Final Evaluation Report

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This report describes the activities and findings related to the evaluation of Project Pi r^2 (Partners in Inquiry Resources and Research) THREE, a teacher professional development project directed by Emilio Duran from Bowling Green State University, and funded by the Ohio Board of Regents' Improving Teacher Quality program. The report begins with an overview of Project Pi r^2, including some background information and descriptions of the project activities and participants. The report then describes the methods by which the project was evaluated before outlining the evaluation findings. Finally, the report closes with general conclusions regarding the success of the project, as determined by the evaluation findings.

Project Overview

Project Pi r^2 THREE was funded in January 2013 and implemented from June 2013 to June 2014. The project was an extension of the original Pi r^2 project funded by the Ohio Board of Regents in 2009. The focus of Project Pi r^2 THREE was to provide second to fifth grade science teachers with high-quality professional development and outreach services from community partners. The project was designed to address teachers' self-reported lack of qualification for teaching science.[1] The project activities, therefore, aimed to improve teachers' confidence in teaching science using reform-based strategies such as formative assessment and inquiry-based learning. The project activities also focused on improving teachers' content knowledge about science, since teachers often possess misconceptions about science concepts that could affect the quality of their instruction.[2] In general, the project aimed to improve the quality of teachers' science instruction, and ultimately student learning in science. Project Pi r^2 sought to achieve three goals:

1. Improve teachers' content knowledge in science
2. Increase teachers' use of reform-based teaching strategies in science
3. Improve student achievement in science

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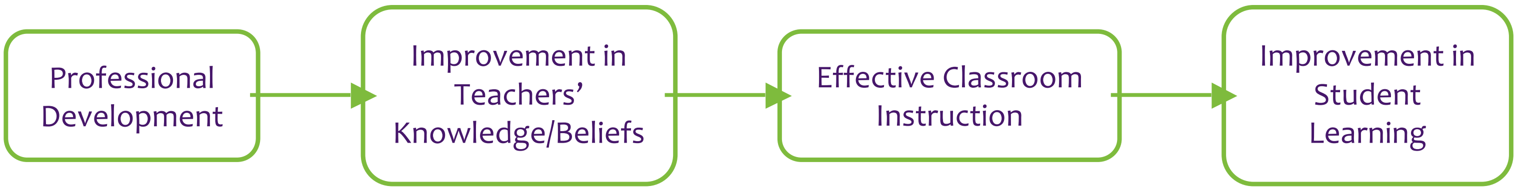
[1] Weiss, I. R., Banilower, E. R., McMahon, K. C. & Smith, P. S. (2001). *Report on the national survey of science and mathematics education*. Chapel Hill, NC: Horizon Research, Inc.

[2] Burgoon, J. N., Heddle, M. L., & Duran, E. (2011). Re-examining the similarities between teacher and student conceptions about physical science. *Journal of Science Teacher Education, 22(2),* 101-114.

The design of the project was based on the theory that participation in effective professional development leads to improvements in teachers' knowledge, beliefs, and attitudes, which in turn leads to more effective classroom instruction, which ultimately leads to improvements in student learning. The figure below illustrates the theoretical model upon which Project Pi r^2 was designed.



In applying this model specifically to Project Pi r^2, teachers participated in several professional development activities (e.g., a summer workshop and monthly professional development sessions) that were intended to improve their beliefs about science teaching and science content knowledge. These improvements in knowledge and beliefs were assumed to contribute to the teachers' implementation of effective science instructional strategies in their classroom. Several reform-based instructional strategies were modeled for teachers during the project, and teachers were often provided with materials that would allow them to use those strategies in their classroom. It is assumed that the use of these strategies was mediated in part by teachers' knowledge and beliefs about science instruction. The classroom outreach programs (see the following section for a detailed description) served as professional development for the teachers, but also contributed to effective classroom instruction. The outreach programs in conjunction with teachers' implementation of project knowledge and resources were assumed to result in improvements in student learning.

Project Activities

Project Pi r^2 engaged teachers in over 100 total hours of professional development, which included participation in the summer workshop, STEM in the Park, monthly professional development sessions during the school year, and classroom outreach programs.

During the summer, teachers participated in an eight-day workshop focused on science content and science pedagogy. Each morning, all teachers participated in so-called “general” sessions, wherein an educational expert (e.g., faculty member from BGSU, administrator from an Educational Service Center) would present an important issue related to science pedagogy. The issues included: an overview of the 5-E learning cycle, differentiated instruction, formative assessment, and explorations of state-level concerns such as standards and testing. In the afternoons, teachers participated in “content” sessions depending on their grade level. Teachers split up during the content sessions to attend content module that addressed concepts specific to their grade level. Content modules were developed around science content standards that are similar among two or more grades. For example, the Forces and Motion module addressed standards at the second and fifth grade levels, and the Landforms module addressed standards at the third and fourth grade levels. Teachers participated in three content modules (at least one focused on Earth Science concepts and one focused on Physical Science concepts) over the course of the summer workshop. The last two days of the workshop were spend developing three lesson plans, structured according to the 5-E learning cycle.

During the school year, teachers attended two events intended to improve their awareness of instructional resources, and provide opportunities for sharing their pedagogical knowledge with others: STEM in the Park (September 2013) and the NWO Symposium on STEM Teaching (November 2013). Teachers also convened four other times during the school year to learn about strategies for using technology in their classroom, but also to discuss teachers’ progress in implementing the three 5-E lessons they created during the summer workshop. Teachers met in October, December, February, and May.

