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) TWO, 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 TWO was funded in January 2011 and implemented from June 2011 to June 2012. 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 TWO was to provide K – 6 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 five goals:

1. Help retain and support teachers in science.
2. Expose teachers to effective models in science instruction.
3. Integrate informal educational resources in the region's classrooms to model inquiry.

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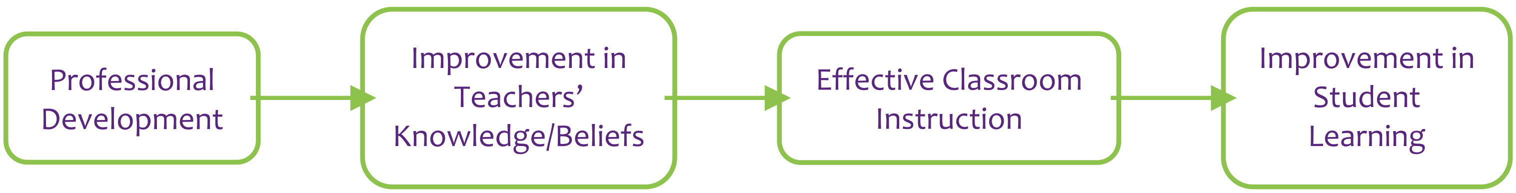
[1] Weiss, I. R., Banilower, E. R., McMahon, K. C. & Smith, P. S. (2001). *Report on the national survey of science and mathematics education*. Chapel Hill, NC: Horizon Research, Inc.

[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.

4. Improve student learning in science.
5. Promote the use of research-based best practices in science teaching in northwest Ohio classrooms consistent with local, state, and national standards.

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., the Community Resources Workshop, 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. For example, teachers engaged in a formative assessment activity and several inquiry-based science activities during each monthly professional development session, and were provided with materials to implement those activities in their classrooms. 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 Community Resources Workshop, STEM in the Park, monthly professional development sessions during the school year, and classroom outreach programs. Each of these activities is described in detail below.

The Community Resources Workshop. Teachers participated in the Community Resources Workshop (CRW) from June 20 – 24, 2011. The CRW is a one-week summer professional development program that has been implemented in Toledo since 1998. The main objectives of the CRW are to make teachers more aware of and familiar with local educational resources in the community, for the ultimate purpose of increasing the teachers' use of community resources in their classroom. During the CRW, the teachers visited the Franciscan Center at Lourdes College, Secor Metropark, Imagination Station, The Toledo Museum of Art, WGTE Public Media, The Toledo Zoo, the Challenger Learning Center of Lucas County, Fifth Third Field (of the Toledo Mud Hens), and the Toledo Public Library. In addition, the teachers were engaged in presentations by Scrap 4 Art, the Toledo Symphony, Sauder Village, Fort Meigs, Toledo Botanical Garden, Maumee Valley Historical Society, Nature's Nursery, and the Toledo Downtown Walking Tour. All 30 teachers enrolled in Project Pi r^2 participated in the CRW along with 19 additional teachers who were not enrolled in Project Pi r^2.

STEM in the Park. Teachers participated in the STEM in the Park event on September 10, 2011 at Bowling Green State University. STEM in the Park is a free community event coordinated by the Northwest Ohio Center for Excellence in STEM Education (NWO), featuring interactive STEM activities facilitated by higher education institutions, K-12 educational agencies, community non-profit organizations, and local businesses. The 2011 STEM in the Park event featured 49 interactive STEM activity stations and was attended by 1,400 adults and children from northwest Ohio and southeast Michigan. Teachers enrolled in Project Pi r^2 were given the choice to simply attend the event or volunteer to help facilitate the activities at one of the activity stations. More contact hours were awarded to those teachers who volunteered to help facilitate STEM activities.

Monthly Professional Development Sessions. Teachers enrolled in Project Pi r^2 participated each month (from September 2011 to April 2012) in a professional development session designed to improve teachers' knowledge of science content and effective teaching strategies. Each month, the professional development addressed a different science concept such as animal adaptations, states of matter, and soil. The professional development sessions were co-facilitated by a local master teacher proficient in the use of reform-based science teaching strategies, a scientist, and an informal educator (from a community organization such as the Toledo Zoo), who modeled the use of effective instructional strategies such as formative assessment, collaborative learning, and inquiry-based learning. The general format of the professional development sessions went as follows:

1. The teachers participated in a formative assessment activity, which allowed the session facilitators to see what the teachers already knew about the science concept that was going to be addressed during the session. The activity also introduced the teachers to the science concept they would explore during the professional development session.
2. The teachers explored the science concept through a short inquiry-based activity facilitated by the K-12 teacher leader and scientist.
3. The informal educator facilitated a one-hour activity about the science concept. These activities were modified versions of the activities the informal educators delivered to the teachers' students during the outreach phase of the project. The "teacher version" was more comprehensive and complex regarding the science content.

