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# Teacher Professional Development in Grades 3-5: Fostering Teachers' and Students' Content Knowledge in Science and Engineering


## Abstract

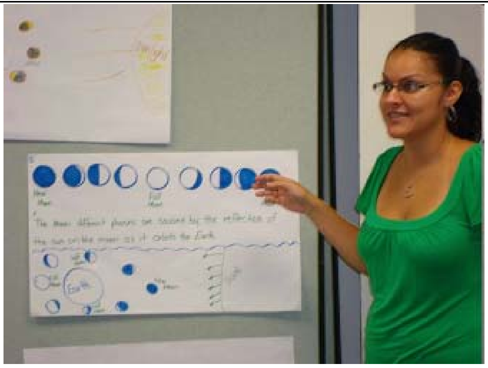
Innovative, research-based professional development is needed to help teachers implement science and engineering education in elementary schools. This is a challenging task, particularly for teachers who many have little familiarity with either science inquiry or the engineering design process (EDP), and who may not have developed the instructional strategies needed to facilitate student inquiry and engagement in EDP. In the Partnership to Improve Student Achievement (PISA) study, 43 grade 3-5 teachers in New Jersey participated in a two-week summer workshop, three workshops during the school year, and received monthly classroom support visits, which comprised one year of instructional activities in a three-year professional development program. The study also included 737 students taught by teachers in the treatment group, 35 teachers in the comparison group, and 684 students taught by teachers in the comparison group. We analyzed pre- and post- tests of teachers and students in both groups and teacher activity implementation surveys. Results from the pre- and post- tests showed that the treatment teachers significantly increased their content knowledge in science and engineering compared to the comparison group. Similarly, post-test scores of students in the treatment group were significantly higher than the post-test scores of students in the comparison group. Teachers noted that scientific inquiry and the engineering design process promoted 21$^{st}$ century skills such as problem solving, critical thinking, collaboration, and communication among students. Finally, further data analysis revealed that the number of PISA lessons that teachers implemented in their classrooms was a significant predictor of students' test scores. In this paper, we report on the professional development model that we used and the results of our study.


## Introduction

Exemplary professional development (PD) for teachers can have a positive impact on students' learning and the classroom environment. Specifically, Blank & de las Alas[1] found successful PD experiences for math teachers contributed to an increase in teachers' subject knowledge, pedagogy, and students' content knowledge. However, teacher PD that focuses on integrating science and engineering in elementary schools is still in its infancy. The engineering component of science, technology, engineering, and mathematics (STEM) education has been overlooked in K-12 teacher education for many years[2]. To address these challenges, an intensive teacher professional development program was launched in 2007 to infuse high quality, research-based engineering lessons into elementary science education by working with the same group of teachers over a three-year period. Results from the first year 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[3]. Further, teachers' knowledge of and use of inquiry-based science instruction also increased[4]. In the second year of this program, the PISA built on professional development efforts by providing 43 grade 3-5 teachers in N.J. with inquiry-based coursework focusing on strengthening teachers' understanding of science concepts (in this case, earth science); hands-on experience using research-based science and engineering curricula; classroom-support visits; , and mentoring in additional key content topic areas. As in the first year, the partnership included six urban districts in northern N.J., a science center, a teacher education institution, and an engineering university. Teachers received 124 hours of intensive PD during the two week summer institute followed by monthly classroom support visits (coaching, modeling, curriculum alignment, and planning), and three full-day workshops during the 2008-2009 school year. A treatment group of 737 students received instructions from teachers who were in the program. In September 2008, a comparison group of 35 teachers with 684 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 for the second year of the program were: (1) Does the professional development 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 EDP? and, (3) Will the treatment group students improve their content knowledge in specific 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 *lessons implementation survey* collected from teachers in the second year of the three year program.

