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Enhancing Elementary Teachers' STEM Teaching Practice through a NGSS-Focused Professional Development Program

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Abstract

With the recent release of the Next Generation Science Standards, there has been a pressing need for school districts to provide sustained science professional development for teachers, particularly elementary school teachers. This paper reports findings from a two-year investigation on the effects of a PD program on helping 2nd grade teachers within one high needs suburban school district transform their teaching practice. The aim of this study was to explore changes in teachers' ability to enact the Next Generation Science Standards Science and Engineering Practices This study utilizes the constructs of effective PD design as a teacher learning tool and the role science practices in facilitating student learning. Findings indicated that teachers engaged in NGSS practices at a deeper level as well as focused more on student-centered learning during their STEM classroom instruction.

1. Introduction

The United States' Next Generation Science Standards (NGSS) calls for students to engage in the authentic practices of science and engineering. In order for students to be fully immersed in these practices, teachers must be adequately prepared through professional development to facilitate inquiry-based lessons and discussions. However, there is an ongoing need for school districts to provide sustained science professional development (PD) for teachers. This need is particularly dire at the elementary level, in which science instruction is "noticeably inadequate" and opportunities for science PD are lacking [1]. This paper reports on findings of a two-year investigation on the effectiveness of the PD on helping the teachers transform their science teaching to engage students in the Science and Engineering Practices of the Next Generation Science Standards.

2.Theoretical frame

The Next Generation Science Standards challenges students to operate at the cross section of three dimensions of learning: Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas. A key philosophy of the NGSS is that students should learn disciplinary core ideas in the context of science and engineering practices. In other words, content cannot be divorced from practice. "Standards and performance expectations that are aligned to the framework must take into account that students cannot fully understand scientific and engineering ideas without engaging in the practices of inquiry and the discourses by which such ideas are developed and refined" [2]. The NGSS outlines eight practices based on what professional scientists and engineers do.

In order to tailor the professional development program specifically to support teachers and their students in engaging in the practices of science, we examined research on what counts as effective PD design. The PD that we implemented was based on well-documented research that effective, capacity-building PD is long-term and tailored to unique situations and contexts [3, 4]. Moreover, "high-quality" PD efforts to improve teacher knowledge and practice should be designed to engage teachers in active learning that allows them to make sense of what they learn in meaningful ways and supported by coaching, modeling, observation, and feedback [5]. Structural features of PD should be of (a) sufficient duration in terms of both number of contact hours and span across school year and (b) include collective participation of teachers from the same school, department, or grade level [6].

3. Research design

Based on effective PD research, the professional development occurred across two school years and consisted of afterschool working-shops, curriculum planning meetings, in class coaching and modeling of NGSS-focused lessons, and a summer institute at the end of each school year. The working-shops consisted of meeting in a large group setting to present and discuss a topic; demonstration lessons were taught by subject matter experts to model best practices in science as outlined in the NGSS Science and Engineering Practices more effectively into lessons. Teachers participated as students in the learning experiences. The PD providers elicited ideas for content to correlate with what teachers were teaching to facilitate and model student-centered learning. Two of the researchers, former classroom teachers, visited each of the teachers' classrooms and co-taught NGSS-embedded science lessons. The PD providers also developed a summer institute at the end of both years. The second summer institute was dedicated to assembling all of the lessons developed during years 1 and 2 into a cohesive curriculum around environmental awareness and citizenship.

4. Method

This study was conducted in a suburban high-needs school district in the United States. There were 468-second grade students enrolled during year 1 of the PD; 62% of the second graders were eligible for free or reduced lunch, 86% were of black or Hispanic ethnic origin, and 22% were designated limited English proficient. Twenty-two 2nd grade teachers across all elementary schools in the district participated in the PD. The teachers range in experience from five years to over twenty years of experience.

4.1 Research questions

This study explored: 1) Which practices did teachers engage in in classroom instruction? 2) What changes occurred in how teachers enacted the practices in classroom instruction?

4.2 Data collected

In order to ascertain teachers' initial ability to enact the NGSS practices with their students, teachers were observed within one month of the start of the PD. The researchers created an observation tool based on the competencies for the K-2 grade band from Appendix F of the NGSS [7]. Two researchers observed the lesson together, but scored each lesson via the observation tool independently. To ensure reliability, the researchers cross-validated the ratings until 90% agreement was reached. At the end of year 2, teachers were observed again to ascertain changes in enactment. Frequencies of teacher and student actions were taken in order to examine which practices the teachers enacted and to what extent learning was student-centered. Teachers were not told to incorporate more practices, rather to incorporate those practices they felt most relevant to a greater depth. These frequencies were then cross-referenced with field notes to paint a more complete picture of what occurred during the lessons.