The table below outlines the science content addressed during each professional development session, as well as the facilitators of each session.

Project Pi r^2 Monthly Professional Development Sessions

Month	Science Content	Session Facilitators
September	Living and Non-Living	Master Teacher and Scientist
October	Adaptations of Reptiles and Amphibians	Master Teacher, Scientist, and The Toledo Zoo
November	Native Species and Habitat Change	Master Teacher, Scientist, and The Toledo Metroparks
December	Soil	Master Teacher, Scientist, and Toledo Botanical Garden
January	Rocks and the Rock Cycle	Master Teacher, Scientist, and Challenger Learning Center of Lucas County
February	States of Matter	Master Teacher, Scientist, and Sauder Village
March	Nature of Matter	Master Teacher, Scientist, and Imagination Station
April	Natural Resources	Master Teacher, Scientist, and Seven Eagles Historical Society

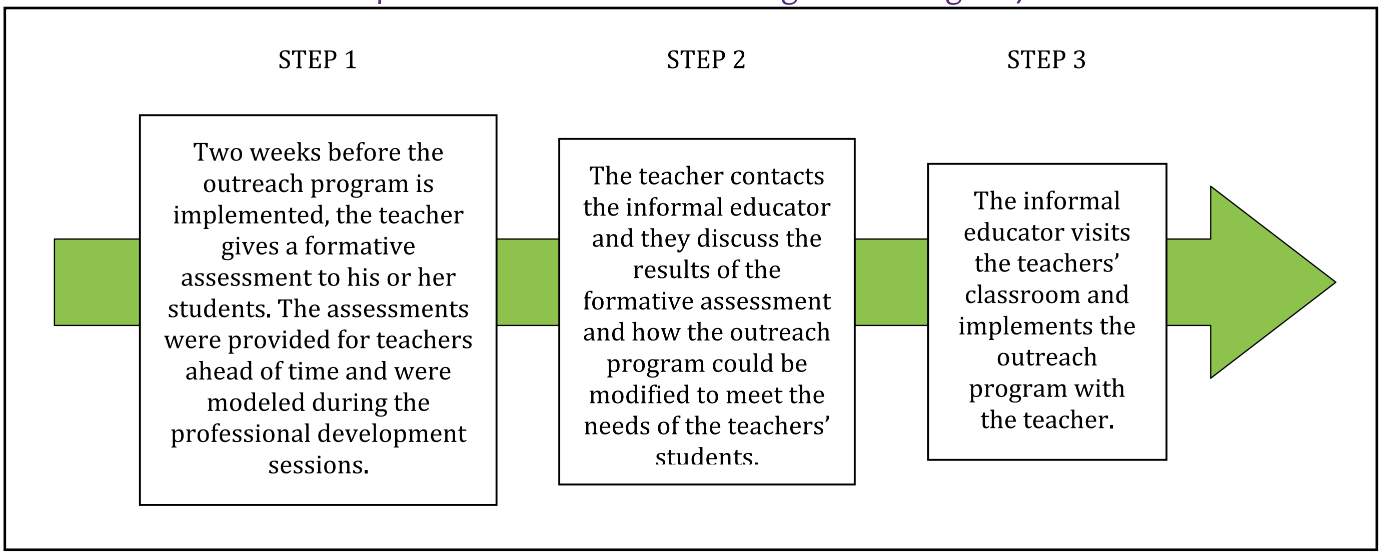
Classroom Outreach Programs. As part of their participation in Project Pi r^2, teachers were given six outreach programs throughout the school year. The outreach programs were inquiry-based "traveling programs" conducted in the teachers' classrooms by one or more informal educators from community science organizations such as The Toledo Zoo and Toledo Botanical Garden. The table below includes descriptions of the outreach programs provided by the informal educators during the project.