Each year of the three-year PISA program focused on a different science discipline with associated engineering and technology content. As the program requires that teachers engage with "university-level content, " the 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. During the two-week summer institute that was held in 2008, teachers learned earth and space science content based on 28 science and 7 engineering lessons presented by the faculty and instructors of the engineering and teacher-education colleges. Sample science lessons included Phases of the Moon, Reasons for Seasons, Classifying Rocks and Minerals, and Correlating Fossil Evidence. Science lessons were developed using the science inquiry framework[5,6] and constructivist approach to learning[7]. Teachers also went through two *Engineering is Elementary (EiE)* modules (developed by the Museum of Science, Boston) over the summer to learn the engineering design process. The first module was the *Sticky Situation* where they learned about different earth materials and designed their own walls (The second module was *Catching the Wind,* where they studied weather and designed their own windmills.



Phases of the Moon Lesson

Classifying Rocks and Minerals

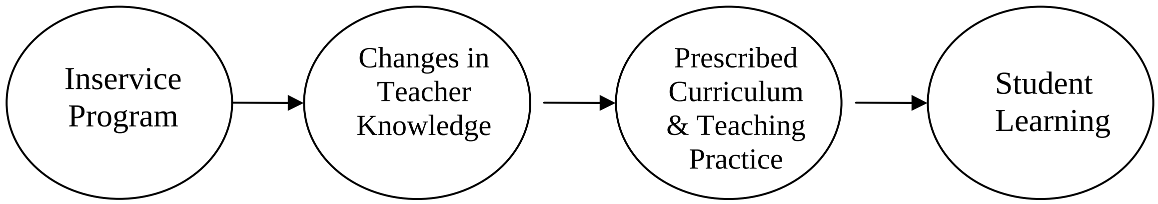
Classroom support visits were another component of the program intended to ensure that teachers were successful in classroom implementation of what they learned over the summer. Visits were also used to document and assess the needs of teachers and students. Three PD sessions conducted during the school year (two face-to-face and one online) expanded and reinforced the science content knowledge that teachers learned during the summer institute.

PISA aims to address the challenges presented by the Committee on K-12 Engineering Education[2] which recommends: (1) the development and implementation of research-based engineering curricula in elementary schools; (2) funding research studies to determine how science inquiry is connected to engineering design; (3) increasing numbers of PD for elementary teachers in STEM education; and (4) outreach to girls and minority students.

**Background**

In today's changing economy and global workforce, several published policy documents advocate an increase in STEM, specifically engineering, in K-12 education[2,8,9]. The U.S. economic growth in the 1950s was attributed to the scientific and technological advances during that decade[10]. Today, scientific and technological literacy are crucial for our students to compete in the 21st century[8,11]. Scientific inquiry and the engineering design process promote "habits of mind" such as critical thinking, problem solving, communication, collaboration, creativity, and innovation, which are essential skills to be productive citizens. Other potential benefits of engineering in K-12 education include improved learning and achievement in science and mathematics, engagement in the engineering design process, awareness of engineering as a career, and increased technological literacy[2]. Unfortunately, inequalities in instruction and qualifications of teachers and resources result in widely different learning opportunities for different group of students[12]. Most teachers teaching engineering as part of the K-12 curriculum lack the knowledge about what engineering is and how they might teach the subject[13]. At the same time, most teachers attend only a few hours of PD programs and most programs available to teachers lack the content, continuity, and depth to make meaningful changes in their content knowledge and teaching behaviors[14].

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[15]. We hypothesized that through the instructional lessons in the workshops, which are designed to promote scientific inquiry and the engineering design process, teachers' content knowledge and classroom practices will be enhanced. Students' content knowledge, in turn, will indirectly improve as a result of these experiences.




In this next section, we will present a brief review of the literature that connects the PD program to students' learning. Specifically, the review will illustrate the different features of the program that contribute to teacher content knowledge, classroom enactment, and student content knowledge.

