Abstract Name Teacher Professional Development Programs in Grades 3-8: Promoting Teachers' and Students' Content Knowledge in Science and Engineering

MSP Project Name: Partnership to Improve Student Achievement in Physical Science: Integrating STEM Approaches ($PISA^2$)

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Strand 2: The use of student data to inform and refine MSP work: Examination of the links between professional development and data on student success.

Summary:

The NSF MSP Partnership to Improve Student Achievement in Physical Science: Integrating STEM Approaches ($PISA^2$) is based on findings from a USED NJ MSP Project. This presentation examines components of the NJ MSP project's PD program that contributed to science learning gains among teachers and students using a quasi-experimental design. In Year 3 of that three-year program, 46 elementary teachers attended a two-week summer institute, three school-year PD days, and received monthly classroom visits. Results indicated that teachers and students significantly increased their content knowledge in science and engineering compared to the comparison group; teacher post-test scores were a significant predictor of student science learning; as were the number of program lessons taught and the number of engineering lessons taught.

Question/Issue for Dialogue at Learning Network Conference Session

This paper will examine the links between professional development and data on student success.

Research findings from a USED NJ MSP program provided a foundation for the development of the NSF *Partnership to Improve Student Achievement in Physical Science: Integrating STEM Approaches (*$PISA^2$) project (start date June 1, 2010). In five years, over 400 Grade 3-8 teachers from 12 school district partners will participate in 15-credit hours of graduate coursework and related professional development to strengthen their science content knowledge in physical and earth sciences with emphasis on sustainability and global resources awareness. In addition, teachers will improve their understanding of how students learn STEM subjects, their use of science inquiry and engineering design, and their ability to facilitate student learning of 21st century skills such as innovation and creativity, problem-solving, and teamwork. School and district administrators will benefit from leadership training and strategic planning efforts to chart a course for strengthening STEM programs in their districts. Similar to the NJ MSP, monthly classroom visits will support teachers as they implement new lessons and content in their classrooms.

Our evaluation and research questions in the $PISA^2$ program focus on the contributions of a PD program which utilizes scientific inquiry and the engineering design process (EDP) to achieve *increases in teachers' content knowledge* of science and engineering, on their *attitudes and beliefs about teaching science*; and on the program's impact on *students' content knowledge of science and engineering* and on their *learning of 21st century skills, such as innovation, creativity, and problem-solving.*

Context of the work within the STEM education literature and within your MSP Project:

Exemplary professional development (PD) for teachers can have a positive impact on students' learning and the classroom environment. Specifically, Blank and de las Alas (2009) found successful PD experiences for math teachers contributed to an increase in teachers' subject knowledge, pedagogy, and students' content knowledge.

The USED-sponsored NJ MSP program, *Partnership to Improve Student Achievement (PISA*) integrated engineering curricula with model-based science inquiry in a three-year program with approximately 50 Grade 3-5 teachers in six urban districts in northern NJ.

The PISA program was launched in 2007 to infuse high quality, research-based engineering lessons into elementary science education with the aim of promoting problem-based learning approaches in science and increasing student and teacher content knowledge. The engineering component of science, technology, engineering, and mathematics (STEM) education has been overlooked in K-12 teacher education for many years (Committee on K-12 Engineering Education, 2009). Results from the first and the second years of the program showed that teachers and students in the treatment group had statistically significant learning gains in science and engineering concepts and skills as well as in the targeted science content alone (Macalalag, Brockway, McKay, & McGrath, 2008; Macalalag, Lowes, Guo, McKay, McGrath, 2009).

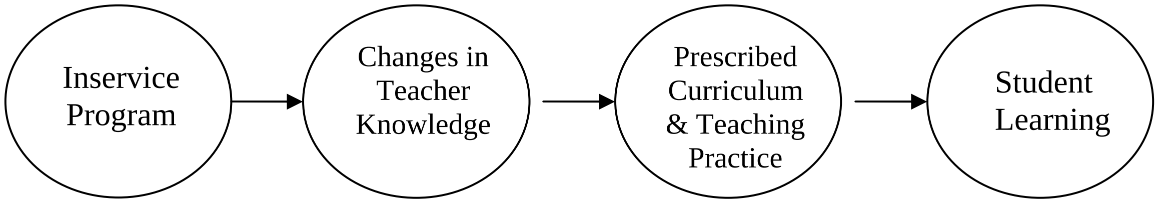
In the third year, 46 grade 3-5 teachers experienced 124 hours of PD consisting of inquiry-based coursework in physical science; experiential, problem-based learning activities using research-based science and engineering curricula; and classroom support visits. Teacher PD consisted of a two-week, 80-hour summer institute, three PD days during the school year, and monthly classroom support visits (coaching, modeling, curriculum alignment, and planning). These 46 treatment teachers impacted 796 Grade 3-5 students. A comparison group of 38 teachers with 769 students was selected and matched against the treatment group based on schools' geographic location, demographics, grade level, and subjects taught by the teacher.