Project Pi r^2 Classroom Outreach Programs

Organization	Description of Outreach Program
Toledo Zoo	During the program, students observed demonstrations and engaged in activities that taught them about the characteristics of reptiles and amphibians as well animal adaptations. Students began by discussing reptilian and amphibian characteristics. Students sorted characteristics as amphibian, reptilian, or both. Students then learned about reptile and amphibian adaptations by watching video clips, looking at pictures, and interacting with live animals.
Toledo Botanical Garden	During the program, students engaged in several activities that taught them about the components of soil. Students began by simply investigating a sample of soil using magnifying glasses and microscopes. Next, students examined small clear containers that held the components of soil (weathered rock, sand, silt, clay, air, water, plant material and small animals). Students discussed the different components of soil and how rocks break down to smaller pieces. Students were then given pure samples of sand, silt and clay to look at with microscopes. Students then set up a sedimentation experiment to determine the content of an unknown soil sample. Students finally experimented with three different agents of weathering: wind, friction/gravity, and water.
Toledo Metroparks	During the program, students engaged in activities and discussions that taught them about animal habitats. Students began by matching a picture of a bird to the habitat in which it would best survive. Students discussed why the bird would survive there, and the discussion was extended to include several kinds of habitats (e.g., desert, woodland, swamp). Students made observations about bird characteristics before playing a “detective game,” in which students had to figure out where a particular bird’s feeding habitat would be based on the bird’s beak and foot shape.
Challenger Learning Center	During the program, students observed demonstrations and engaged in activities that taught them about the processes that shape the Earth as well as the nature and formation of rocks. The students observed several demonstrations about the different processes that shape the earth (e.g., two candy bars pushed together showed mountain formation). Then students looked at several pictures of several landforms and discussed how they could have formed. Students then engaged in a core sampling activity, where they used a clear straw to take core samples from a candy bar in order to figure out what kind of candy bar it was.
Sauder Village	During the program, students engaged in activities and discussions that taught them about solids (specifically, butter) as well as how to conduct an experiment with multiple variables. Student began by discussing what butter is and how it is made. Then, students made their own butter by shaking cream (either cold or room temperature and with or without yogurt) in little containers. Student recorded how long it took for the butter to form, and figured out which condition was best for making butter. Students then made observations about the butter, and discussed more about how it was formed.
Imagination Station	During the program, students observed demonstrations and engaged in activities that taught them about the different states of matter and the processes by which one state changes into another. Students observed several demonstrations in which liquid nitrogen was used to freeze water or condense air in a balloon. Each demonstration helped students complete a graph at the front of the room that included all states of matter and processes of phase change. Students made observations about an unknown liquid (Sprite), and then dropped raisins in the liquid to see what would happen. The students observed more demonstrations that addressed the concepts of mixtures and solutions
Seven Eagles	During the program, students interacted with several Native American artifacts and engaged in discussions that taught them about natural resources and the conservation of natural resources.

Teachers and informal educators were expected to follow the format outlined in the figure below regarding the implementation of the outreach programs.

Intended Format for the Implementation of Outreach Programs During Project Pi r^2



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. Both of these claims – that teachers and students benefitted from the outreach programs – were evaluated as part of the Project Pi r^2 evaluation.

Several STEM faculty members from local institutions of higher education were recruited to participate in Project Pi r^2. These scientists visited teachers' classrooms several times during the project, each during an outreach program. The scientists were given time to answer students' questions about science and being a scientist, then were available during the outreach program to help facilitate activities or answer questions. All of the participating teachers received one visit from a scientist during the project. The scientist visits were not only meant to benefit the students, but were also meant to benefit the scientists by increasing their awareness of the K-12 educational setting, and the practices that are used to teach science.

Project Participants

Thirty science teachers from northwest Ohio participated in Project Pi r^2. One teacher stopped attending project activities early in the project, so a total of twenty-nine participated in all of the project activities. Most of the participants were female, white (non-Hispanic), intermediate (4-6) teachers from urban or suburban school districts. The participating teachers represented seventeen different schools from northwest Ohio, twelve of which were public. Of the twelve public schools, two had a school effectiveness rating of "Excellence with Distinction," five had rating of "Excellent," three had a rating of "Effective", and two had a rating of "Continuous Improvement". The table below summarizes the demographic information for the teachers who participated in Project Pi r^2.

