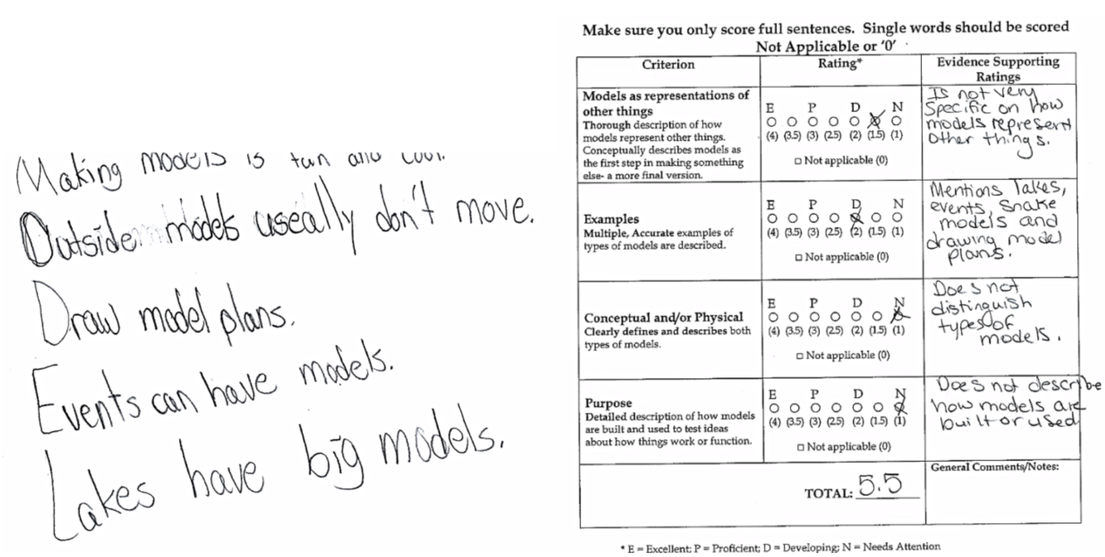
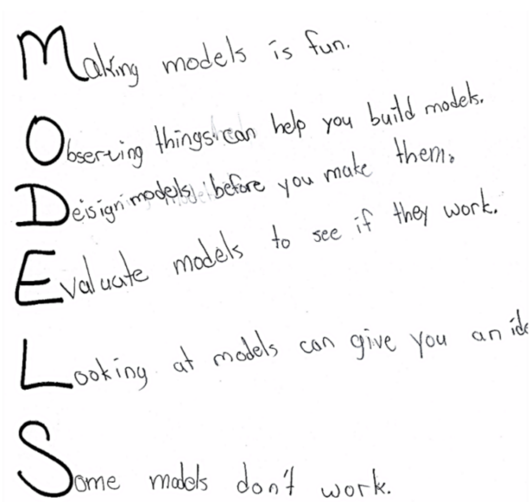
provide insight into the change in elementary students' understanding over the course of the field experience while also modeling innovative methods to measure student knowledge.

For a more detailed view into the assessments, one semester lessons that were derived from the FOSS Unit, Models & Designs, can be more closely examined. Modifications were made to explicitly target scientific and engineering practices as well as to make it align with the 5E learning cycle (Bybee et al., 2006). This science unit contains four investigations that engage students in the process of engineering design and construction which particularly targets the NGSS scientific and engineering practice of "developing and using models." Students learn about models and how they can be used to enhance understanding while they simultaneously engage in the design process that requires refinement of the models to improve the design. To evaluate changes in students' conceptual understanding about models, an acrostic embedded assessment was used, called "first-word last-word" which was adapted from Keeley (2008). Students wrote the word "MODELS" in a vertical column on the left side of a page. Students were then challenged to write a sentence or a complete thought about models that begins with each of the letters of the word "MODELS."

Figure 2 shows one of the student's pre and post First Word/Last Word assessment to illustrate this assessment technique. PSTs used a rubric (Figure 3) which was developed by the external evaluators and myself to evaluate student responses. Each semester we developed a different rubric for a different science unit because students often participated in the after school program multiple semesters. Different aspects of models were examined with the rubric which included the following: models as representation of real things, examples of uses of models, recognizing that models can be conceptual and/or physical, and identifying the purpose of models. Across all the after school sites, there were statistically significant differences (t=3.6, p<.01) between First Word and Last Words. However, this was a challenging assessment to administer with fidelity across sites because many of the PSTs acknowledged that they did not follow the instructions by asking for and requiring complete sentences. Asking students to write (particularly complete sentences) in the after school learning space was problematic. Nonetheless, these types of assessments served as models for alternative embedded assessments that many PSTs continued to utilize in their teaching experiences.