Ingvarson, Meiers, and Beavis[16] conducted a survey study that impacted 3,250 teachers who participated in 80 individual PD studies. The review of research studies aimed to identify exemplary models and characteristics of effective PD programs. 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. Finally, when looking at impact on knowledge and practice together, the significance of a professional community became apparent.

Fishman, Marx, Best, and Tal[17] presented an analytic framework in their study linking PD to student and teacher learning. The participants included 40 teachers teaching sixth, seventh, and eighth grade students in 14 urban schools in Detroit, Michigan. Teachers learned project-based science through inquiry pedagogy, which is in line with the constructivist notion of learning. Analysis of pre- and post- assessment, surveys, focus-group discussions, and classroom observations showed positive impact on teachers' knowledge, beliefs about teaching, and classroom enactment. Students' post-test scores also increased after participating in the curriculum projects.

Blank & de las Alas[1] conducted a meta-analysis of sixteen studies of teacher PD programs in mathematics and science. The project aimed to inform educational leaders of how to use teacher PD to improve student achievement. The majority of studies that are part of this meta-analysis included programs for mathematics teachers. Most program designs included strong emphasis on teachers learning specific subject content as well as pedagogical content. Results of the meta-analysis showed evidence that teacher PD in mathematics does have significant positive effects on student achievement.

Yoon, Duncan, Lee, Scarloss, &Shapley[18] examined nine studies in terms of the effect of teacher PD on student achievement in science, mathematics, and language arts. The authors 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. All nine studies employed workshops of summer institutes for elementary teachers.

Hynes and dos Santos[19] designed a PD study to prepare thirteen middle school teachers in Massachusetts to teach an after school engineering/technology robotics unit. The majority of the teachers in the study did not have any formal training in teaching engineering/technology before joining the program. Research findings suggested that the two-week PD was successful in improving teachers' confidence in their knowledge and in teaching engineering principles. Teachers benefited from the program by engaging in multiple hands-on opportunities with the materials practicing teaching the engineering lessons in a safe environment afforded by the program, and by learning from other teachers.

In this brief review, we described the different features of PD that influenced teachers' and students' content knowledge. In our PISA program, we provided a two-week summer institute and three follow up workshops over one year of a three-year program. These were part of 124 hours of intensive PD aimed at provide teachers with increased understanding of targeted science and engineering concepts through active learning, specifically through science inquiry, engineering design, and reflection. We hypothesized that treatment teachers' content knowledge would increase similar to what Ingvarson, Meiers, and Beavis[16] and Yoon, Duncan, Lee, Scarloss, &Shapley[18] found in their reviews. Given the findings of Fishman, Marx, Best, and Tal[17] and Blank & de las Alas[1] we predicted that students' content knowledge in specific science and engineering concepts would increase as teachers implemented what they learned from the program. In contrast with Hynes and dos Santos[19], we integrated the engineering design process in teaching science and provided monthly classroom visits to help teachers implement the program.

**Methods**

The second PISA summer institute was held in the summer of 2008. Of the 49 treatment teachers who participated in the first year of the project, 6 left during the school year, resulting in 43 remaining teachers in the treatment group. Teachers from the treatment group taught 737 students in grades 3-5 from 18 public and 3 non-public schools in northern N.J.. The participating teachers included classroom teachers, inclusion teachers, special education teachers, and a computer technology teacher. In September 2008, a comparison group of 35 teachers was selected and matched against the treatment group of teachers based on the school's geographic location, demographics, grade level, and subjects being taught. Many teachers in the treatment group were co-teaching the same group of students, therefore only one comparison teacher was needed. A comparison group of 684 students were taught by these teachers.

| Group | Teachers (N=78) | Students (N=1421) | Classes (N=72) |
|---|---|---|---|
| Treatment | 43 | 737 | 37 |
| Comparison | 35 | 684 | 35 |

Most of the teachers participating in this project had more than two years of teaching experience.

