A BOLD EXPERIMENT

TEACHERS TEAM WITH SCIENTISTS TO LEARN NEXT GENERATION SCIENCE STANDARDS

BY SHARON L. GILMAN AND MARTHA C. FOUT

The Next Generation Science Standards place an emphasis on the practices of science and engineering, where ensuring that students understand and experience how science works is as important as, or maybe more important than, memorizing facts. The idea is that, while some facts may change, the practices will always be applicable, and it is important for citizens to understand how scientists arrive at their conclusions, in addition to what those conclusions are.

The standards' emphasis on the practices of science represents a culmination of the long-running understanding that people learn science by doing science. In the classroom, this has translated to inquiry-based lessons, where students design and conduct experiments, form explanations from evidence, evaluate and justify those explanations, and communicate their work.

The question is: What is the best way for the teachers to learn the practices and see how they represent how science actually works, and what type of professional learning will best lead them to understand and embrace this approach?

This article describes a model for professional learning in which graduate students in science, technology, engineering, and mathematics (STEM) work with teachers in K-12 classrooms to introduce science research content and practices. It meets the requirements understood to work

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in quality professional learning, and it enhances relationships between teachers and practicing scientists. As a side benefit, the model also builds the communication skills of future scientists, something increasingly important in building a scientifically literate population.

HOW THE PROGRAM WORKED

In summer 2013, teachers at 18 middle and high schools in a Southeastern state were in the final year of a three-year professional learning program when they teamed with six graduate fellows participating in GK-12, a National Science Foundation-funded program that supports fellowships and training for graduate students in science, technology, engineering, and mathematics. The program's goal is to improve the

SAMPLE DAILY WORKSHOP SCHEDULE		
TIME	**ACTIVITY**	**FOCUS**
Block 1	Pretest.	Developed by researcher, distributed by facilitator.
Block 2	1. Distribute the framework (NRC, 2012) reading on the practice addressed today. 2. Distribute or post journal questions and allow time for personal writing or reflection. 3. Think-pair-share about journal entries.	*Journal or discussion questions:* 1. What do students in my grade level or course need to know and be able to do when it comes to this practice? 2. How can I determine what students have learned in previous grades about this practice? 3. Should there be a scope and sequence to teaching this practice in my grade level? If so, what is that sequence for teaching? 4. How will I differentiate instruction for various groups of students? 5. What are some important points to remember about this practice?
Block 3	Relate practice to the research to be presented. (Facilitator is familiar enough with the research to develop these, or the researcher could offer questions for consideration.)	*Journal or discussion questions* (examples) 1. What types of animals do you believe are predators on turtle nests? 2. What factors do you believe protect turtle nests from predators?
Block 4	Research presentation by researcher. (May include data sets for classroom use.)	Allow questions from teachers throughout. Be sure researcher understands the focus on a particular practice, but others will come up, too.
Block 5	Group discussion about how this practice was used in the research.	1. Compare notes with colleagues. 2. Follow-up questions (for example): What are the ways that knowledge of planning and carrying out investigations helps you master the content of this research?
Block 6	Post-test.	
Block 7	View Bozeman.com video on the practice.	This puts the practice back in the classroom.
Block 8	In school, grade, or course teams, examine own curriculum and find areas where this practice would fit well with the content.	As team members make connections and develop ideas, they draw a concept map or some other visual display on a white board for presentation.
Block 9	Presentations by teams for entire group.	Allows feedback and articulation across grade levels.

graduate fellows' communication and teaching skills through interactions with teachers and students in K-12 schools while enriching STEM content and instruction for their K-12 partners.

The teachers and fellows, who were master's students in an ecology-focused degree program, participated in two weeks of summer workshops as well as follow-up over the course of the academic year. The fellows presented the content portion of the workshops, based on their own research, and focused on the eight science practices in the Next Generation Science Standards rather than on particular content standards.

During the workshops, teachers and fellows spent half the day on content and the other half on lesson development. They learned about the ecology being explored in the research and saw how the scientists used each practice. The teachers worked together in their school or content-area teams to incorporate the practices the graduate students addressed into their own lesson plans. The district uses the 5-E science instruction model, where students are *engaged, explore,* work toward an *explanation* which may then be *elaborated* on, and *evaluation* occurs throughout (Trowbridge & Bybee, 1996), so lessons followed this format. Teachers then presented their ideas to the whole group at the end of the day, with time for discussion.