Figure 2 (Click image to enlarge). **Initial First-Word assessment to describe "models" (top left). End of unit Last-Word assessment (bottom left). PSTs analysis using the rubric in Figure 3 are shown in right panels.**





Make sure you only score full sentences. Single words should be scored Not Applicable or '0'

Criterion	Rating*	Evidence Supporting Ratings
Models as representations of other things Thorough description of how models represent other things. Conceptually describes models as the first step in making something else- a more final version.	E P D N (4) (3.5) (3) (2.5) (2) (1.5) (1) — (2.5) marked; □ Not applicable (0)	Describes how observation, design and evaluate are important for models.
Examples Multiple, Accurate examples of types of models are described.	E P D N (4) (3.5) (3) (2.5) (2) (1.5) (1) — (1) marked; □ Not applicable (0)	No examples given of types of models
Conceptual and/or Physical Clearly defines and describes both types of models.	E P D N (4) (3.5) (3) (2.5) (2) (1.5) (1) — (1) marked; □ Not applicable (0)	Does not specifically mention types of models
Purpose Detailed description of how models are built and used to test ideas about how things work or function.	E P D N (4) (3.5) (3) (2.5) (2) (1.5) (1) — (3.5) marked; □ Not applicable (0)	Describes that observation helps students build models, design models, evaluate, and some models dont work.
	TOTAL: 8	General Comments/Notes:

* E = Excellent; P = Proficient; D = Developing; N = Needs Attention

Figure 3 (Click image to enlarge). **First Word/Last Word assessment (example provided in Figure 2) rubric.**

Rubric for Assessing First Word/Last Word – "Model"

	Excellent	Proficient	Developing	Needs Attention
Models as representations of real things	Thorough description of how models represent other things. Conceptually describes models as the first step in making something else- a more final version.	Accurate description for how a model looks like something else. Does not indicate that models are used as part of a bigger process of testing and building.	Vague or incomplete description of how models look like other things. Description does not apply to all types of models.	None of the sentences indicates that models are used to represent other things.
	Excellent	**Proficient**	**Developing**	**Needs Attention**
Examples of Use	Multiple, Accurate examples of types of models are described. Includes examples of both physical and conceptual models.	Several examples of models are described; not all are relevant to engineering (ie…fashion, art are technically correct in terms of definition).	Vague or incomplete example listed. Examples do not clearly imply who uses them or what they are used for.	None of the sentences mentions an example of a model.
	Excellent	**Proficient**	**Developing**	**Needs Attention**
Conceptual &/or Physical	Clearly describes the difference between conceptual and physical models by defining both types of models and uses in detail.	Accurately describes conceptual and physical models but description lacks detail.	Defines one type or the other but does not include both.	None of the sentences provides any reference to conceptual or physical models.
	Excellent	**Proficient**	**Developing**	**Needs Attention**
Purpose	Detailed description of how models are built and used to test ideas about how things work or function.	Accurate description of how models are built to describe how something will look; does not include description of how things work or function.	Basic description of using models but does not clearly describe purpose.	None of the sentences describes models as having purpose or use in problem solving.

Learning from Mistakes: PSTs growth

During the first part of the after school field experience, PSTs implemented the FOSS Models & Designs lessons and the aforementioned embedded assessments which included the targeted NGSS scientific and engineering practices of planning and carrying out investigations, analyzing and interpreting data, constructing explanations and designing solutions, and obtaining, evaluation and communicating information. They then implemented their own 5 lesson science unit created with their co-teaching team which built upon these ideas of models and design which were required to include the NGSS practices. To gain better insight into the program and the PSTs experience, one PST, Kirsten, will serve as an example to illustrate the power of this experience for those elementary educators who are "science hesitant." Kirsten was a traditional elementary education student who did not feel particularly confident in teaching science. I chose to include her comments because she spoke with me several times about her lessons in an effort to prepare the best possible lesson for her students. This was not always the case as most students chose to develop their lessons independently. Her experiences illustrate a powerful learning opportunity when teaching experiences do not go as well as planned. Longitudinal comments from other participants are presented in the Lessons Learned section of the paper.