Also during the school year, teachers brought up to three outreach programs into their classrooms during their 5-E lessons. The outreach programs were inquiry-based “traveling programs” conducted in the teachers’ classrooms by one or more informal educators from community science organizations such as Imagination Station and Toledo Botanical Garden. The organizations would send an educator to facilitate a hands-on lesson using examples and materials that students might encounter at the organization itself. The outreach programs were meant to benefit both the teachers and their students, first by serving as a model for effective inquiry-based instruction for teachers, and second by engaging students in meaningful and active science instruction. Therefore, the outreach programs were considered part of the teachers' professional development, but were also assumed to play a large role in the improvement of student learning.

Project Participants

Twenty-six science teachers from northwest Ohio participated in Project Pi r^2. The participating teachers represented seventeen different schools from northwest Ohio, fifteen of which were public. Most teachers (75%) taught in self-contained classrooms, and teaching experience ranged from 1 to 38 years, with an average of 17 years. The table below summarizes the demographic information for the teachers and students who participated in Project Pi r^2.

Project Pi r2 Teacher Participant Characteristics

Demographic Variable		# (%) of teachers
Gender	Female	24 (100%)
	Male	0 (0%)
Racial/Ethnic Background	White, non-Hispanic	18 (75%)
	Black, non-Hispanic	4 (17%)
	Hispanic	1 (4%)
Grade Level*	Grade 2	7 (27%)
	Grade 3	7 (27%)
	Grade 4	7 (27%)
	Grade 5	5 (19%)
Teaching Experience	1 to 10 years	6 (23%)
	11 to 20 years	11 (42%)
	21 to 30 years	7 (27%)
	31 to 40 years	2 (8%)

* Some teachers multiple grades, but had to choose one level in which to participate for grouping

Project Pi r^2 Student Demographic Information

Demographic Variable		# and % of Students
High Needs (Economically Disadvantaged)	Yes	240 (65%)
	No	130 (35%)
Race	White, non-Hispanic	183 (49%)
	Black, non-Hispanic	117 (32%)
	Hispanic	44 (12%)
	Asian/Pacific Islander	7 (2%)
	American Indian/Alaskan Native	1 (<1%)
	Other	14 (4%)
School Location	Urban	287 (76%)
	Suburban	79 (21%)
	Rural	22 (6%)
Special Needs	Limited English Proficient	46 (12%)
	Disabled/Handicapped	38 (10%)
	Migrant	2 (<1%)
	Gifted and Talented	43 (12%)

Project Evaluation

The ultimate purpose of the Project Pi r^2 evaluation was to determine the success of the project in achieving its stated goals and objectives. A mixed methods approach was used to evaluate both the implementation and impact of the project activities.

Evaluation Questions

The following questions guided the evaluation of Project Pi r^2:

1. What is the quality of the professional development and classroom outreach programs implemented during the project?
2. What is the impact of the project on teachers and their teaching?
3. What is the impact of the project on student learning?

These questions correspond to the professional development model described in the "Project Overview" section of this report. The evaluation of the project followed the logic of that model, and therefore sought to determine the effectiveness of the professional development, the impact of the professional development on teachers' knowledge/beliefs, and the impact of the project on student learning.

Evaluation Methods

Both quantitative and qualitative data were collected during the project in order to determine the success of Project Pi r^2 in achieving its goals and objectives. Quantitative data included student and teacher content test data, and teacher survey data. Qualitative data included professional development observations and teacher reflections. This section explains how each aspect of project was evaluated.

Quality of the Professional Development and Outreach Programs. The quality of the professional development was determined using teachers' responses to reflection prompts as well as data from observations conducted during professional development activities.

The project evaluator observed portions of two content sessions and one general session during the summer workshops as well as one school year session (in December). The observations were conducted to determine the extent to which the professional development was implemented as intended, including the instructional strategies used during the sessions.

Teachers' perceptions about the professional development and outreach programs were also used to determine its overall quality. Teachers completed two reflections during the project, one after the summer workshop (in July 2013) and another after the project (in May 2014). The reflections were completed online.

Impact on Teachers and Their Teaching. The impact of the project on teachers and their teaching was determined using data collected from a content knowledge instrument, an online teaching beliefs survey, and teacher reflections. Teachers' science content knowledge was measured using six locally developed instruments, one for each content module. The instruments were designed in alignment with the content statements addressed by each module. Each assessment had eight to ten multiple-choice items. Most of the items were selected from existing content instruments, such as the instruments developed by MOSART[3], the AAAS Project 2061 Science Assessment Initiative[4], the Ohio Achievement and Graduation Tests, and the National Assessment of Educational Progress. The project evaluator developed the remaining items. The teachers completed only the assessments that corresponded with the modules they attended. Therefore, each teacher completed three assessments. In order to maximize statistical power, all teachers were analyzed together by pooling their responses to the assessments into one score. The overall assessment score represented the percentage of correct responses a teacher provided on the three assessments she completed. Teachers completed the assessments online on the first and last day of the summer workshop.