All lesson plans were posted on the social network Edmodo. This allowed teachers to communicate among themselves outside the workshop and through the academic year. In addition, they presented their lesson plans to

RESEARCH PROJECT PRESENTATION TOPICS AND THE PRACTICE ASSOCIATED WITH EACH			
PRESENTER	**RESEARCH TOPIC**	**SCIENCE PRACTICE**	**FOCUS QUESTIONS**
Fellow 1	Shark interactions in local estuarine habitats.	Analyzing and interpreting data.	What types of data could be collected about sharks? What are ways these types of data could be useful?
Fellow 2	Plant composition, nutrient levels, and abiotic factors in natural vs. human impacted salt marshes.	Asking questions.	What are some ways humans can impact salt marshes? Predict some of the effects of these impacts.
Fellow 3a	Population abundances of dolphins in three estuarine sites.	Using mathematics and computational thinking.	What data can be collected concerning population abundance of dolphins? How can these data be useful?
Fellow 3b	Are dolphins nonhuman persons?	Engagement in argument from evidence.	What animals do you believe to be the most intelligent? What criteria do you use to judge intelligence?
Fellow 4	Predation on diamondback terrapin nests.	Planning and carrying out investigations.	What types of animals do you believe are predacious on turtle nests? What factors do you believe protect turtle nests from predation?
Fellow 5	Spatial, thermal, and nesting ecology of diamondback terrapins.	Developing and using models.	What are important factors to the success of turtle nests? How can modeling help a scientist find out about the ideal environment for a turtle nest?
Fellow 6	Habitats as a predictor of marsh sparrow population abundance.	Constructing explanations.	What type of habitat do you believe a marsh sparrow needs? How do you think one would model "good" habitat for marsh sparrows?

teachers districtwide at the start of each academic year and to their common planning groups at their schools.

Two pre- and post-tests — one addressing specific content from the research presentations, and the other addressing more general understanding of the scientific practices — assessed content knowledge gains. The fellows developed the pre- and post-tests corresponding to their presentations, and the grant evaluator created the more general assessment of the practices using practice questions for the ACT tests.

To assess teachers' views of the organizational support from their colleagues and school for science in general, we gave them open-ended surveys asking about the climate for science — whether they got adequate support, supplies, space, and time in class, and time to collaborate. We asked if they got guidance, or perhaps too much guidance, and whether their administrators and colleagues appreciated the challenges of their job. Finally, we asked teachers to evaluate the overall workshop. We also asked the graduate student presenters about their experience working with the teachers.

WORKSHOP DESIGN

In a typical workshop session, teachers would read about the day's scientific practice in *A Framework for K-12 Science Education* (NRC, 2012) Using a think-pair-share format, they considered journal questions related to the practice.

The graduate fellow presented his or her work and described how their project used the particular practice. The teachers engaged in discussion with the fellow about how this practice was essential to the research and then watched an online video (**www.bozemanscience.com/next-generation-science-standards**) about the practice. They then had time to work with their school or content teams to look for lessons in their curriculum that could be done in the context of, or related to the context of, the particular practice. In some cases, the graduate students gave them data sets with which they could work.

Teachers used a whiteboard to sketch out their ideas, which they presented to the whole group for feedback, thoughts, and discussion. We were able to do seven of the eight practices directly but did not have enough days to include "Obtaining, evaluating, and communicating information." However, each fellow demonstrated this practice by communicating results to the teachers themselves.

DID IT WORK?

The graduate fellows presented research on the topics and practices as shown in the table on p. 27. Teachers showed significant gains in content knowledge and understanding of the practices on assessments based on the graduate student presentations. The mean number correct increased from 69% on the pretests to 83.4% on the post-tests. In addition, general assessments focused on the practices, experimental design, and data analysis, modeled after questions on the ACT tests. Teachers also made gains here, with mean correct rising from 58.8% on the pretest to 70% on the post-test.