In her written commentary (described in Appendix B) where she described the effectiveness of the lesson, Kirsten explains the lessons that she and her co-teacher team devised for their unit:

> *Prior to my lesson were our other transportation lessons that went along with our unit, including a lesson on asphalt, or the materials that help to make a road, and a lesson investigating the different forms of transportation one can take. After my lesson, another math and science lesson was taught on different modes of transportation as well. My video shows students working cooperatively in groups of three to explore the greenhouse effect.*

PSTs were challenged this semester to continue the idea related to engineering and models (as discussed previously) into their own units of instruction that were implemented during weeks 10-12 of the semester. Kirsten's team developed a set of lessons related to transportation engineering. One of the lessons included an expert visitor, a transportation engineer, to come and speak with the students. Kirsten's lesson targeted the environmental impacts of transportation and the burning of fossil fuels which contribute to the greenhouse effect. She selected the classic Alka-Seltzer tablet lab to do with her students where two Alka-Seltzer tablets are placed inside a 2-liter bottle to release carbon dioxide. Two bottles with temperature sensors (one with the extra carbon dioxide and one with normal air/water as the control) are then placed under a light where the temperature is monitored over several minutes. Before she did this with her students, we discussed the challenges with this lab because it seldom finishes in a timely manner with the expected results. She said she practiced it at home and was able to do it successfully.

Kirsten describes her feeling about the effectiveness of the lesson in her written commentary. She writes, "The lesson investigation did not work out as planned… the classic greenhouse gas experiment with Alka-Seltzer tablets is problematic and seldom works as planned." She recognized the challenges associated with this lab. The warning that I provided her helped her to remain calm because she had already thought about possible explanations she would provide students. She outlines her thoughts for revising the lesson below:

> *My first revision for this lesson would have to be concerning the second experiment involving the carbon dioxide. Time-wise, it made it impossible to finish my lesson in the sixty minutes I was given. I did not think recording the temperatures for ten minutes, for a total of twenty minutes with both experiments, would be as time consuming as it was. Second, the experiment with carbon dioxide did not give us the desired results, and although we discussed our possible errors in our experiment, successful results would have been better for the students.*

Although successful results are always preferred and definitely feel better in the moment, teachers oftentimes remember those experiences that do not work for a longer time. These experiences provide opportunities to grow as an educator and to frame our thinking about the next time we will tackle that investigation. Kirsten echoes these thoughts below:

> *The knowledge I have gained from this lesson will certainly impact my future instruction in a positive manner. I am glad that everything in my lesson did not go perfect because it allowed for reflection and improvement. I greatly enjoyed working with my students and I can only hope that they got as*

> *much out of Sci-Talks [the after school program] as I did.*

Kirsten tackled one of the most challenging investigations of her team's unit and recognized that it did not go as well as she had hoped. However, she gained much from the experience and recognized the importance of the students investigating something first-hand. She wrote the following in her reflection as she began to plan her lessons for her unit, "I noted that in prior Sci-Talks lessons with the FOSS kits, students were always more excited to get their hands on something and develop an answer to a question in that manner."

Lessons Learned for Implementation

After coordinating this program across two different communities and universities, several important lessons were learned which could make replication of this program easier in other areas. The next section describes the important characteristics of the after school site, the "instructional" setting, storage of materials, co-teacher preservice teams, and the mentor teacher.

The PSTs lack of experience teaching, along with low-efficacy in science instruction particularly, necessitated that I find the most favorable teaching setting to maximize the likelihood of their success which was also the reason that I provided examples of very "doable" curricula materials like FOSS and *Picture-Perfect Science.* Several times throughout our program, PSTs became very troubled by their inability to be a "proper teacher" when the challenges were more about the setting (inadequate teaching space with too many distractions) and the children (not accustomed to after school enrichment activities). Therefore, after several semesters, I chose to deliver our program primarily at schools with after school childcare that included other ongoing enrichment activities that often happened at school locations. When the students receive instruction at a school in a classroom, they tend to behave with more appropriate school-like behavior even in the after school hours. Additionally, the preferred sites were those that provided transportation home after the enrichment activities although this was a rarity. As students would be picked up by parents to go home before the end of the lesson, our PSTs were not able to discuss the results from the investigation with everyone and the slow trickle of students leaving for the day would become frustrating to them.

If the after school science program requires the PSTs to teach multiple times over the semester, careful thought should be given about transporting supplies and finding a place to store them on-site and to ensure that they were available during these hours. If PSTs must carry a large box to and from the site each day, this can take up more time and possibly frustrate them even more. Figuring out these seemingly small logistical issues help to ease frustration levels and sources of potential anxiety.