Teachers' beliefs and behaviors regarding science teaching were measured using the Perceptions of Science Teaching Practices (P-STeP) survey. The P-STeP consists of two sections. The first section includes ten items that measure teachers' self-efficacy beliefs regarding science teaching. Some examples of items from the first section include, "I know the steps necessary to teach science concepts effectively," and "The inadequacy of a student's science background can be overcome by good teaching". The items in this section are measured on a five-point scale, with 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. The second section lists twenty-seven best-practices teaching strategies for science and asks teachers to rate the emphasis placed on the strategies during their science lessons (with 1=None, 2=Very little, 3=Some, 4=More than some and 5=A lot) and their confidence in using the strategies (with 1=Not at all confident, 2=Slightly confident, 3=Fairly confident, 4=More than fairly confident, and 5=Very confident). Some examples of the teaching strategies include, "Having students make connections between science and other disciplines," and "Asking students to demonstrate more than one way to solve a problem". Teachers completed the P-STeP online before the summer workshop (July 2013) and after the project was complete (May 2014).

Teachers' reflections were thematically analyzed to identify themes among the responses that would support or contradict the findings from the quantitative data described above.

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[3] MOSART (Misconceptions-Oriented Standards-based Assessment Resources for Teachers) is an NSF-funded RETA (Research, Evaluation, and Technical Assistance) grant that has developed several multiple-choice instruments designed to measure K-12 students' science content knowledge.

[4] See http://assessment.aaas.org/pages/home

Impact on Student Learning. The impact of the project on student learning was determined using data collected from three student content knowledge instruments, one for each grade from third to fifth grade. The instruments were developed for a federally funded grant project targeting the same grade levels, and thus were deemed appropriate for this project. The instruments were developed using the utmost rigor, including multiple rounds of examination by a research team, a review panel comprised of teachers and scientists, and field-testing. In order to more accurately measure the impact of the project on student knowledge, students taught by non-participating teachers were recruited to participate in the evaluation as a control group. Teachers participating in the project were asked to recruit their non-participating third through fifth grade colleagues to be included in the control group. Teachers administered the content knowledge instruments to their students at the beginning and end of the school year. A total of 373 matching student responses were included in the analysis. The table below shows how many Pi r^2 and comparison students completed each assessment.

Number of matching student responses to content assessments

Grade	Pi r^2 Students	Comparison Students	Total Students
Three	51	73	124
Four	74	49	123
Five	66	63	129
Total	191	185	373

Findings

The evaluation findings in this section are organized according to the four steps in the previously described model of effective professional development (found on page 2 of this report). The evaluation data collected throughout the project were analyzed to determine the extent to which each stage in the model was successfully achieved.

Quality of the Professional Development

The quality of the monthly professional development sessions was evaluated against several characteristics known to be effective for enhancing teachers' knowledge and teaching beliefs.[5] These characteristics include sustained instruction over a long period of time, opportunities for active learning, collective teacher participation (especially of teachers from similar grades or content areas), and instruction situated within teachers' classroom practice.

The organization and intended format of the professional development was in alignment with these characteristics. The instruction was sustained over almost one year, starting with the summer workshop in July 2013, and ending with the last school year session in May 2014. This sustained instruction provided teachers with over 100 total contact hours, most of which occurred during the school year (including the hours provided via outreach programs). In addition to the sustained nature of the professional development, the project was also intended to engage teachers in active hands-on learning, and situate instruction within the teachers' classroom. These intended features would theoretically make the professional development more effective, according to the research cited above. Therefore, the professional development observations and teacher reflections were analyzed to determine the extent to which the professional development met these standards of effectiveness.

The four professional development observations demonstrated that the professional development engaged the teachers in active and collective learning. The observation conducted during a content session revealed teachers participating in active demonstrations about the properties of air and water. Teachers also engaged in active discussion about science concepts

[5] Some of these characteristics are summarized in Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a notion sample of teachers. *American Educational Research Journal, 38 (4),* 915-945.

and teaching issues. One observation was conducted during a general session about assessment. The teachers engaged in an intense discussion about the assessments their students were required to take by the state. Almost all of the teachers participated in the discussion. Another observation was conducted during the last day of the summer workshop when teachers were developing their 5-E lesson plans. Teachers grouped themselves by grade level, and collectively negotiated the creation of the lessons. Teachers asked each other questions about the content of the lessons, and helped each other to remember the activities they did during the workshop in order to include them in the lessons. The facilitators were an active part of the lesson development. They provided guidance by suggesting different resources and instructional strategies (especially related to assessment) that teachers could include in their lessons.

Teachers generally perceived the professional development to be valuable and worthwhile. Teachers appreciated the general sessions during the summer workshop, especially the sessions related to the 5-E learning cycle, the Ohio science standards, and assessment. Teachers also appreciated the co-teaching approach adopted for the content sessions, with teacher-leaders facilitating with scientists and informal educators. And although teachers reported learning a lot during the content sessions, many teachers perceived some of the content to be irrelevant because two or three grade levels participated in the same module. Teachers suggested that grade levels be separated in the future so all instruction can be situated within one grade level. Some of the teachers wrote:

> *I feel they were very good. I realize it would be hard to have content modules for each grade level separately but it would be beneficial. Sometimes they didn't pertain to my particular grade level. Although they were good, I would have liked more time to focus on lessons for my content area.*

> *It was hard with weather/weathering to have 2 grade levels in one room. I understand the value of seeing what is taught above our level but I'd prefer to have different sessions.*

> *I liked the ideas I received for my grade level, but wish their would have been more lessons directed at 4th grade. I could adapt a bit of the 2nd and 3rd material, but for some, it was really too much of a stretch (not bad, just not as closely related as I would like for the time I have to teach)*

