

How Teacher Professional Development can Improve STEM Education In a Standards-Based Classroom

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The United States is falling behind in math and science education, which is problematic in a world where the global job market is relying more heavily on math, science, and problem solving skills (Organization for Economic Cooperation and Development [OECD], 2010). In order to better prepare our next generation of workers, we need to encourage more students to graduate with STEM degrees. To do this we need to make high-quality science teaching more of a priority in our K-12 school systems. This is a two part process: (a) make science a priority in our elementary and secondary schools and (b) ensure that teachers are able to create high quality lessons by investing in teacher certification programs and continuing professional development opportunities (Drew, 2011).

Science Accountability in our Schools

Test-based accountability is not new to education and has been influencing science education for decades, but No Child Left Behind

(NCLB) has increased schools' focus on reading and math, and therefore has negatively affected science education (DeBoer, 2006). A nationwide study from the Center for Education Policy reported that, between 2001 and 2007, 28% of elementary school districts have reduced science education classroom time by an average of 75 minutes per week, which resulted in 45 fewer hours per year spent on science education (McMurrer, 2008). Judson (2012) found that in states where science was included in Adequate Yearly Progress standards, fourth grade students performed significantly better on standardized science exams. This suggests that if science were given the same weight as reading and mathematics in elementary school, then science performance on standardized exams would increase. However, it is essential to consider how these standardized science exams affect science teaching.

Accountability standards in schools have also changed the nature of what is being taught and how. Anderson (2012) completed a meta-analysis of studies examining how science accountability affected science teaching. Schools at elementary, middle, and secondary levels were subjects of the analyzed studies. Standardized tests tended to assess knowledge of facts, rather than deep content knowledge or critical thinking; teaching to the test tended to water down curriculum; and teachers faced immense pressure to get through the material, rather than encourage curiosity and deeper understanding (Anderson, 2012).

Standardized tests can also dictate

what types of science are taught in the classroom. One high school physical science teacher stated, "Since the [state test] covers mostly biology, my 9th grade class in physical science are mostly biology topics and I spend little time on physics and chemistry" (Sunal & Wright, 2006, p. 133). The teacher's statement suggests that in years when students are tested, the content of the test dictates what the students learn rather than the purpose of the course. In this example, physical sciences were being shortchanged in the physical science course. Additionally, with the increasing focus on accountability and standardized tests, teachers have sacrificed outside activities, such as inviting local scientists to the classroom to inspire students (Anderson, 2012).

Marlette and Goldston (2006) studied teachers in Kansas and found that accountability tests caused the material on the tests to be the content focus of science education rather than the state science standards. Further, teachers adjusted their teaching to include more multiple choice evaluations in preparation for the standardized tests. Multiple choice questions have limited ability to assess inquiry skills or understanding, which are both essential in being successful in science (Marlette & Goldston, 2006). It is easy to understand why standardized tests utilize multiple choice questions when factoring in the cost of administration and evaluation: open-ended items cost 80 times more and standardized exams with a laboratory component cost 300 times more than a multiple choice exam (Gabel, 2006). The question is: How can we address accountability tests

without sacrificing inquiry-based learning?

Current State of the Science Classroom

While the discussion about how standards have affected classroom teaching is important, it is even more important to consider the deeper issue of how prepared our teachers are to teach inquiry-based science. As Anderson (2012) points out, "teachers may say that testing reduces opportunities to use inquiry-based activities even though they rarely, if ever, used them previously" (p. 123). When teachers in an Alabama study were asked to submit a narrative about a lesson they recently taught that reflected their views of science education, 54% of the reported lessons were transmission lessons that relied on presentations and step-by-step instructions as opposed to only 36% that were inquiry lessons that focused on interactions between students, investigative strategies, and use of hands-on materials (Sunal & Wright, 2006). Banilower, Smith, Weiss, and Pasley (2006) found that teachers were likely to equate students doing anything hands-on with inquiry-based learning, regardless of whether it involved students following step-by-step instructions or true investigative learning.

In this same study, Banilower et al. (2006) conducted nationwide research where they reviewed lesson plans and observed classroom instruction, finding that:

- Only 21% of lessons provided investigative experiences for students.
- Only 14% of lessons were conducted in a climate of

intellectual rigor and encouraged challenging of ideas.

