analyzed.
Feature 3: Learners formulate explanations and conclusions from evidence to address scientifically oriented questions.				
Item: Learners formulate conclusions and/or explanations from evidence to address scientifically oriented questions.	Learner is prompted to analyze evidence (often in the form of data) and formulate own conclusions/ explanations.	Teacher prompts learners to think about how analyzed evidence leads to conclusions/explanations, but does not cite specific evidence.	Teacher directs learners' attention (often through questions) to specific pieces of analyzed evidence (often in the form of data) to draw conclusions and/or formulate explanations.	Teacher directs learners' attention (often through questions) to specific pieces of analyzed evidence (often in the form of data) to lead learners to predetermined correct conclusion/ explanation (verification).

Feature 4: Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.				
Item: Learners evaluate their conclusions and/or explanations in light of alternative conclusions/ explanations, particularly those reflecting scientific understanding.	Learner is prompted to examine other resources and make connections and/or explanations independently.	Teacher provides resources to relevant scientific knowledge that may help identify alternative conclusions and/or explanations. Teacher may or may not direct learners to examine these resources, however.	Teacher does not provide resources to relevant scientific knowledge to help learners formulate alternative conclusions and/or explanations. Instead, the teacher identifies related scientific knowledge that could lead to such alternatives, or suggests possible connections to such alternatives.	Teacher explicitly states specific connections to alternative conclusions and/or explanations, but does not provide resources.
Feature 5: Learners communicate and justify their proposed explanations.				
Item: Learners communicate and justify their proposed conclusions and/or explanations using appropriate content knowledge.	Learners specify content and layout to be used to communicate and justify their conclusions and explanations.	Teacher talks about how to improve communication, but does not suggest content or layout.	Teacher provides possible content to include and/or layout that might be used.	Teacher specifies content and/or layout to be used.

Note: For each item, the coder could also mark "Not applicable".

Appendix B: S-STEM Constructs Item Descriptions

Math Attitudes

1. Math has been my worst subject. (-)
2. I would consider choosing a career that uses math.
3. Math is hard for me. (-)
4. I am the type of student who does well in math.
5. I can handle most subjects well, but I cannot do a good job with math. (-)
6. I am sure I could do advanced work in math.
7. I can get good grades in math.
8. I am good at math.

Science Attitudes

1. I am sure of myself when I do science.
2. I would consider a career in science.
3. I expect to use science when I get out of school.
4. Knowing science will help me earn a living.
5. I will need science for my future work.
6. I know I can do well in science.
7. Science will be important to me in my life's work.
8. I can handle most subjects well, but I cannot do a good job with science.
9. I am sure I could do advanced work in science.

Engineering and Technology Attitudes

1. I like to imagine creating new products.
2. If I learn engineering, then I can improve things that people use every day.
3. I am good at building or fixing things.
4. I am interested in what makes machines work.
5. Designing products or structures will be important for my future work.
6. I am curious about how electronics work.
7. I would like to use creativity and innovation in my future work.
8. Knowing how to use math and science together will help me to invent useful things.
9. I believe I can be successful in a career in engineering.

21st Century Learning Attitudes

1. I am confident I can lead others to accomplish a goal.
2. I am confident I can encourage others to do their best.
3. I am confident I can produce high quality work.
4. I am confident I can respect the differences of my peers.
5. I am confident I can help my peers.
6. I am confident I can include others' perspectives when making decisions.
7. I am confident I can make changes when things do not go as planned.
8. I am confident I can set my own learning goals.
9. I am confident I can manage my time wisely when working on my own.
10. When I have many assignments, I can choose which ones need to be done first.
11. I am confident I can work well with students from different backgrounds.

Appendix C: S-STEM "Your Future" Career Interests

Here are descriptions of subject areas that involve math, science, engineering and/or technology, and lists of jobs connected to each subject area. As you read the list below, you will know how interested you are in the subject and the jobs. Fill in the circle that relates to how interested you are. There are no "*right*" or "*wrong*" answers. The only correct responses are those that are true for you.

- **Physics**: is the study of basic laws governing the motion, energy, structure, and interactions of matter. This can include studying the nature of the universe. (aviation engineer, alternative energy technician, lab technician, physicist, astronomer)
- **Environmental Work**: involves learning about physical and biological processes that govern nature and working to improve the environment. This includes finding and designing solutions to problems like pollution, reusing waste and recycling. (pollution control analyst, environmental engineer or scientist, erosion control specialist, energy systems engineer and maintenance technician)
- **Biology and Zoology**: involve the study of living organisms (such as plants and animals) and the processes of life. This includes working with farm animals and in areas like nutrition and breeding. (biological technician, biological scientist, plant breeder, crop lab technician, animal scientist, geneticist, zoologist)
- **Veterinary Work**: involves the science of preventing or treating disease in animals. (veterinary assistant, veterinarian, livestock producer, animal caretaker)
- **Mathematics**: is the science of numbers and their operations. It involves computation, algorithms and theory used to solve problems and summarize data. (accountant, applied mathematician, economist, financial analyst, mathematician, statistician, market researcher, stock market analyst)
- **Medicine**: involves maintaining health and preventing and treating disease. (physician's assistant, nurse, doctor, nutritionist, emergency medical technician, physical therapist, dentist)
- **Earth Science**: is the study of earth, including the air, land, and ocean. (geologist, weather forecaster, archaeologist, geoscientist)
- **Computer Science**: consists of the development and testing of computer systems, designing new programs and helping others to use computers. (computer support specialist, computer programmer, computer and network technician, gaming designer, computer software engineer, information technology specialist)
- **Medical Science**: involves researching human disease and working to find new solutions to human health problems. (clinical laboratory technologist, medical scientist, biomedical engineer, epidemiologist, pharmacologist)
- **Chemistry**: uses math and experiments to search for new chemicals, and to study the structure of matter and how it behaves. (chemical technician, chemist, chemical engineer)
- **Energy**: involves the study and generation of power, such as heat or electricity. (electrician, electrical engineer, heating, ventilation, and air conditioning (HVAC) technician, nuclear engineer, systems engineer, alternative energy systems installer or technician)
- **Engineering**: involves designing, testing, and manufacturing new products (like machines, bridges, buildings, and electronics) through the use of math, science, and computers. (civil, industrial, agricultural, or mechanical engineers, welder, auto-mechanic, engineering technician, construction manager)