An important aspect of the professional development during the summer was the development of 5-E lesson plans. Although some teachers reported some difficultly and hesitation with using the 5-E model, teachers generally perceived the lesson development to be a very valuable aspect of the project. Some of the difficulty came from having to develop three lessons in two afternoons. Teachers suggested that the lesson plans be developed directly after each content module. The benefits to this method are: 1) that content would be more easily accessible to teachers because they would have just learned it during the previous two days, and 2) the workload for lesson development would be spread out over the course of the workshop instead of being concentrated in the last two days. Aside from the logistical concerns, teachers saw the lesson development to be beneficial. Teachers especially appreciated the collaborative nature of the lesson development, and the opportunity to reflect on what they had learned during the workshop. Some of the teachers wrote:

> *I think writing the 5E plans at the end of the week was great. I liked that we could work with our peers to write the plans. We were able to bounce ideas off of each other and I walked away with 3 awesome 5E plans that I will use in my classroom this year. To develop these plans we used the instruction we got this week and tweaked it for our classroom. I plan to use the 5E lesson plan in my science class for every lesson.*

> *In my opinion, this was a very important part of the program. If I had not sat down to write out these 3 plans, many of the things I had learned about would have been forgotten with the chaos of the beginning of the school year. Now I have concrete lessons and ideas all laid out for me.*

> *I am so excited to use my 5 E lesson plan! I am still working on it, but it is so rich and deep in activities and learning. I am glad we were able to work on it during the workshop because it is time consuming, but this is the way units should be written.*

> *I have never used the 5E lessons in my own planning and am so grateful that to have been taught the method and how to develop the lessons. Looking at the lessons I've created over these past two days allows me to see where my students need to be. Even though they are time-consuming, I see myself planning and hopefully thinking more along the lines of a 5E when I develop my plans for this coming year.*

Providing time for teachers to develop meaningful lessons is one way by which the professional development was situated within the teachers' own practice. Another important way is the inclusion of informal outreach programs throughout the project. The outreach programs were not only intended to improve student learning, but also to model for teachers how inquiry-based activities can be implemented in the classroom. Teachers perceived this aspect of the project to be valuable and important for improving student learning. Some teachers wrote:

> *Community resources was probably my favorite part of the last two weeks and learning about the different grants to possibly get even more community resources in my room. Community resources are very important to my students because for the most part my students don't have parents that take them to the Botanical Gardens, Imagination Station, or the Challenger Center. It helps to give them the real life situation experience that they need.*
>
> *I can't wait to have the community resource folks come to my classroom!!! It was great to see what and how each person would present. I made a few notes about what to do before and after the community resource would come to our classroom.*
>
> *I am excited to invite the community resource personnel into my classroom this year. Therefore, field trips are almost impossible, but having the field trip brought to my class is invaluable! My students will get the chance to experience exciting lessons in science from experts in the field.*

One aspect of the project that teachers seemed to appreciate was its emphasis on collaboration, both during the summer workshop and the follow up sessions. Collaboratively learning content, sharing resources, and developing lessons provided teachers with a support system that likely made their experience more valuable and effective. Regarding the collaborative nature of the project, some of the teachers wrote:

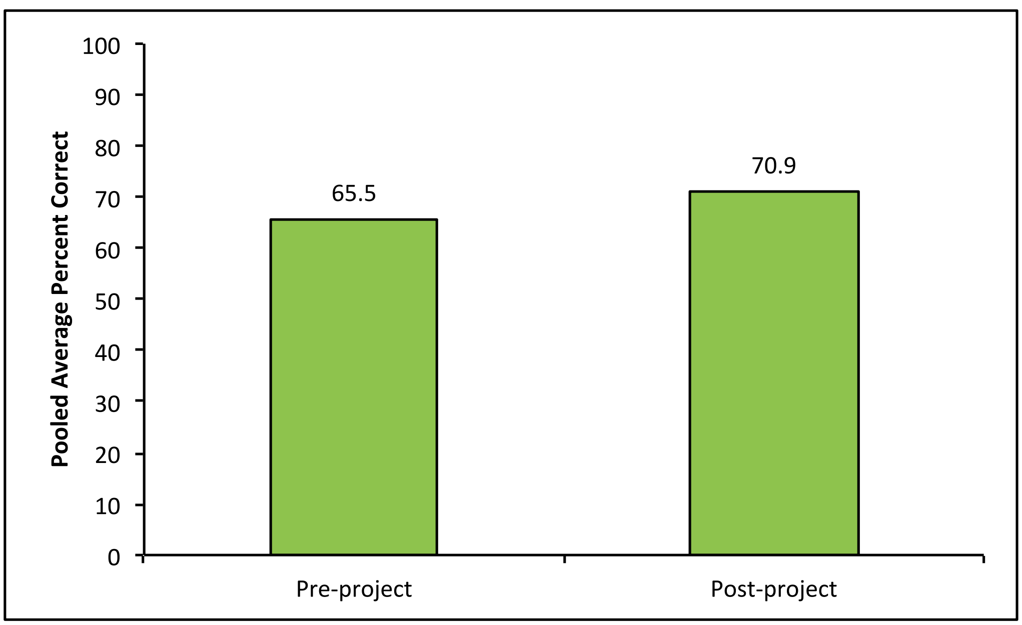
> *It was so nice to be able to collaborate with other third grade teachers when using the standards and writing the 5-E lesson plans*
>
> *I also feel like I have the support of my peers through the wiki and exchanging e-mails and phone numbers.*

Having the opportunity to share with others gives me more ideas and better ways to teach the concepts.