One of the most significant components of the program that the PSTs positively reflect on is the importance of the partnership between themselves and their fellow preservice teacher partner. They highly value the support that they receive from their co-teacher team as they work together to overcome challenges with teaching science and managing a room of students for the first time on their own. One preservice teacher shared the following during her interview conducted while student teaching:

> *[The co-teacher team] made [the program] stronger, simply because there was another presence in the room. Just another presence in the room helps tremendously. It helps keep order, helps keep them calm. If I had a few minutes where I had to stop for a computer issue or pass out markers or do this and that… having someone there that we both know what's going on and we know, at this point, we need to pass this out, at this point, we need to have this ready… it helped because one can be teaching and one can be gathering materials and then we swap out at some point and we*

> *just trade off of each other and worked off of what we know we were doing. So, I thought it was a tremendous experience.*

Another aspect of the program that helped ensure success was the presence of a classroom mentor teacher in the after school learning space. Ideally, the mentor teacher provided their classroom to be the learning space and was familiar with the students participating in the program. Effective mentor teachers provided suggestions on grouping students, intervention when classroom management started to break down, and constructive feedback at the end of the lesson. I provided support to mentors and provided appropriate mentor teacher feedback because their role truly impacted the preservice teacher's self-efficacy and self-perception in teaching. This support included a meeting prior to the start of each semester with each mentor to highlight their desired role as well as ongoing feedback during the semester as program leaders visited each site. Mentor teachers could range between too domineering or distracted and could jeopardize program effectiveness. The PSTs generally found the mentor teachers to be quite helpful because they knew the students well and had much more experience managing a classroom of busy students than the PSTs did.

Longitudinal Impacts on PSTs

The after school field experience program provided the PSTs a valuable opportunity to test out their own lesson plans in a pseudo-classroom space that they managed themselves. Traditional field experiences seldom provide sufficient opportunities for the preservice teacher to feel that they are "in charge" of the learning space. Follow-up interviews conducted during student teaching and their first years in the classroom reveal that nearly all SCI-TALKS students felt this is the single most important contribution of the program. The constructivist approaches implemented in the after school environment to teaching science transferred into their traditional classroom instruction (Cartwright, 2012). PSTs have more positive ideas about science after participating in the after school science experience and are more willing to overcome the barriers that often exist for science teaching during student teaching such as a lack of confidence in teaching science, time for science instruction, and limited resources (Cartwright, Smith & Hallar, 2014).

Currently, longitudinal follow-up research is being conducted with PSTs who are now classroom teachers. This research includes an online questionnaire for all graduates, along with interviews and classroom observations for a convenience sample that are teaching similar grades within a drivable distance to campus. The comments shared about the program that they experienced 2-3 years ago reflect what they have found to be most beneficial and perhaps influential in creating their own instructional spaces. One teacher wrote the following:

> *For my science methods course, I participated in Sci-Talks. The experience of teaching real students, real science lessons was amazing. During these lessons, I was asked to not only plan science lessons, but also to implement them. As a result, I was able to see how a real classroom worked. Sometimes, my lessons looked great on paper, but then flopped in the classroom. I was able to take these experiences into my real classroom with me. In addition, during my time in Sci-Talks, I learned along with the students. As a result, in my real classroom I am more willing to take risks and allow students to explore science content.*

This student recognized the importance of actually implementing the lessons that they wrote so they could see what would work and what may not. This willingness to "take risks" is an important component for themselves as well as their students (Le Fevre, 2014). Similarly, another teacher wrote the following:

> *I believe that this class prepared me as much as possible. Not all of the classes give you that hands on, in the classroom, experience. It was the best teaching experience I had received until I did my student teaching. Because in Sci-Talks, we were the teachers. We gave the lessons and we made the preparations. It was a great experience that prepared me for the real world of teaching.*

Preparation for the "real world of teaching" cannot happen in the college classroom. It seldom happens observing someone else teach a science lesson. PSTs need their own teaching experiences as mentioned by another student who said the following in her interview during our longitudinal research in her own classroom, "I would just like to say Sci-Talks is wonderful and just before that I was so nervous and I thought, 'Oh Lord, how am I going to teach it I can't even talk' you know. But, after Sci-Talks I was like, Hey, I can do this I can teach science. Just because it's my weakest subject, I can teach anything." Many PSTs perceive science and math as their weakest areas of content. Providing them a safe after school field experience where they themselves are the primary teachers can have long-term impact on their willingness to facilitate guided inquiry instruction in their own classrooms.

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Supplemental Files

Cartwright-Supplemental-Materials.docx

References

Appleton, K. (2007). Elementary science teaching. In Abell, S. K. & Lederman, N. G. (Eds.). *Handbook of Research on Science Education* (pp. 493-535). Oxford UK: Taylor & Francis.

Bell, R. L., Smetana, L., & Binns, I. (2005). Simplifying inquiry instruction. *The Science Teacher*, 72(7), 30-33.