| Treatment Group Years teaching | Count (N=43) | Percent | Comparison Group Years Teaching | Count (N=35) | Percent |
|---|---|---|---|---|---|
| **New (1-2 years)** | 2 | 5% | **New (1-2 years)** | 1 | 3% |
| **Somewhat experienced (3-5 years)** | 12 | 28% | **Somewhat experienced (3-5 years)** | 8 | 23% |
| **Experienced (6-10 years)** | 11 | 26% | **Experienced (6-10 years)** | 15 | 43% |
| **Veteran (11 years and up)** | 18 | 42% | **Veteran (11 years and up)** | 11 | 31% |

Three instruments were developed to measure changes in teachers' and students' content knowledge and teachers' implementation of PISA activities. The first instrument was the pre- and post-test to assess the content knowledge of both groups of teachers in specific earth and space science topics, and engineering. There were 22 science and 4 engineering multiple choice questions. Science questions were selected from the available 8th or 12th grade level question published online by the Trends in International Mathematics and Science Study (TIMSS), Misconceptions-Oriented Standards-Based Assessment Resources for Teachers (MOSART), Praxis Test Prep Materials, and A Private Universe Project. Engineering questions were selected from the *Engineering is Elementary* evaluation questions developed by the Museum of Science, Boston. Pre-tests were given to treatment teachers on the first day of the summer workshop and were administered individually to comparison teachers in September 2008. Both groups of teachers received their post test in May 2009.

The second instrument was the pre- and post-test to assess students' content knowledge in both groups. There were 18 science and 5 engineering questions in specific earth and space science topics. The science questions were taken from the 4th or 5th grade level questions published online by the TIMSS, MOSART, and A Private Universe Project. Engineering questions were selected from the *Engineering is Elementary* evaluation questions developed by the Museum of Science, Boston. Tests were administered to the treatment and comparison groups in September 2008 and May 2009.

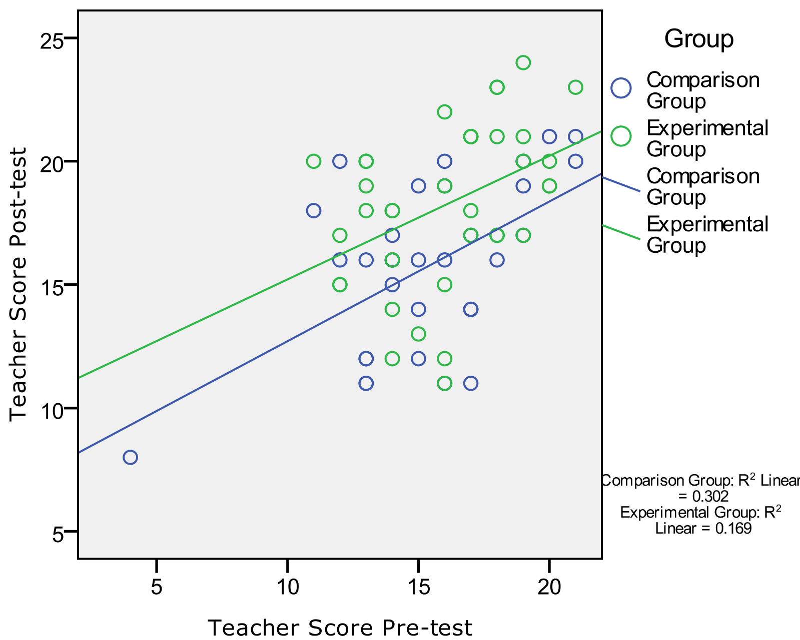
The last instrument was a survey to capture the lessons that teachers in the treatment group implemented and considered had worked well during the school year. The lesson implementation survey was administered on the first day of the summer institute. This survey asked teachers to: (1) indicate the lessons that they had used in their class, (2) list activities that had worked well and that they intend to do again, (3) describe the changes that they would make, and, (4) enumerate the challenges that they encountered in teaching the lessons.