- Less than half of lessons, 47%, rated high in actively encouraging the participation of all students.
- Only 16% of lessons included questions likely to move student understanding forward.
- A majority of K-12 science lessons, 62%, including lessons with a laboratory component, were low in quality and were not likely to improve student understanding of the subject material.

Many lessons involved term memorization, worksheets from textbooks, or laboratories with step-by-step instructions. Lessons of this nature do not set students up for success in college science courses (BaniLower et al., 2006). The United States has a vested interest in getting students into science majors and graduating students into STEM fields to remain competitive in the global market (Education Commission of the States, 2011).

Professional Development Programs: A Solution

A teacher's science content knowledge and pedagogical practices are influenced by his or her initial exposure to science and the ways in which it is taught both before and during formal training (Weiss, 2006). Teachers are shaped by their own school experiences in addition to their formal preparatory program. Since past school experiences cannot be changed, it is imperative to focus on

teacher preparation programs and continuing professional development as a channel of reform that can be influenced by policy. To look at ways teacher professional development can be enhanced, it is essential to study how professional development opportunities have already been successful.

The University of Colorado Denver partnered with classroom teachers in science research to allow teachers to act as scientists and learn appropriate science pedagogy (Gabel, 2006). The case study showed that this experience had a significant impact on teachers' inquiry lessons and thus improved students' science inquiry process skills. Students in classes with teachers involved in the University of Colorado Denver program and students in classes with teachers from a control group were observed for usage of higher order thinking skills during science discussion lessons. The upper levels of Bloom's taxonomy define higher order thinking skills, including analysis, synthesis, and evaluation. The bottom levels of Bloom's taxonomy define lower order thinking skills, including application, comprehension, and knowledge (Bloom, Krathwohl, & Masia, 1984). Students of teachers engaged in the university research program were observed to use higher order thinking skills in 74% of their statements. In comparison, only 28% of the statements by students in the control group used higher order thinking skills (Gabel, 2006).

The University of the Incarnate Word in Texas partnered with a local urban school district to train middle school science teachers in a newly-

developed Master of Arts in Multidisciplinary Sciences. This was in response to new state education standards that required a larger variety of sciences to be taught in middle school (MacKinnon, Fowles, Gonzales, McCormick, & Thomann, 2006). The program invited university faculty to volunteer to teach seminal science courses in chemistry, physics, biology, and life sciences. The goals of the degree were to enhance content knowledge, integrate pre-algebra and algebra concepts into science teaching, and enhance the implementation of reform-based science. The teachers who enrolled in the program were given pre- and post-tests on all subjects and demonstrated a statistically significant increase of knowledge in biology, chemistry, and physics. Teachers reported changing their teaching styles and feeling more comfortable with the curriculum. Across economic groups, students of trained teachers demonstrated higher scores on the state science standardized test by several percentage points (MacKinnon et al., 2006).

Kansas State University coordinated with K-12 schools to enhance teacher professional development projects (Shroyer, Miller, & Hernandez, 2006). A superintendent, a mathematician, two scientists, two science educators, a district coordinator, and a teacher led the project. Participants included 30 education faculty and 30 arts and science faculty from the university, in addition to 80 K-12 teachers and administrators. The project focused on creating ongoing professional development opportunities and reviewed curriculum activities for

individual courses. Teachers involved in this opportunity reported changing their teaching styles to focus on big ideas and feeling that gaps in their preparation were addressed through the professional development opportunities. These teachers became change agents at their own schools, with most leading reforms in their respective science departments. Students in these districts performed better than the mean of all the state's districts on the state science exam (Shroyer et al., 2006).

These studies reflect three very different and localized examples of how focusing on professional development for teachers has been an effective way to raise test scores and improve classroom teaching. Providing funds for teacher professional development and providing incentives for universities and industries to partner with K-12 schools can continue to enhance the science education our youth receive in the classroom. The next generation needs to have a solid background in science in order to help the United States maintain its dominant global position. Currently, the United States is not the leader in science performance (Education Commission of the States, 2011). Focusing on professional development opportunities is one way to improve science education. It requires investments of time and money, but can help develop change agents to affect local school districts.

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