Project Pi r2 Teacher Participant Characteristics

Demographic Variable	Values	N	%
Gender	Female	30	100%
	Male	0	0%
Racial/Ethnic Background	White, non-Hispanic	29	97%
	Asian/Pacific Islander	1	3%
Grade Level	K-3	13	43%
	4-6	14	47%
	7-8	3	10%
Subjects Taught	Self-contained (all or most subject)	20	67%
	Science only	3	10%
	Math only	1*	3%
	Math and Science	2	7%
	Other or Multi-Subject combinations	4	13%
Type of School	Public	20	67%
	Private	10	33%
Teaching Experience (n = 28)	1 to 10 years	7	25%
	11 to 20 years	10	36%
	21 to 30 years	8	28%
	31 to 40 years	3	11%

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 (corresponding objectives are listed below each evaluation question):

1. What is the quality of the professional development and classroom outreach programs implemented during the project?

   Teachers will participate in high-quality and meaningful professional development

   Students will be engaged in inquiry-based outreach programs

2. What is the impact of the project on teachers and their teaching?

   Teachers will increase their awareness of and confidence in using community resources

   Teachers will increase their science content knowledge

   Teachers will report an increase in their self-efficacy and outcome expectancy beliefs about science teaching

   Teachers will feel more prepared to use inquiry-based teaching strategies

   Teachers will more frequently use inquiry-based teaching strategies, including formative assessment

3. What is the impact of the project on student learning?

   Students will increase their science content knowledge

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, teacher survey data, informal educator survey data, and scientist survey data. Qualitative data included professional development and classroom observations, monthly teacher reflections, informal educator survey responses, and scientist survey responses. This section explains how each aspect of project was evaluated.

Quality of the Professional Development. The quality of the professional development was determined using data collected from the Community Resources Workshop Evaluation survey, three professional development observations and teacher reflections. The Community Resources Workshop Evaluation survey consisted of 15 items that measured teachers' perceptions of the quality of the workshop as well as the impact the workshop had on the teachers' awareness of and attitudes toward community resources. Teachers completed the survey on the last day of the workshop.

The project evaluator observed portions of three professional development sessions in December, January, and March. The observations were conducted to determine the extent to which the professional development was implemented as intended, including the general format of each session and the instructional strategies used during the sessions.

Teachers' perceptions about the professional development were also used to determine its overall quality. Teachers completed seven reflections during the project, one each month from September to April with the exception of October. Each month, the evaluator sent teachers a reflection prompt about a particular aspect of the project (e.g., format of the professional development, outreach programs, formative assessment). The teachers responded to each prompt, and e-mailed their responses back to the evaluator each month.

Quality of the Outreach Programs. The quality of the outreach programs was determined using data collected from six classroom observations, teacher reflections, the informal educator survey, and the scientist survey. The evaluator observed the implementation of six classroom outreach programs (all but the Seven Eagles program were observed). The observations were conducted to determine the extent to which the outreach programs used active learning strategies and were engaging for students.

Teachers were asked to reflect upon the success of the outreach programs, and the value of having scientists visit their classroom. Teachers' responses to those prompts were useful in determining the quality of the outreach programs, including the scientist visits.

The informal educators were asked to complete an online survey after each outreach program they implemented. The survey asked the educators' to describe the communication between themselves and the teacher regarding the results of the formative assessment activity that was supposed to be competed prior to the outreach program. The survey also asked the informal educators to describe the extent to which teachers were involved in the outreach program, and their perceptions regarding their overall experience during the program.

The visiting scientists likewise were asked to complete an online survey after visiting a classroom. The survey asked the scientists to describe their involvement and the teachers' involvement during the outreach program, as well as their perceptions of their overall experience during the classroom visit.

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, the Community Resources Workshop, and teacher reflections. Teachers' science content knowledge was measured using a locally developed instrument, modified from the first round of funding for Project Pi r^2. The instrument was designed in alignment with the science content that was addressed during the professional development. The instrument included 20 items – 18 multiple-choice questions and 2 open-ended – that yielded a potential maximum score of 22. Most of the items were selected from existing content instruments, such as the instruments developed by MOSART[3], the AAAS Project 2061 Science Assessment

[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.

Initiative[4], the Ohio Achievement and Graduation Tests, and the National Assessment of Educational Progress. The project evaluator developed the remaining items. A content specialist confirmed the scientific accuracy of the test before it was administered. The teachers completed the instrument in September 2011, before the monthly professional development sessions, and also in April 2012, after the professional development was complete.

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 in September 2011, before the monthly professional development sessions, and in April and May 2012, after the professional development was complete.

Teachers' awareness and use of community resources was measured using the Community Resources Workshop survey, which was described above. Responses to items regarding the impact of the workshop were particularly used to measure teachers' awareness and use of community resources.