5. Findings

For Time 1, the three most commonly enacted practices were 1, 3, and 4 (Practice 3 had the highest means: Planning and Carrying out investigations 2.82 mean; student mean 2.29). Lessons ranged from very student-centered to very teacher-centered instruction. A second round of observations was conducted to ascertain changes in teacher practice over the course of the PD (Table 1). Again, the observation tool was used to determine which practices the teachers engaged in during science instruction.

	Time 1		Time 2	
Practice	Tchr Avg	Stud Avg	Tchr Avg	Stud Avg
1. Asking questions, defining problems	1.78	0.44	2.00	1.22
2. Developing and using models	0.67	0.11	1.25	1.00
3. Planning and carrying out investigations	3.00	1.56	2.88	3.00
4. Analyzing and interpreting data	2.44	2.22	1.22	3.56
5. Using mathematics and computational thinking	0.11	0.22	0.78	0.56
6. Constructing explanations, designing solutions	0.44	0.22	1.00	1.44
7. Engaging in argument from evidence	0.00	0.00	1.78	1.56
8. Obtaining, evaluating, and communicating information	0.89	1.00	1.33	2.33

Table 1. *Comparison of teacher actions and student actions during observations*

The most commonly enacted practices by teachers at time 2 were 1, 3, 7, and 8. Practice 3 again had the highest means: Planning and carrying out investigations 2.88 mean; student mean 3.00. This was a logical finding in that all teachers observed engaged their students in an investigation. Practice 4 had the highest mean for student enactment as also in time 1 but with a higher frequency in time 2.

In all of the time 2 lessons, teachers engaged their students in developing explanations based on evidence and communicating their findings to others. Through strategic questioning teachers focused their students thinking to consider specific pieces of evidence they were gathering. They also emphasized the need for students to record their data in an organized manner to share more clearly with others. For example, in one lesson, students worked in pairs to clean up an oil spill in metal pans. This lesson took place in a special education classroom with two teachers and two aides. Pairs were allowed to choose three tools to clean up their oil spill (spoons, funnels, filters, cotton, etc) and explain their reasoning. Then they engaged in cleaning up their oil spill. Teachers asked students to explain what they were doing and why. Later, the teacher facilitated a discussion on engineering design using one group's plan as an example:

T: Let's talk a little bit about what's working and what's not working. As scientists we really want to stop and think about what we are doing and then you might have to adjust it and try and make it better. ---- came up with a system. Would you like to tell the class about your system?

S1: First we used a pipette and a funnel and we got a cotton ball into the funnel between the tube and then we kept squirting and putting it out in the...

T: In the funnel. So they are actually doing a two-system clean up job. They are sucking up the oil with the pipette and then created...

S2: A filter.

T: Can you see the water in the cup? What color is it?

S3: White, clear.

T: Totally clear. They have managed to separate the oil from the water. Is this going quickly or slowly?

All: Slowly.

T: Does anyone have a quicker way that they are able to suck up the oil?

S4: We used the sponge and we created lots of oil. The sponge works perfectly, the pipette works a little, the cotton balls doesn't work that much. We put the cotton ball in it [funnel] and then we sucked up all the oil and put it in here and only the clean water.

The exemplar questioning and student dialogue as presented in the case above was typical of the time 2 observations. This example was particularly outstanding in that the classroom contained a majority of students with delayed speech and/or cognitive abilities. Through an engaging, discourse-rich lesson, students were able to demonstrate grade level linguistic and conceptual aptitude. Overall, we noticed teachers engaged in more practices and their associated competencies, and more importantly, an increased average of student-enacted practices. There were marked increases in instances of student enactment for all 8 practices, with Practice 7 Engaging in argument from evidence displaying the highest gains.

6.Discussion and implications

The conclusions of this study further refine our theoretical constructs of the qualities of highly effective PD and the role of teacher efficacy in improving practice. Findings align to Darling-Hammond et al.'s [5] assertion that PD is highly effective when it is designed to engage teachers in active learning that allows them to make sense of what they learn in meaningful ways and supported by coaching, modeling, observation, and feedback. There was a clear need to make a direct connection between NGSS concepts and the 2nd grade science curriculum that the teachers were using week to week. The PD needed to be further differentiated among schools and even among individual teachers. There were variances in teachers' pedagogical confidence and content knowledge, which showed through how they planned and taught science lessons. Teachers unanimously agreed that the PD helped them make science more fun and engaging and improved their questioning techniques to increase student critical thinking skills. Teachers repeatedly reported benefits from the in-class coaching and hands-on nature of the working-shops.

It is our hope that the design and implementation of this project brought to light effective ways of supporting teachers in supporting their students to engage in scientific and engineering practices and thus assist in developing thoughtful, engaged citizens for the 21st century.

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