Our research questions were: (1) Does the PD enhance the teachers' content knowledge in targeted science and engineering topics? (2) Does the PD result in improved classroom practice, defined as implementation of science inquiry and the engineering design process (EDP)? and, (3) Will the treatment group of students improve their content knowledge in physical science topics and engineering after one year of an intensive teacher PD program? Data for this paper included *pre and post tests* administered to teachers and students in both treatment and comparison groups and the *lesson implementation survey* collected from teachers in the third year of the three year program.

Each year of the three-year program focused on a different science discipline with associated engineering and technology content. As the program required that teachers engage with university-level content, teachers were challenged with higher-level content, through a variety of inquiry-based lessons presented by faculty and instructors. Year 1 was devoted to life and environmental sciences; Year 2, to earth and space sciences; and Year 3 to physical sciences. Classroom support visits were another component of the program intended to ensure that teachers successfully implemented new content in their classrooms. Visits were also used to document and assess the needs of teachers and students. Three PD sessions conducted during the school year (two face-to-face and one online) expanded and reinforced the science content knowledge that teachers learned during the summer institute.

Professional Development Framework

In this study we hypothesized that the teacher PD program would enhance teacher content knowledge, pedagogy, and student content knowledge. This path of inservice teacher education was described in the literature by Kennedy (1998). We hypothesized that through the instructional lessons in the workshops, which were designed to promote scientific inquiry and the engineering design process, teachers' content knowledge and classroom practices would be enhanced. Students' content knowledge, in turn, would indirectly improve as a result of these experiences.



Ingvarson, Meiers, and Beavis (2005) conducted a survey with 3,250 teachers who participated in 80 individual PD studies. Their findings suggested that *the program's content has the most impact on teachers' knowledge*. Follow-up workshops also contribute to knowledge gains. In terms of factors that influence teachers' classroom practices, programs that provide many opportunities for active learning and reflection on practice top the list. In another study that examined nine studies in terms of the effect of teacher PD on student achievement in science, mathematics, and language arts, Yoon, Duncan, Lee, Scarloss, & Shapley (2007) found *a* relationship between the number of PD hours for teachers and student achievement. Specifically, *studies that had more than fourteen hours of PD showed a positive and significant effect on student achievement*. The three studies that involved the least amount of PD (5-14 hours total) showed no statistically significant effects on student achievement.

In looking at the PD that focused on preparing middle school teachers to implement engineering/technology education in the classroom, Hynes and dos Santos (2007) found that *the two-week PD was successful in improving teachers' confidence in their knowledge and in teaching engineering principles*. Specifically, teachers benefited from the program by engaging in multiple hands-on opportunities with the materials by practicing teaching the engineering lessons in a safe environment afforded by the program, and by learning from other teachers. Our brief review described the different features of PD that influenced teachers' and students' achievement.

Claim(s) or hypothesis(es) examined in the work (anticipating that veteran projects will have claims, newer projects will have hypotheses):

In our USED NJ MSP project, we hypothesized that treatment teachers' content knowledge would increase similar to what Ingvarson et al., (2005) and Yoon et al., (2007) found in their reviews. In contrast with Hynes and dos Santos (2007), we integrated the engineering design process into the teaching of science and provided monthly classroom visits to help teachers implement the engineering and technology lessons of the program.

In our NSF PISA[2] project, we hypothesize that the components of our intensive professional development program consisting of (1) 5 graduate courses or equivalent to deepen teachers conceptual knowledge of physical and earth sciences; (2) problem-based learning methodology (the engineering design process); (3) classroom support visits, will lead to improved teacher content knowledge, and increased self-efficacy in teaching science. We also hypothesize that this PD experience will lead to improved student learning in science and in student attainment of 21st century skills of creativity/innovation and problem-solving.

Evaluation and/or research design, data collection and analysis

<u>Teachers</u>

The Year 3 teacher pre- and post-tests had 25 questions--20 relating to science and science-related mathematics and 5 relating to engineering. The treatment teachers had a statistically significant increase in their test scores, from a pre-test mean of 14.09 points to a post-test mean of 16.52 points ($t(45)= -3.453$, $p<.01$), which was a 17 percent increase. The mean post-test score of the comparison teachers increased by 7 percent, but in this case the difference was not statistically significant ($t(37)= -1.386$, $p>.05$). In order to compare the performance of the treatment and comparison teachers, it was necessary to adjust for the differences in the pre-test scores between the two groups. Using these scores as a covariate, the analysis of covariance (ANCOVA) showed that the teachers' pre-test scores were a significant predictor of their post-test scores ($F(1,80)= 18.309$, $p<.01$). The ANCOVA without the interaction component (Group*TeacherScorePre) showed that the difference in post-test scores between the two groups was significant (F(1,81)= 12.498, p<.01) when the pre-test scores are statistically held constant. *In other words, the treatment teachers' post-test scores improved significantly more than the comparison teachers' post-test scores even after their slightly higher pre-test scores were taken into account.*

Teachers were asked if they would have liked to use more of the project lessons and if so, what stopped them from doing so. Thirty-one out of the 44 teachers mentioned time constraints as one of the reasons for not being able to use more project lessons. For many of the teachers, *test prep took priority over conducting hands-on activities*. In grades where teachers could not connect/link activities to the curriculum standards, the activities became additional content to be covered in a *limited time*. Some teachers solved this problem by using activities they learned in previous institutes or by creating their own activities based on the knowledge/experience they had gained over the past three years. *Having students who were not well-prepared* also made it difficult for some teachers to integrate the project activities. Some teachers also noted that it took time to prepare for project activities, as well as to conduct them during short class periods. In addition to the time constraints, five teachers mentioned *lack of materials* as a deterrent in using more activities in the classroom. Another reason was *different curriculum or pedagogical focus of the school/administration*.