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

[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 the student content knowledge instrument. Students' science knowledge was measured using a locally development instrument based largely on the teacher content knowledge instrument. Many of the same questions, in fact, were included in both instruments. The student science knowledge instrument was designed in alignment with the science content that was addressed during the professional development as well as the fifth grade Ohio Revised Science Standards. The instrument included 15 items, all multiple-choice, that yielded a potential maximum score of 17. The development of the student content knowledge instrument followed the same procedures as the teacher content knowledge instrument, with most items being selected from existing knowledge instruments.

The range of grades taught by participating teachers (i.e., K – 6) made it impractical to evaluate every student in the project, since multiple instruments would need to be developed to accommodate differences in students' reading levels and cognitive development, as well as the curricular differences among grades. Therefore, only fifth grade students were included in the evaluation of student content knowledge. There were more fifth grade teachers in the project than any other single grade, so fifth grade was selected to maximize the number of students participating in the project evaluation. 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 fifth grade colleagues to be included in the control group. Ultimately, only one teacher was recruited, and therefore only one class of students participated in the evaluation as control students. Teachers administered the content knowledge instruments to their students at the beginning and end of the school year.

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

Teachers in Project Pi r^2 began their professional development with the Community Resources Workshop in June 2011, and reported their perceptions of the workshop via the workshop evaluation survey. Four questions on the survey measured teachers' general perceptions of the quality of the workshop. The teachers attending the workshop[5] believed that the workshop provided new and applicable information regarding the use of community resources. The teachers' responses are shown in the table below.

Teachers' Perceptions of the Community Resources Workshop

Survey Item	Responses (n = 45)				Mean Rating
	Disagree	Somewhat Disagree	Somewhat Agree	Agree	
I learned new things about community resources	0%	0%	2% (1)	98% (44)	3.97
I will use the information I learned during workshop in my professional practice	0%	0%	9% (4)	91% (41)	3.91
The workshop met my expectations	0%	2% (1)	7% (3)	91% (41)	3.89
I would recommend this workshop to others	0%	0%	2% (1)	98% (44)	3.97

Note: 1=Disagree, 2=Somewhat Disagree, 3=Somewhat Agree, 4=Agree

The quality of the monthly professional development sessions was evaluated against several characteristics known to be effective for enhancing teachers' knowledge and teaching

[5] The Community Resources Workshop was open to all teachers who wanted to attend, but Pi r^2 teachers comprised the majority of the group. Thirty of the fifty teachers who attended the workshop were participating in Project Pi r^2.

beliefs.[6] 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 the entire duration of the school year, with the first session held in September 2011 and the last session held in April 2012. This sustained instruction provided teachers with over 80 contact hours 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 three professional development observations demonstrated that the monthly sessions engaged the teachers in active and collective learning. Teachers participated in a formative assessment activity at the beginning of each professional development session. In each of the three observed sessions, teachers were given the opportunity to participate collectively in the formative assessment activity. During one session, teachers participated in the activity as one large group. The facilitator read the teachers a book that included different types of rocks (e.g., sand, pebbles, boulders), and teachers discussed as a group how rocks are defined, and which materials should be counted as rocks. During the other two sessions, teachers participated in the formative assessment activity individually, and then discussed their thoughts with another teachers before finally sharing their thoughts with the whole group. The group discussions allowed teachers to listen to and respond to each other's ideas about the concept being assessed. A few teachers emphasized the importance of participating and interacting with fellow teachers in their monthly reflection regarding their perceptions about the professional development. According to two teachers,

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[6] 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.

I enjoy the way the sessions are broken up into small group and whole group activities. I like being paired with veteran teachers who teach the same grade level science content as I do. I appreciate the opportunity to network with these teachers ...

Another plus from this cohort is the friendships that have been made and the collaborative ways in which we interact with one another. We have opportunities to share what we are doing in our classes as well as our districts.

The session observations also demonstrated the hands-on nature of the professional development activities. During one observation, teachers participated in a rock cycle activity that required them to travel to different stations around the room that represented the stages of the rock cycle. At each stage, they rolled a dice that told them which stage to go next. Teachers recorded the steps of their journey, and discussed their ideas with their fellow teachers and the professional development facilitators. Later, the teachers engaged in several activities facilitated by the Challenger Learning Center, one of the informal educational organizations who provided outreach programs during the project. Although not all of the sessions were observed, it is assumed that all of the sessions followed the same format and included activities that used the same type of active learning strategies that were observed during the three professional development observations.