Impact on Teachers and Their Teaching

Science Knowledge. The impact of Project Pi r^2 on teachers' science content knowledge was measured using a battery of online assessments. Teachers completed the assessments before and after the summer workshop in order to measure their changes in science content knowledge as a result of the project. Each teacher completed three assessments—one for each content module they participated in—and teachers' responses to the assessments were pooled into one overall score representing the percentage of correct responses. The results of a dependent t-test indicate that teachers' mean post-workshop science assessment score ($M = 70.9$, $S.D. = 9.9$) was significantly higher than their mean pre-project science assessment score ($M = 65.5$, $S.D. = 10.2$), $t(21) = 2.91$, $p < .01$[6], $ES = 0.62$[7]. The figure below illustrates teachers' improvement in science content knowledge during the project.

Changes in Teachers' Science Content Knowledge



[6] As is typical for educational research, p-values less than 0.05 were considered statistically significant for the analyses conducted for this evaluation.

[7] Effect sizes (ES) offer another measure of the difference between two distributions of scores. Effect sizes are valuable because unlike significance, they are independent of sample size. Traditionally, effect sizes greater than 0.20 are considered small, greater than 0.50 are considered medium, and greater than 0.80 are considered large.

The teachers' reflections provided support further support for the impact of the project on teachers' content knowledge. Several teachers emphasized the value of the project in improving their science knowledge. Four teachers wrote:

> *I learned more about weather, motion, and electricity. It's always great to learn more about what you teach. Being given new resources and activities helps to deepen my and my students' understanding of the topics. Having the opportunity to share with others gives me more ideas and better ways to teach the concepts.*

> *I definitely have learned a lot these last two weeks. I didn't even know how to complete a circuit and that is a major element of our physical science standards! I'm so happy I can teach that with a little confidence now!*

> *I thought I was pretty knowledgeable before taking this workshop, however, I did learn background information that filled in the gaps that will make this teacher an even better teacher. It is so important to know your subject inside and out.*

> *My science knowledge has been impacted by that my misconceptions were addressed and hopefully I will be able to correct students that have similar misconceptions. I feel that by doing the activities my knowledge has more of a foundation then before.*

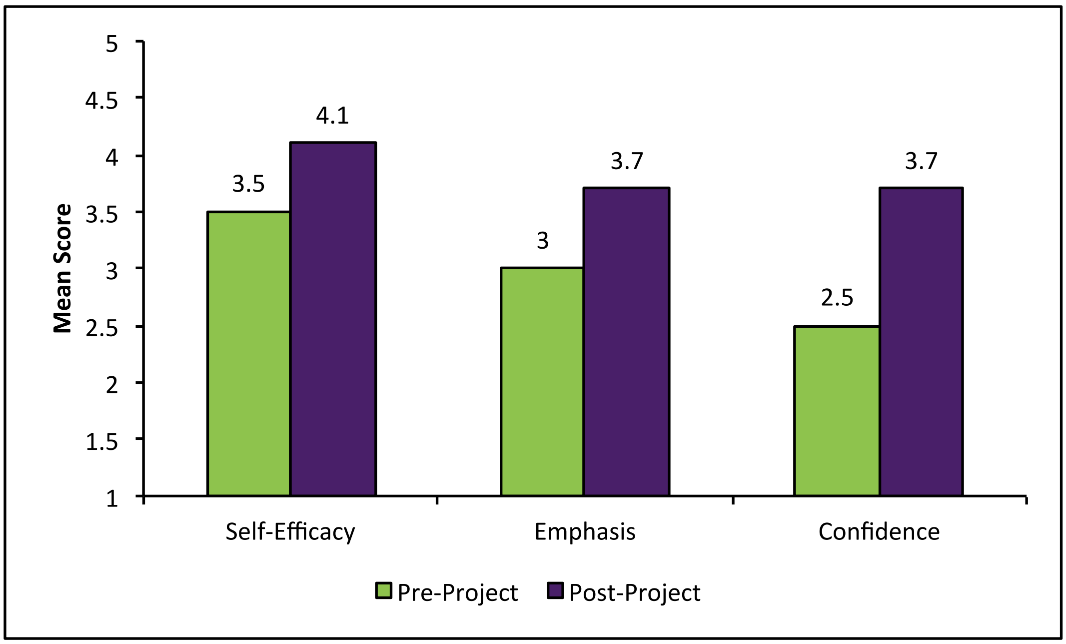
Teaching Beliefs. The impact of the project on teachers' beliefs and behaviors regarding science instruction was measured using the Perceptions of Science Teaching Practices survey. Teachers completed the survey online in July 2013 and May 2014 in order to measure their changes in beliefs and behavior as a result of the project. Reliability analyses conducted using the pre- and post-project survey scores indicate that each scale on the instrument (i.e., self-efficacy, emphasis, confidence) was sufficiently reliable according to common instrumentation standards (> 0.70). A series of dependent t-tests were conducted to determine if the changes in teachers' beliefs and behavior were statistically significant. The results indicate that teachers significantly increased their self-efficacy beliefs about teaching science, the emphasis they place on reform-based instructional strategies, and their confidence to use reform-based instructional strategies. The table and figure below illustrate the teachers' changes regarding their science teaching beliefs and behavior.

Summary of the P-STeP Analyses

Scale	Pre-Project Mean (S.D.)	Post-Project Mean (S.D.)	t value	Effect Size
Self-efficacy	3.52 (0.62)	4.07 (0.54)	3.72***	0.79
Emphasis	3.01 (0.68)	3.78 (0.48)	5.91***	1.29
Confidence	2.47 (0.71)	3.69 (0.63)	8.45***	1.85

* p < .05, ** p < .01, *** p < .001

Changes in Teachers' Science Teaching Beliefs and Behavior



Note: Self-efficacy was measured on a five-point scale while Emphasis and Confidence was measured with a four-point scale.