<u>Students</u>

When looking at each group separately, the treatment group had a significant increase in its post-test scores, from M=6.68 to M=9.77 (t(637)= -23.543, p<.01). This was a 46 percent increase. Although the comparison group also had a significant increase in its post-test scores, from M=7.16 to M=8.39 (t(540)= -10.346, p<.01), the increase was only 17 percent. Since the difference between the two groups on the pre-test was significant statistically (t(1177)= -3.188, p<.01), an analysis of covariance (ANCOVA) was used in the analysis of the post-test scores, in order to control for the differences in the pre-test scores. This showed that the difference in post-test scores between the two groups was significant (F(1,1176)= 100.079, p<.01) when the pre-test scores were held constant. *In other words, treatment students improved significantly more than the comparison students when their slightly lower pre-test scores were taken into account. When the students' pre-test scores were held constant, the treatment students had higher post-test scores (M=9.869) than the comparison students (M=8.282).*

When the teachers' post-test scores were added as another variable, they were a significant predictor of the students' post-test scores (F(1,1162)= 56.412, p<.01). Furthermore, the interaction component--group and teacher post-test score--was significant. *In other words, if two teachers, one treatment and one comparison, had equal post-test scores, the students of the treatment teacher were more likely to do well than the students of the comparison teacher.* The project activities therefore contributed to the students' post-test scores. An analysis of covariance (ANCOVA) was performed to examine if the number of activities conducted in the classroom would explain the variance in the students' post-test scores. Students' pre-test scores were used as a covariate to adjust for the variability in the pre-test. *The number of activities students were exposed to in the classroom was a statistically significant predictor of their post-test scores.*

When the teachers' post-test scores (signifying teacher content knowledge) were added as another independent variable, the model improved further (R Squared = .477). The number of activities conducted in the classroom, the teacher post-test score (signifying teacher content knowledge), and the students' pre-test scores explained 47 percent of the variance in the students' post-test scores; 30 percent of this can be attributed to the number of activities conducted. In addition, the interaction effect between total number of activities and teacher post-test score was one of the significant predictors. This suggests that (1) *the more activities a teacher performed the higher the students' post test scores* and (2) *when activities were conducted by teachers with higher post-test scores, students' post test scores were higher.*

<u>Integrating the engineering design process into the science curriculum</u>

Five engineering design activities were introduced during Year 3. Over half of the students were exposed to three or more of the five. The analysis of covariance (ANCOVA) was performed to examine if the number of engineering activities conducted in the classroom explained the variance in the students' post-test scores on science questions. Students' science pre-test scores were used as a covariate to adjust for the variability in the pre-test. The model explained 24 percent of the variability in students' post-test scores on the science questions. *The number of engineering activities that the students were exposed to in the classroom was a significant predictor of their science post-test scores.*

Key insights

The purpose of the NJ MSP study was to examine the PD program in terms of its contributions to teachers' content knowledge, teachers' classroom implementation of project activities, and students' content knowledge. The program was designed to help teachers implement science and engineering lessons in elementary classrooms in response to the challenges presented by the Committee on K-12 Engineering Education (2009). We chose a PD model described in the literature by Kennedy (1998). This path or model targets an improvement in students' content knowledge through changes in teachers' knowledge and teaching practices. Based on our analysis of pre- and post-tests given to teachers, the treatment teachers' post-tests scores improved significantly compared to the comparison group, even when the treatment teachers' higher pre-test scores were taken into account. Teachers in the treatment group improved their content knowledge in specific physical science and engineering concepts after one year of continuous PD. These findings were similar to the reviews of Ingvarson, Meiers, and Beavis (2005) that showed improvements in teachers' knowledge as a result of intensive professional development programs.

Students of teachers in the treatment and comparison groups both showed significant increases in their mean post-test scores although students of treatment teachers improved significantly more than the comparison students when their slightly lower pre-test scores were taken into account. Further analysis of teachers' and students' test scores revealed that teachers' post test scores were a significant predictor of their students' post-test scores. This suggested that the test itself may be better tied to the content being taught by teachers. These findings were reflective of the reviews of research conducted by Blank & de las Alas (2009), which reported correlation between PD for teachers and student achievement. In addition, our study has shown the implication of promoting the engineering design process in teacher PD. The engineering design lessons engaged teachers as well as students in learning the required science concepts. The number of engineering activities that the students were exposed to in the classroom was a significant predictor of their science post-test scores.

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