Teachers engaged in these activities as their students would, which many teachers reported to be a beneficial aspect of the professional development. One way in which many teachers believed the teacher-as-student format to be valuable was in helping the teachers to anticipate student thinking or problems in implementing the activity into their classroom. Three of the teachers wrote:

It is very easy as a teacher to understand the flow of the lesson when the information is delivered this way. Questions will arise from the teachers that will also arise from the students. Also, if experiments or activities go "wrong" we have the immediate understanding and support of an expert to tell us why. It is easier to address these concerns up front, before they even happen.

I think we as educators were able to put ourselves in our students' shoes and think about their learning process and see what kind of questions they would ask during a lesson.

I also think [the teacher-as-student format] provides the teacher with a more realistic account of how the activities are seen through a student's eyes. The teacher is able to be more empathetic to students' difficulties if he/she has recently experienced it as the "student." I believe that it also gives the teacher the opportunity to experience first hand what challenges the lesson/activity may pose for the students ahead of time. This allows the teacher to plan and adjust the lesson so that it is better able to meet the needs of his/her students.

These comments suggest that the format of the professional development not only engaged the teachers in active learning, but also helped to support the teachers' implementation of the activities in their classroom. By learning as their students would learn teachers were able to think ahead to how they would implement the activity in their classroom. Several teachers suggested that the professional development was helpful in this way because it made them more comfortable with the science content and learning materials, and thus they were more likely to implement the activities in their classroom. Two of the teachers wrote:

By having the activities modeled I now know how to use the activities within the classroom and how to build in scaffolds to support learning. I learned how to use Science Court as an effective tool within the classroom to foster inquiry, encourage a dialogue of sharing ideas, form cooperative groups and to problem solve. If I were just given the materials I may not have utilized them appropriately in my class or I may not have used them at all.

We develop a better understanding of how the activity was designed to work. With this knowledge we develop a comfort level with a particular activity or experiment. It's much more likely that a teacher will incorporate an activity in her lesson if she feels comfortable doing it.

In addition to the use of the teacher-as-student format, the professional development also situated instruction within the teachers' own practice by offering ways in which activities could be adjusted for younger or older students. The master teacher who co-facilitated the professional development sessions was observed at least once during each of three observations explaining how the formative assessment or inquiry-based activity could be adjusted for younger students.

For example, during the rock cycle activity described above, the facilitator suggested that the activity could be modified for younger students by changing the names of the stations (to less technical names) and the dice.

The outreach programs represent another way by which the professional development was situated within the teachers' own practice. 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. The quality of these programs is discussed in the next section.

Quality of the Outreach Programs

All participating teachers received six outreach programs that were implemented in their classroom during the school year. The quality of the programs was determined based on the extent to which they used active and engaging learning strategies, and their adherence to the intended format (implementation of formative assessment, communication of assessment results, delivery of inquiry-based outreach program with teachers as co-facilitators; see the figure on page 7 of this report). The quality of the scientist visits (which represent another aspect of the outreach component) was determined based on the scientists' and teachers' reflections regarding their visits.

The evaluator observed the implementation of all but one of the outreach programs in order to determine the extent to which the programs used active and engaging learning strategies. The observations demonstrated that the outreach programs did indeed use inquiry-based instructional strategies to teach science. Each of the programs included at least one hands-on activity, and many also included demonstrations that used materials not typically found in a classroom. For example, Imagination Station did several demonstrations using liquid nitrogen, and the Toledo Zoo brought live reptiles and amphibians into the classroom. The informal educators effectively used questioning techniques to facilitate students' construction of knowledge, and also prompted the students to interact with each other during the outreach programs by facilitating group activities in which each group shared a common goal. Many of the outreach programs also seemed to focus the nature of science in addition to science concepts such as soil or matter. The informal educators emphasized the importance of observation in science, and talked about variables when conducting experiments.

The outreach programs' use of active and engaging learning strategies was further documented by several teachers' reflections. Some of the teachers wrote:

The presentation was interactive with children engaged in discussion, questioning and answering throughout the afternoon. I thought there was a variety of learning modalities addressed through lecture, hands-on activities and even video.

The programs are great examples of inquiry-based learning. The presenters gave my students many opportunities to create, touch, explore and question science! What a great way to teach Kindergarten students.

Overall, the students enjoyed working in small groups, synthesizing hypotheses, gathering data, engaging in hands-on exploration, and drawing conclusions. Many students voiced enjoyment over the cooperative component of student-directed inquiry. They appeared eager to gather data, share thoughts, and synthesize their conclusions.