Teachers' reflections provided additional support for the findings presented above. Teachers attributed the project activities not only with increasing their confidence to teach science, but also their excitement for teaching science. Some teachers wrote:

> *This project experience was power packed! It energized my spirit and rekindled my love for teaching. I have been teaching for a while. I have become stuck in routine and began to loose passion for teaching. I am always excited to start the school year, but I have never felt this passionate and better equipped at the same time. I feel like I have a new*

teacher's passion and an old (experienced) teacher's knowledge, especially in the science field.

This project has increased my science knowledge quite q bit. Even better, this project has sparked an excitement for teaching science. I am sure I will enjoy the rest of my summer, but I can't wait to implement the lessons I learned these 2 weeks. I feel better equipped to teach a subject that previously scared me a bit. I am going into this new school year ready to "shake things up" and "dazzle" my students with new investigations.

I feel the most confident about teaching science than I ever have before. I feel more comfortable with the standards and how to teach science in a more in depth way for student understanding. I can feel like I can actually use the community resources around to help connect learning to the community.

Teachers changed their beliefs not only about their own ability to teach science, but also about the nature of science teaching in general. Several teachers commented that prior to the project they believed science should be taught in a hands-on and active way, and their participation in the project reaffirmed that belief. Some teachers wrote:

I have always thought that effective science teaching involves students "doing" science, not just reading about science in a book. This workshop emphasized the importance of inquiry. Students need the time to work through processes, develop thoughts and questions, and time to test

I have always felt that science should be taught as hands on investigative experiments. Now, I am convinced that it shouldn't be taught any other way. Effective science teaching looks like a Laboratory and the world is your workshop.

The project helped to reaffirm that science should be taught hands-on. Sometimes when we get overwhelmed with content we get lazy and teach from the book, but I had some time to think about and work on new lessons. I know that I need to make time to teach the hands-on science.

Other teachers reported a more dramatic change, citing somewhat of a revolution in their beliefs about science teaching.

> *I have a different attitude about science. It must be discovered. You should not stand and lecture or even tell students what they are about to learn. They should be given questions and parameters to work within to discover what they should learn.*

> *I used to rely on the book OFTEN. Now, I hardly touch the science books, simply because they are boring and my students are completely unengaged when reading them. Because of this class, I now know how to give my students things to "play" with and ask them questions like, how can you light that light bulb? Why do you think this plant is growing sideways. What happens to the water that evaporates in the sky? Why is this picture of a mountain so much different now after 100 years? Etc.... My kids have much more meaningful lessons that are based around their own understanding.*

5-E Lesson Implementation. As the model on page 2 illustrates, the project intended to not only impact teachers' knowledge and beliefs, but also their actual teaching practice. Teachers developed three 5-E lessons at the end of the summer workshop based on the content and pedagogical knowledge they gained during the workshop. After the workshop, teachers were asked about their implementation of these lessons. A majority of teachers (45%) reported implementing all three lessons, and most others (40%) reported implementing two of the three lessons. Two teachers only implemented one lesson, and one did not implement any of the lessons (because of maternity leave). In addition, most of the teachers (70%) reported their implemented lessons to "somewhat closely" match the originally planned lesson. This means that some significant changes were made to the original lesson. Another 25% reported their lessons "very closely" matched the original lessons. The changes made to the lessons generally seemed to be a result of students' needs—variations in learning styles, reading levels, general academic readiness.

Impact on Student Learning

The impact of the project on student learning was determined mostly using the three student content knowledge instruments described in the "Evaluation Methods" section of this report. Teachers' monthly reflections were also used to evaluate the project's impact on student learning.

Third through fifth grade teachers administered the grade-appropriate instrument to their students at the beginning and end of the school year in order to measure the changes in students' knowledge over the course of the year. A series of factorial ANOVAs were conducted to determine if there was a significant difference in knowledge gains between Pi r^2 and comparison students. Factorial ANOVAs are conducted when there are two independent variables—in this case, time and group status (i.e., Pi r^2 or comparison)—influencing the dependent variable (in this case, science knowledge). The factorial ANOVA can test the effect of time and group status separately science knowledge, which might determine if students' knowledge changed over time regardless of the students' group status. More importantly, however, factorial ANOVAs can test whether the science knowledge is influenced by an interaction between time and group status. A significant interaction effect might indicate that group status influences science knowledge differently at each time point. If the Pi r^2 teachers were more effective than the comparison teachers, we would expect to see a larger gain in student learning over the course of the project. That is, we would expect group status to have a larger influence on science knowledge at the end of the project than at the beginning of the project (where all students are assumed to start with comparable levels of knowledge).

The results of the factorial ANOVAs indicate that although Pi r^2 students significantly improved their science knowledge during the school year, the gain was not different from that observed in the comparison group. This means that improvements in students' science knowledge cannot be solely attributed to the project. The table and figures below illustrate the changes in students' knowledge during the project.