**Results**

Teachers' Content Knowledge in Specific Earth and Space Science Topics and Engineering

We first examined whether the treatment group and the comparison group teachers had the same baseline knowledge. To do this, a T-test was used to compare their pre-test mean scores. A T-test found that there was no significant difference between the two groups' mean scores, which indicated that the *two groups had the same baseline knowledge* (t(70)=.595, p=.55>.05). The treatment group had a pre-test mean score of 15.75 (SD=2.98), which was very close to that of the comparison group (M=15.31, SD=3.35). Next, we looked at how each group improved in their post-test scores. The mean post-test scores for the treatment group increased significantly, from 16.11 to 18.27 points (t(36)=-3.991, p<.01). The comparison group showed almost no increase, with their mean post-test results increasing from 15.33 to 15.73 (t(32)=-.707, p=.485>.05). In percentage terms, *the treatment group's mean score increased by about 13 percent while the comparison group's mean score increased by only about 3 percent.*

Analysis of covariance (ANCOVA) was used to examine whether the treatment group improved more than the comparison group on their post-tests. The ANCOVA without the interaction component (Group*TeacherScorePre) showed that the difference in post-test scores between the two groups was significant (F(1,67)=8.846, p<.01) when the pre-test scores were held constant. In other words, *the treatment teachers' post-tests scores improved significantly even when their slightly higher pre-test scores are taken into account*. Put another way, before teachers' pre-test scores were held constant (in ANCOVA), the treatment group teachers had higher post-test scores (M=18.27, SD=3.297) than the comparison group teachers (M=15.73, SD=3.421). When the teachers' pre-test scores are held constant, the treatment teachers still had higher post-test scores (M=18.074) than the comparison teachers (M=15.948) and the difference in the post-test scores between the two groups was significant (F(1,67)=8.846, p<.01).