The extent to which the outreach programs were implemented as intended was determined in part using the informal educator and scientist surveys, which were completed after each outreach program or classroom visit. All but one of the informal educators completed the online survey, and each these educators completed the survey at least 14 times during the school year. Most of the informal educators (71%, 85) reported that teachers communicated the results of the formative assessment before the outreach program, thus meeting the second intended step of the outreach process. The informal educators reported communicating with the teachers via e-mail and phone before the outreach programs to discuss the results of the formative assessment. While many informal educators reported not modifying their outreach program, several others reported altering their programs to meet the needs of the teachers' students. Two of the informal educators wrote:

[The teacher] expressed concerns about some of the students being confused by non-rigid solids on the preassessment. I made it a point in my presentation to especially present these types of substances clearly to help address this concern.

Her students seemed to be most confused about whether or not you could make more soil so I spent a little extra time talking about how soil is formed and emphasizing that it is a process that takes a such a long time that man cannot make more soil.

The last intended step in the outreach process was the implementation of the outreach programs in the classroom. Teachers were expected to play an active role during the outreach program in helping to facilitate the program activities. Both the informal educators and visiting scientists were asked to rate the involvement of the teacher during each outreach program for which they were present. Overall, the informal educators and scientists reported that most teachers were actively involved during the outreach programs, with only 15% as barely or not involved. The table below shows the survey responses regarding teachers' involvement in the outreach programs.

Teachers' Involvement During the Classroom Outreach Programs

Survey Respondents	# Completed Surveys	Responses			
		Not Involved	Barely Involved	Moderately Involved	Actively Involved
Informal Educators	120	3% (4)	8% (10)	33% (40)	55% (66)
Scientists	12	8% (1)	42% (5)	17% (2)	33% (4)
Total	132	4% (5)	11% (15)	32% (42)	53% (70)

According to the informal educators, the teachers were involved in the outreach programs in a number of ways. The teachers mostly helped to facilitate program activities, keep their students on task, and document the outreach program with pictures or video. Teachers' involvement in the outreach programs was intended to benefit the teachers by providing a model for inquiry-based teaching. Many of the teachers' reflections demonstrate that the outreach programs did indeed serve to improve teachers' beliefs about inquiry-based teaching. Some of the teachers wrote:

What I appreciate the most is the added knowledge I get from the experts that visit my class. (You can ask Reed about my note taking during his presentation.) I am wiser from *these experiences which makes me a more knowledgeable guide for my students learning journey.*

I have observed during the programs, I have helped the presenters pass things out, helped re phrase some of the concepts in Kindergarten language and tried the experiments with them! I am definitely more comfortable with trying inquiry-based teaching in my science lessons.

I think that I have always been comfortable in using inquiry based activities with my students, but the programs that Pi r^2 have provided have just reaffirmed my belief that it is the best teaching/learning tool for kids.

The evaluation data also demonstrated that the visiting scientists were a valuable aspect of the outreach component. Most of the visiting scientists (69%, 9) reported being moderately involved during the outreach program. While all of the scientists reported answering students' questions about being a scientist, most also reported helping facilitate the outreach program, including offering content expertise. The teachers also emphasized the value of having the scientists visit the classroom. Most of their comments were about the impact of the scientists on their students' attitudes toward science and science careers. These comments will be presented in the "Impact on Student Learning" section of this report.

Impact on Teachers and Their Teaching

The evaluation of Project Pi r^2 measured the impact of the project on teachers' awareness and use of community resources, science content knowledge, and beliefs and behaviors regarding science instruction.

Teachers' awareness and use of community resources was measured with the Community Resources Workshop evaluation survey. For the four questions regarding their awareness and use of community resources, teachers provided two responses – one to represent their opinion at the end of the Workshop and another to represent their opinion as it was before the Workshop.

Wilcoxon tests[7] were conducted to evaluate whether the participants' responses significantly changed as a result of the Workshop. The results indicate that after attending the Workshop, teachers were significantly more aware of the educational resources/services that are offered by local organizations ($Z = 5.99$, $p < .001$), more confident in their use of community resources ($Z = 5.77$, $p < .001$), and more certain that using community resources could get their students excited to learn ($Z = 4.36$, $p < .001$). Furthermore, teachers estimated they would use community resources significant more times per month during the next school year than they did during the previous school year ($Z = 4.77$, $p < .001$).