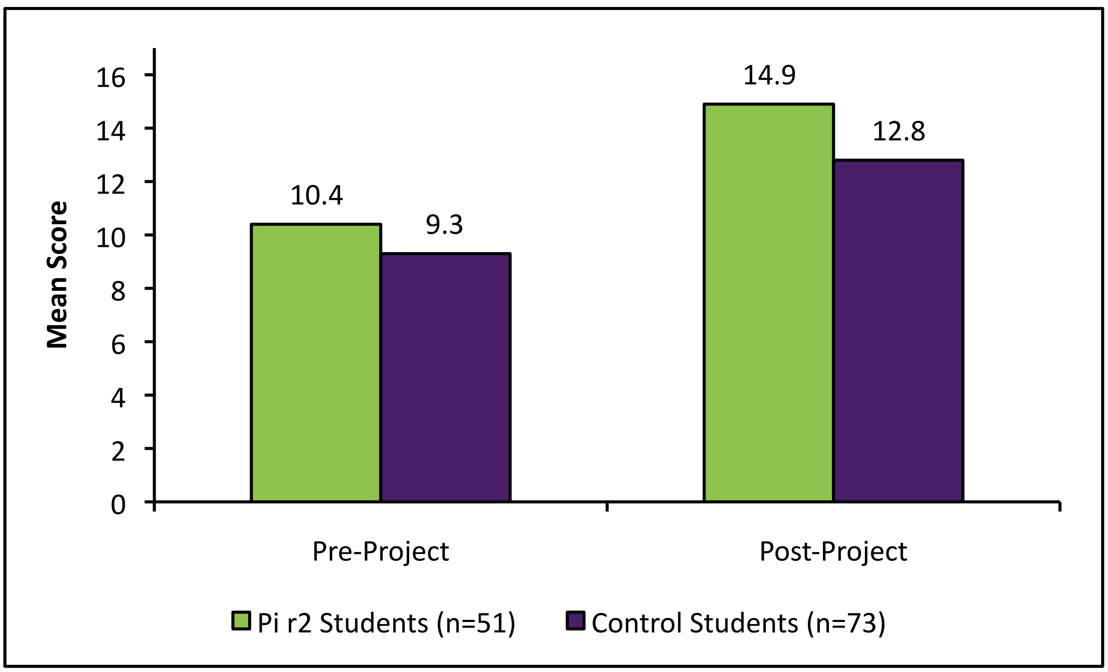
Summary of the student content test analyses

Instrument	Group	Sample Size	Max. Score	Pre-Year Score (SD)	Post-Year Score (SD)	F Statistic
Third Grade	Pi r^2	51	25	10.4 (3.9)	14.9 (3.8)	2.09
	Comparison	73		9.3 (3.9)	12.8 (3.7)	
Fourth Grade	Pi r^2	71	21	8.4 (3.6)	10.6 (4.1)	0.03
	Comparison	49		8.1 (3.1)	10.3 (3.5)	
Fifth Grade	Pi r^2	66	21	8.5 (2.8)	11.4 (3.9)	0.13
	Comparison	63		8.2 (2.8)	11.5 (3.6)	

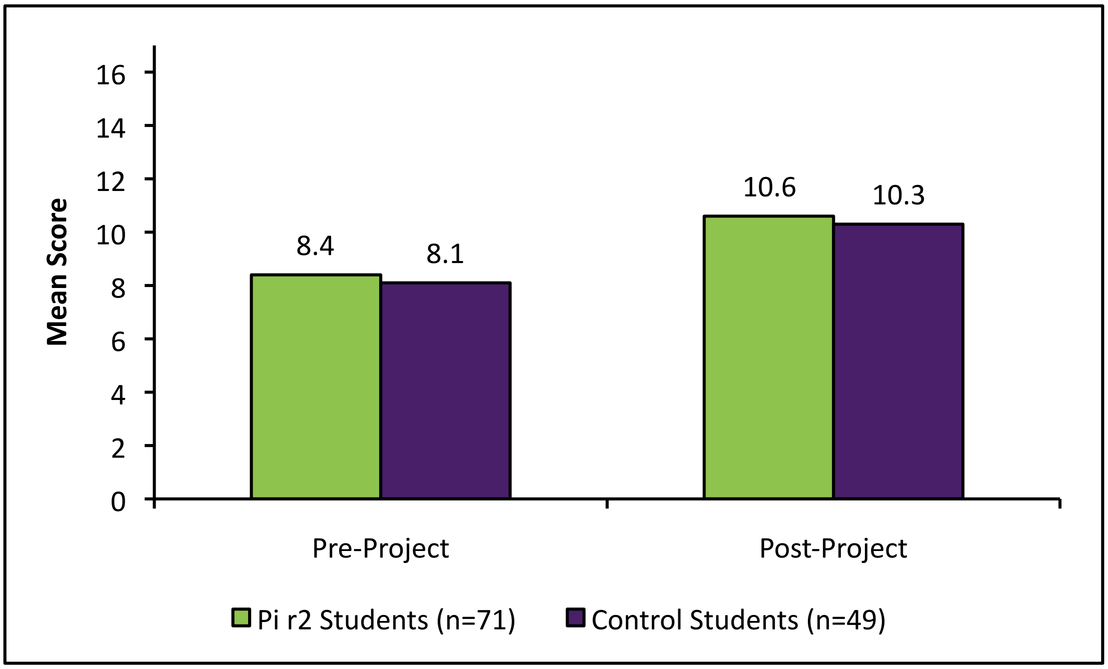
Note: the F statistic refers to the specific test about the interaction between time (pre and post) and group