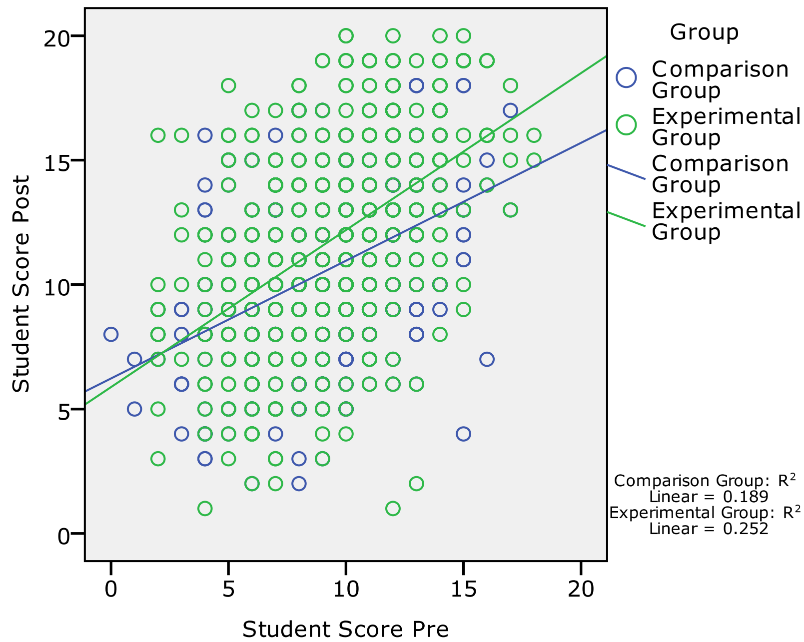

We then analyzed each group's improvements in science and in engineering separately. When looking at each group separately, the treatment group had a significant increase in their test scores, from 13.51 to 15.05 points (t(36)=-3.414, p=.002<.01), while the comparison group had virtually no increase, from 13.18 to 13.27 points (t(32)=-.213, p=.822>0.05). An ANCOVA was used in order to control for differences in pre-test scores. The ANCOVA without the interaction component (Group*TeacherSciencePre) showed that the difference in post-test scores between the two groups was significant (F(1,67)=7.197, p=.009<.01) when the pre-test scores were held constant. In other words, the treatment teachers' post-test scores in science questions improved significantly even when their slightly higher pre-test scores were taken into account. Similarly, looking at the engineering questions, the treatment group had a significant increase in their test scores from 2.59 to 3.22 points (t(36)=-2.698, p=.011<.01). The comparison group had virtually no increase, from 2.15 to 2.45 (t(32)=-1.010, p=.320>.05). The ANCOVA without the interaction component (Group*TeacherSciencePre) showed that the treatment teachers' post-tests scores in engineering improved significantly even when their slightly higher pre-test scores are taken into account (F(1,67)=7.41, p=.008<.01).

### Students' Content Knowledge in Specific Earth and Space Science Topics and Engineering

A T-test was used to determine if there was any difference in the pre-test scores between the treatment and comparison students at the beginning of the school year. The treatment group's pre-test scores (M=9.01, SD=3.271) were slightly higher than the comparison group's pre-test scores (M=8.84, SD=2.95), but the difference was not statistically significant (t(1417.883)=.989, p=.323>.05).

When pre- and post-tests were matched by student (n=532), the treatment group of students had a significant increase in mean post-test scores, from M=9.19 to M=11.68, t(531)=-15.638, p<.01). There was also a significant increase for the comparison students, from M=9.01 to M=10.49, t(531)=-10.488, p<.01). However, the treatment group showed more increase in their scores than the comparison group: *the mean treatment group score increased about 27 percent, compared to an increase of only 16 percent for the comparison group.*

The ANCOVA showed that the students' pre-test scores were a significant predictor of their post-test scores (F(1,1060)=297.287, p<.01). However, the interaction effect between the students' pre-test scores and the Group variable (treatment or comparison) was significant (F(1,1060)=6.037, p=.014<.05), with the treatment having a greater positive impact on those students who had better pre-test scores.




Similar to the teachers, we also analyzed each group of students' improvements in science and in engineering separately. When looking at the Science scores separately, *we found that the students in the treatment group had higher post-test scores (M= 10.08, SD= 3.22) in science than the comparison group (M= 9.23, SD= 2.65)*. After students' pre-test scores were held constant statistically in ANCOVA, the treatment group still had higher post-test scores than the comparison students.

Similarly, looking at the engineering questions, the students in the treatment group had a significant increase in their post-test scores (from M=1.05 to M=1.61, t(531)=-8723, p=.000<.01). The comparison group had a lesser but still significant increase in their post-test scores as well (from M=.99 to M=1.27, t(531)=-4.767, p=.000<.01). The ANCOVA without the interaction component (Group*TeacherSciencePre) showed that the difference in post-test scores between the two groups was significant (F1,1061)=20.027, p=.000<.01) when the pre-test scores were held constant. *In other words, the treatment students' post-test scores in engineering improved significantly compared to comparison students*.

Teacher Implementation of PISA Curricula

Thirty-four teachers responded to the survey administered on the first day of the summer workshops in July and August 2009. They were asked to reflect on their use of PISA lessons in their classrooms during the 2008-2009 academic year. The survey was given only to treatment teachers who were part of PISA in year 2. Findings from the survey indicated that over half of the teachers implemented 10 or more of the 27 lessons and lessons learned during the summer workshops the previous year. All but one of the lessons was used by at least one teacher, with six lessons used by over half the teachers. Almost all of the teachers who had used a lesson considered that it had worked well and reported that they plan to use the lessons again. Specific lessons that they said they will do again and were highly rated included Classifying Rocks and

Minerals, Phases of the Moon, Reasons for Seasons, Catching the Wind: Designing Windmills, Lesson on Latitude and Longitude, and A Sticky Situation: Designing Walls.