Teacher feedback showed they viewed the presentations and the workshop overall quite favorably. There was no significant difference between the quantitative evaluations from the middle and high school teachers, and the qualitative comments suggest that the teachers both enjoyed the workshop and felt they gained understanding of content and practice. They liked working with the graduate students and particularly enjoyed the opportunity to collaborate with colleagues both within and across grade levels. Here are some of their comments:

- *"Liked the presentations of graduate work instead of lectures on content."*
- *"Good and interesting content from the GK-12 students — relevant to our practices."*
- *"Learning the eight practices was extremely useful and prepared me to implement these in my class as well as teach other teachers."*
- *"I feel more comfortable about the new standards."*
- *"I felt it was very useful to learn how all grades are connected. This will give me a renewed vigor to really hammer home some concepts."*
- *"The vertical alignment from middle to freshman science was very enlightening and helped me see the overall picture of the students' education."*

The graduate student presenters enjoyed sharing the joys and frustrations of doing science with the teachers. They also welcomed the opportunity to consider how one might effectively teach their particular science content and practice to K-12 students. Two comments sum up their views:

- *"In my workshop presentation on experimental design, I recalled one of my own humbling experiences in straying from the scientific method and the frustrating but educational opportunities that followed. Well-planned experimental design is the foundation of experimental science, and the workshop allowed me and the participating teachers to share our tales of both good and bad (i.e. educational) experimental design."*
- *"The presentation of my research to teachers gave me a great opportunity to practice communicating to a new audience. It also challenged me to expand how I view my research, learning how to change angles in order to figure out ways it can be applied to concepts within K-12 curricula."*

Our model met the requirements of quality professional learning as outlined above. Teachers learned content and worked toward keeping their lessons in the 5-E model embraced by the school district and emphasizing the practices in the Next Generation Science Standards. The facilitator, who was the district science learning specialist, clearly understood the model and the way it should look in the classroom. Teachers worked together to create a model of how each particular practice would build student understanding.

Teachers noted that they had seen "real" scientific investigations and talked to "real" scientists, and, sure enough, those scientists used the practices.

In addition, teachers worked collaboratively in teams by grade, but they also said seeing what was being taught in other grades gave them a better sense of the continuity of their content. They were able to continue that collaborative work through the online professional community established on the Edmodo social network.

They introduced the lessons they developed to their colleagues in districtwide professional learning. They noted that they had seen "real" scientific investigations and talked to "real" scientists, and, sure enough, those scientists used the practices. According to Ball and Cohen's (1999) practice-based theory of professional development, professional learning for teachers should include opportunities to practice and apply what students learn in a real-world context (Huffman, Thomas, & Lawrenz, 2003). The graduate student research presentations provided this real-world context.

OUTCOMES

For professional learning to result in gains in student outcomes, it is necessary for the teachers to feel ownership and be supported at their school (Huffmann et al., 2003). A teacher can't work in isolation. This is why the teachers in this program reported back to their colleagues on what they had done.

But we also found in surveys that teachers said their schools were supportive of science in general. The fact that their own district learning specialist came up with the idea for the professional learning model emphasizing the Next Generation Science Standards practices gave teachers confidence that they would be supported when they introduced these to their classes.

We have not yet able to assess student learning outcomes based on this professional learning model because the science standards incorporating the practices of science just went into effect this year (2016-17). As this academic year ends, we plan to assess how teachers are incorporating the practices into their lessons and whether the experience with the graduate students has had any influence on that. We also plan to track end-of-course exams and ACT scores of the students of these teachers to look for gains in content knowledge and critical thinking skills.

REFERENCES

Ball, D.L. & Cohen, D.K. (1999). Developing practice, developing practioners: Toward a practice-based theory of professional education. In G. Sykes & L. Darling-Hammond (Eds.), *Teaching as the learning profession: Handbook of policy and practice* (pp. 3-32). San Francisco, CA: Jossey Bass.

Huffman, D., Thomas, K., & Lawrenz, F. (2003). Relationship between professional development, teachers' instructional practices, and achievement of students in science and mathematics. *School Science and Mathematics, 103*(8), 378-387.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press.

Trowbridge, L. & Bybee, R. (1996). *Secondary school science: Strategies for developing scientific literacy* (6th ed.). Englewood Cliffs, NJ: Prentice Hall.

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