* $p < .05$, ** $p < .01$, *** $p < .001$

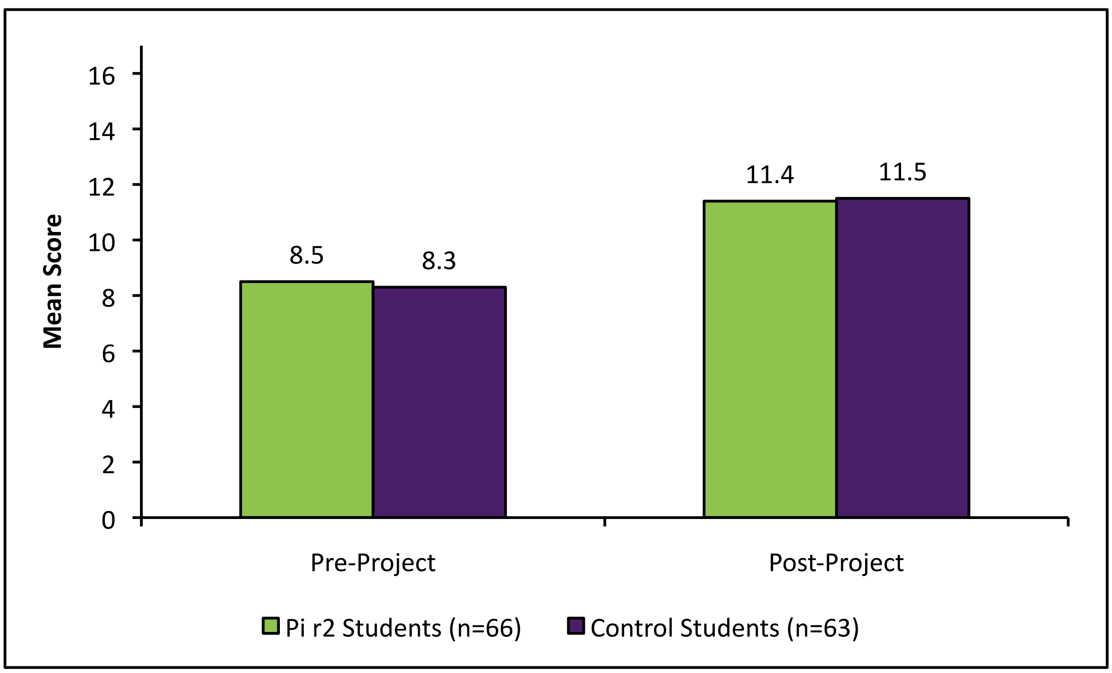
Changes in Third Grade Students' Content Knowledge



Changes in Fourth Grade Students' Content Knowledge



Changes in Fifth Grade Students' Content Knowledge



Although the statistical tests revealed no significant differences between the Pi r^2 and comparison students, it is likely, based on the teachers' reflections, that the project had a positive impact on students' learning. Teachers reported their students retaining information for longer periods of time and improving their ability to articulate concepts and make connections among concepts. Some of the teachers wrote:

> *Students still remember the activities and the concepts that were taught as a result of the engage activities all the way through to the evaluate activities. They were able to see a continuum.*

> *The students retain much more information when I teach using the 5E model. Months later, the students are still discussing information learned previously from the project.*

> *My students aren't generally able to express their learning however given the hands on approach they were able to own the learning thus opening their minds to be able to share what they observed, experienced and make connections.*

> *Not only did my students pass with understanding most of the 4th grade science standards (based on projects and paper tests), they also showed evidence through making connections verbally during discussions*

In addition, teachers suggested the project increased students' engagement in science and excitement about learning science. Some of the teachers wrote:

> *My students were more excited when it was time for science. Prior to this, science usually brought about moaning from the students.*

> *They ask all the time what our next science project is going to be :) It is really is fun teaching science now because I know what I'm doing and my kids WANT to learn. Before, my students dreaded science because they knew we would read out of the book and look at pictures for 30 minutes. Now my students know to expect some exploration of objects, or experiment, or video clip and discussion*

> *Students were definitely more involved with the 5-E lesson plans. I didn't struggle as much with engagement as I would have before I participated in the project.*

They were excited about what we were covering. Because I wasn't or didn't appear too enthusiastic before, I would implement lessons by the book which made for haphazardly inquiry and dulled the lesson. With the hands-on, minds on approach my students seemed with it and in tune with the process of exploring.

Conclusions

The evaluation findings presented in this report indicate that Project Pi r^2 was successful in achieving its objectives. Regarding the quality of the professional development, the evaluation data demonstrate that the organization and format of the project was consistent with research-based "best-practices" in professional development. The project engaged teachers in sustained instruction over a period of eleven months, and the professional development observations demonstrated that teachers actively and collectively participated in instructional activities during the professional development.

The effective implementation of the professional development likely contributed to the observed gains in teachers' content knowledge as well as their teaching beliefs and practices. Teachers significantly improved their science content knowledge as a result of their participation in the project. In addition to gains in content knowledge, teachers also improved their self-efficacy beliefs about teaching science, confidence in using reform-based science instructional strategies, and the emphasis they place on reform-based science instructional strategies. Teachers' reflections indicated that the project not only improved their confidence in teaching science, but also their excitement about teaching science. The reflections also indicate that teachers implemented in their classroom many of the resources and activities provided during the professional development, especially included in the three 5-E lessons they created during the summer workshop.

The evaluation findings demonstrate that students who were taught by teachers who participated in the improved their science content knowledge over the course of the school year. However, the gains observed were not significantly different than the gains observed in the comparison group. Despite these findings, teachers' reflections suggest the project positively impacted student learning, not only in improving their science knowledge, but also in their engagement and excitement about science.