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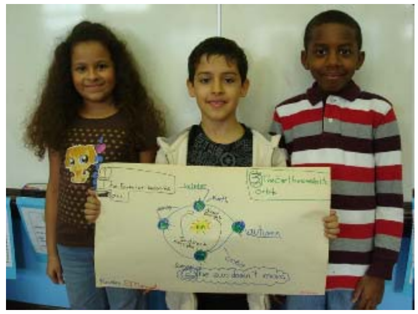
|  |  |  |
| Designing Windmills | Reasons for Seasons | Designing Walls |

The survey asked the teachers if they found integrating the engineering design process (EDP) helpful. Many wrote about how it helped their students' structure their problem solving, including one in the example below who noted that the students transferred what they had learned about the steps into other activities.

> *"The EDP is a great process to incorporate in the classroom. The students begin to apply the process in their learning, not just for the projects. They accept and use the idea of testing and trying again, never giving up."*

Other teachers wrote how the EDP helped their students learn to work in groups. For instance, one teacher described how the EDP not only promoted problem solving but also students' working together.

> *"The engineering design lessons are the ones that [stand out]. I think the fact that they are able to problem solve (even as a group, which is a feat for students) and create/build something drives home the lesson."*

A few emphasized the benefits of iterative problem-solving strategy, with no set solution, in solving a problem. One teacher mentioned that EDP promotes students' thinking of multiple solutions rather than one solution in solving a problem.

> *"…they would fully understand that you can try again to improve your designs. They need to know that there is a correct solution; however it shows them that it is possible to have several other solutions."*

We also asked our teachers in the survey to indicate the extent to which the PISA lessons had helped them meet their own professional goals. The goals were generated from the teachers' applications before they joined program. Findings suggested that having more lessons that *engage and excite students* and *bring science to life* rose to the top of the list.

| | **Not at all/ Not very much** | **Somewhat** | **Very much/ Definitely** |
|---|---|---|---|
| To have more lessons that engage and excite students | 0% | 0% | 97% |
| To have more lessons that bring science to life for students | 0% | 0% | 97% |
| To have more lessons that connect with the real world | 3% | 0% | 94% |
| To have more lessons that include problem-solving and experimentation | 0% | 6% | 94% |
| To improve my ability to instruct students in science | 3% | 3% | 94% |
| To have more projects that can be used with a diverse group of students | 0% | 9% | 91% |
| To have more hands-on projects | 0% | 12% | 88% |
| To gain science content knowledge | 3% | 9% | 85% |

Finally, we asked the teachers what prevented them from using more of the PISA curricula. They mentioned *lack of time* due to the constraints of test preparation and/or the constraints of the existing pace of their curriculum.

Teacher Use of PISA Lessons and Students' Post-test Scores

A total of 34 teachers replied to the section of the year-end teacher survey that asked which of the lessons they introduced in the summer workshop were implemented in their classrooms. Ten teachers were removed from the data analysis: four were non-lead teachers and were removed to avoid duplicate student data; four did not have post-test scores for their students; one had dropped out of the project; and one was a special education teacher. As a result, data from 24 teachers and their 395 students were used for the following analysis.

We also used the survey to see whether the implementation of PISA lessons had an effect on student achievement. There were total of 28 science and engineering lessons that teachers had available from the PISA workshops: 21 science and 7 engineering. The greatest number of lessons conducted by any one teacher was 22, or 78 percent of all activities. The greatest number of science lessons conducted by any one teacher was 19 (90 percent of all science activities) and the greatest number of engineering lessons was 4 (57 percent of all science activities). Students were therefore exposed to different numbers of activities, with about half exposed to 11 or more.