Bhattacharyya, S., Volk, T., & Lumpe, A. (2009). The influence of an extensive inquiry-based field experience on pre-service elementary student teachers' science teaching beliefs. *Journal of Science Teacher Education, 20*, 199-218.

Borko , H. & Putnam, R.T. (1996). Learning to teach. In Berliner, D.C. & Calfee, R.C. (eds.) *Handbook of Educational Psychology*. New York: Macmillan.

Calabrese Barton, A. (2000). Crafting multicultural science education with preservice teachers through service learning. *Journal of Curriculum Studies, 32*, 797–820.

Cartwright, T. (2012). Science talk: Preservice teachers facilitating science learning in diverse afterschool environments. *School Science and Mathematics, 112*(6), 384 – 391.

Cartwright, T., Smith, S. & Hallar, B. (2014). Confronting barriers to teaching elementary science: Afterschool science teaching experiences for preservice teachers. *Teacher Education & Practice*, *27* (2-3), 464-487.

Chiapetta, E., & Adams, A. (2000, April). *Towards a conception of teaching science and inquiry— The place of content and process.* New Orleans, LA: Paper presented at the Annual Meeting of the National Association for Research in Science Teaching.

Cone, N. (2012). The effects of community-based service learning on preservice teachers' beliefs about the characteristics of effective science teachers of diverse students. *Journal of Science Teacher Education*, *23*, 889-907.

Darling-Hammond, L. (Ed.). (1994). *Professional development schools: Schools for developmenting a profession.* New York: Teachers College Press.

Duschl, R. A., Schweinggruber, H. A., & Shouse, A. W. (Eds.). (2007). *Taking science to school: Learning and teaching science in Grades K-8.* Washington, DC: National Academy Press.

Harlen, W. & Holroyd, C. (1999). Primary teachers' understanding of concepts of science: Impact on confidence and teaching. *International Journal of Science Education*,*19*(1), 93-105.

Keeley, P. (2008). *Science Formative Assessment: 75 Practical strategies for linking assessment, instruction, and learning.* Thousand Oaks, CA: Corwin Press.

Kelly, J. (2000). Rethinking the elementary science methods course: A case for content, pedagogy, and informal science education. *International Journal of Science Education*, *22*, 755–777.

Knight, M., & Cunningham, C. (2004). "Draw an Engineer Test (DAE): Development of a tool to investigate students' ideas about engineers and engineering." Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition, Session 2530.

Koch, J. (2012). *Science stories: Science methods for elementary and middle school teachers. (*4 ed.). Belmont, California: Wadsworth Cengage Learning.

Le Fevre, D. (2014). Barriers to implementing pedagogical change: The role of teachers' perceptions of risk. *Teaching and Teacher Education, 38*, 56-64.

Luehmann, A. L. (2007). Identity development as a lens to science teacher preparation. *Science Education*, *91*, 822–839.

Magnusson, S., Krajcik, J. & Borko, H. (1999). Nature, sources and development of pedagogical content for science teaching. In Gess-Newsome. J. & Lederman, N. (eds.) *Examining Pedagogical Content Knowledge*. London: Kluwer Academic.

Mason, C.L., Kahle, J.B., & Gardner, A.L., (1991). "Draw-A-Scientist Test: Future Implications." *School Science and Mathematics*, *91*(5), 193-198.

Marx, R.W., Blumenfeld, P.C., Krajcik, J.S., Blunk, M., Crawford, B.A., & Meyer, K.M. (1994). Enacting project-based science: Experiences of four middle grade teachers. *Elementary School Journal*, *94*, 517–538.

Minstrell, J., & van Zee, E.H. (Eds.) (2000). *Inquiring into inquiry learning and teaching in science.* Washington DC: American Association for Advancement of Science.

NRC. (2011). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington DC: National Academies Press.

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states*. Washington DC: The National Academies Press.

Riedinger, K., Marbach-Ad, G., McGinnis, J. R., & Hestness, E. (2011). Transforming elementary science teacher education by bridging formal and informal science education in an innovative science methods course. *Journal of*

Science Education and Technology, *20*, 51–64.

Teitel, L. (with Abdal-Haqq, I.). (2000). *Assessing the impacts of professional development schools.* New York: American Association of Colleges for Teacher Education.

Wallace, C.S. & Brooks, L. (2015). Learning to teach elementary science in an experiential, informal context: Culture, learning, and identity. *Science Education*, 99(1), 174-198.

Windschitl, M. (2002). Framing constructivism in practice as the negotiation of dilemmas: An analysis of the conceptual, pedagogical, cultural, and political challenges facing teachers. *Review of Educational Research*, *72*(2), 131–175.