Our analysis revealed that student post-test scores were significantly correlated ($p<0.01$) with the number of lessons they were exposed to. ANOVA using student post-test scores as the dependent variable and number of lessons as the independent variable showed that *number of lessons introduced in the classroom was a significant predictor of the students' post-test scores*. When the teachers' post-test scores (signifying teacher subject knowledge) were added as another independent variable, the model improved further (R Squared = .588). The number of lessons conducted in the classroom, the teacher post-test score (signifying subject knowledge of the teacher), and the students' pre-test scores explained 59 percent of the variance in the students' post-test scores. In addition, the interaction effect between total number of lessons and teacher post-test score was one of the significant predictors. *This suggests that when lessons were conducted by teachers with greater content knowledge there was greater effect on student outcomes.*

To see if there was a certain optimum number of activities, students were divided in three groups based on the number of lessons they were exposed to:

| | |
|---|---|
| Low Activity | 1-7 activities |
| Medium Activity | 8-15 activities |
| High Activity | 16-22 activities |

A T-test was used to determine if there was any difference in the mean post-test scores of students who were in the high activity group (16-22 activities) and the low activity group (1-7 activities). The mean score of the high activity group (M=12.71, SD=4.570) was higher than that of the low activity group (M=9.93, SD=3.694). The difference in means is statistically significant ($t=4.853$, $p<.01$). *In other words, on average, the students who were exposed to 16 or more lessons had higher post-test scores than the students who were exposed to seven or fewer activities.*

## Conclusion and Implications

The purpose of this study was to examine the PD program in terms of its contributions to teachers' content knowledge, teachers' classroom implementation of PISA 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[2]. We chose a PD model described in the literature by Kennedy[15]. 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. Specifically, the treatment group's post-test mean score increased by about 13 percent while the comparison group's mean score increased by only about 3 percent. When looking at the test scores in science and engineering separately, we saw that treatment teachers' post test scores in science questions improved significantly even when their slightly higher pre-test scores were taken into account. Similarly, looking at the engineering questions, the treatment group had a significant increase in their test scores while the comparison group had virtually no increase. In other words, teachers in the treatment group improved their content knowledge in specific earth science and engineering concepts after one year of continuous PD. These findings were similar to the reviews of Ingvarson, Meiers, and Beavis[16] and findings of Fishman, Marx, Best, and Tal[17] 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. However, mean scores of the treatment group increased more than the comparison group: the treatment group score increased about 27 percent compared to an increase of only 16 percent for the comparison group. When looking at the test scores in science alone, we found that students in the treatment group had higher post-test scores than the comparison group. Analysis of engineering questions revealed similar results that the students in the treatment group had a significant increase in its post-test scores while the comparison group had a lesser but still significant increase. 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[1], which reported correlation between PD for teachers and student achievement.

Analysis of teacher implementation survey indicated that over half of the treatment teachers implemented ten or more of the 27 lessons presented during the summer workshops. Teachers mentioned that the science and engineering activities, through scientific inquiry and engineering design process, promoted problem solving, critical thinking, collaboration, and communication in their classrooms, which are crucial skills for students to learn to compete in the global economy of the 21st century[10,11]. Teachers also mentioned that PISA met their goals by bringing science to life for their students. The lessons engaged and excited students to learn. Finally, teachers mentioned lack of time due to constraints of test preparation and/or constraints of the school's curriculum prevented them from using more of the PISA activities.

Further analysis of data (students' test scores and teacher implementation survey) revealed that the number of lessons that teachers implemented in their classrooms was found to be a significant predictor of students' post-test scores. Specifically, students who were exposed to 16 or more PISA lessons had higher post-test scores than students who were exposed to seven or fewer activities. This analysis also showed that teachers' content knowledge had an effect on students' post-test scores. We found that there was greater effect on student outcomes when lessons were conducted by teachers with greater content knowledge. The 124 hours of continuous and in-depth PD program bolstered teachers' content knowledge, which was more than sufficient compared to the 14 hours reported by Yoon, Duncan, Lee, Scarloss, &Shapley[18]. We believe that our findings further support the PD model[13] by bolstering students' content knowledge in science and engineering through an increase in teachers' content knowledge and teachers' implementation of engineering and science lessons in elementary classrooms. Our future work includes looking at other features of the PD model that promotes student achievement.

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