Teachers qualitative survey responses supported the findings described above, especially regarding the impact of the Workshop on teachers' awareness of community resources. Three teachers wrote:

> *I thought I knew the community well but this opened me eyes to new ideas, and ways I can integrate resources & materials in my lessons.*

> *This workshop was excellent. I was unaware of all the resources available and the willingness & funds for making these services available. I will share this info with my school.*

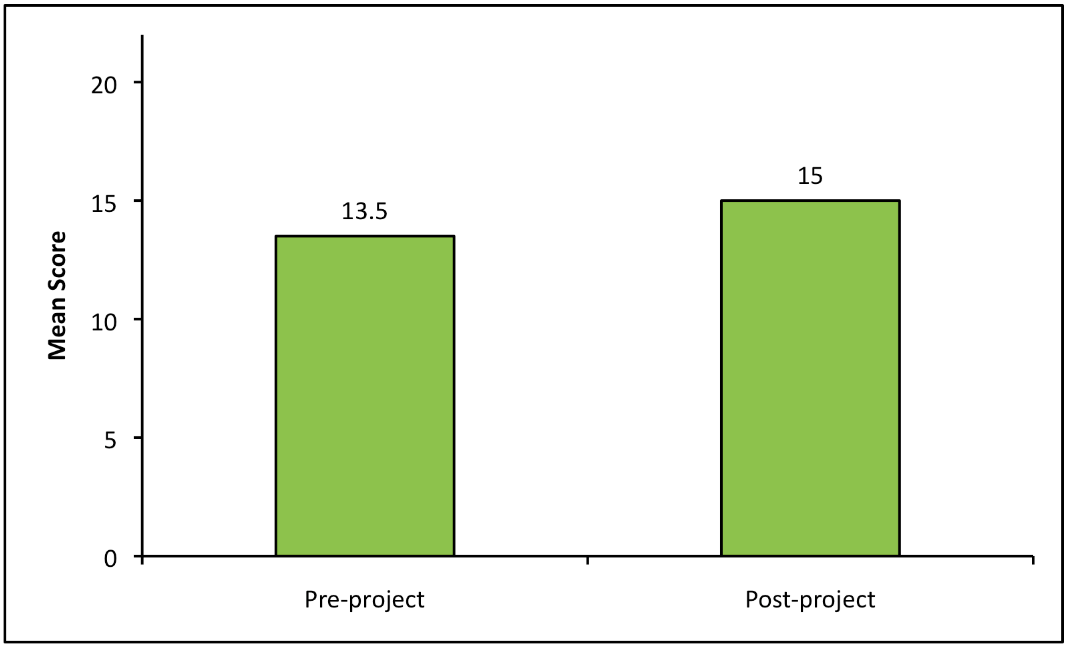
> *I truly enjoyed each and every session. I knew there were many local gems in the Toledo area, but not to their full extent.*

The impact of Project Pi r^2 on teachers' science content knowledge was measured using the teacher science content knowledge instrument described in the "Evaluation Methods" section of this report. Teachers completed the instrument in September 2011 and April 2012 in order to measure their changes in science content knowledge as a result of the project. Reliability analyses conducted using the pre- and post-project test scores indicate that the instrument was sufficiently reliable according to common instrumentation standards (> 0.70). A dependent t-test was conducted to determine if the changes in teachers' science content knowledge were statistically significant. The results of t-test indicate that teachers' mean post-project science test

[7] A Wilcoxon test determines if the median score of one set of numbers is statistically different than the median score of a related set of numbers. For this evaluation, the Wilcoxon tests determined if attendees' median post-workshop score was significantly different than their median pre-workshop score.

score (M = 15.0, S.D. = 3.77) was significantly higher than teachers' mean pre-project science test score (M = 13.5, S.D. = 3.44), $t(25) = 4.16$, $p < .001$[8], ES = 0.82[9]. The results demonstrate the project was most effective at improving teachers' knowledge about physical science concepts (e.g., states of matter, phase changes). The figure below illustrates teachers' improvement in science content knowledge during the project.

Changes in Teachers' Science Content Knowledge



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. Three teachers wrote:

> *I have stated many times, and I will repeat myself here, that I feel like I have learned quite a bit from the classes. The number of misconceptions I had was a bit embarrassing. But, I have a stronger foundation that I did a year ago.*

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

[9] 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.

In the end, I realize science is not a cut and dry subject. It is always evolving and changing as our ideas and tools become more refined. My experience in Pi R-2 has encouraged me to reflect more carefully on the content and has helped me to be more aware of my students' misconceptions as well as my own.

Pi R2 was an awesome experience. I learned so much content through the activities and programs presented to us. I felt like I was able to dig deeper to develop a stronger foundation of the science content. Having a scientist at every class helped me to understand through asking questions until I was able to make sense of the concept within my own mind.

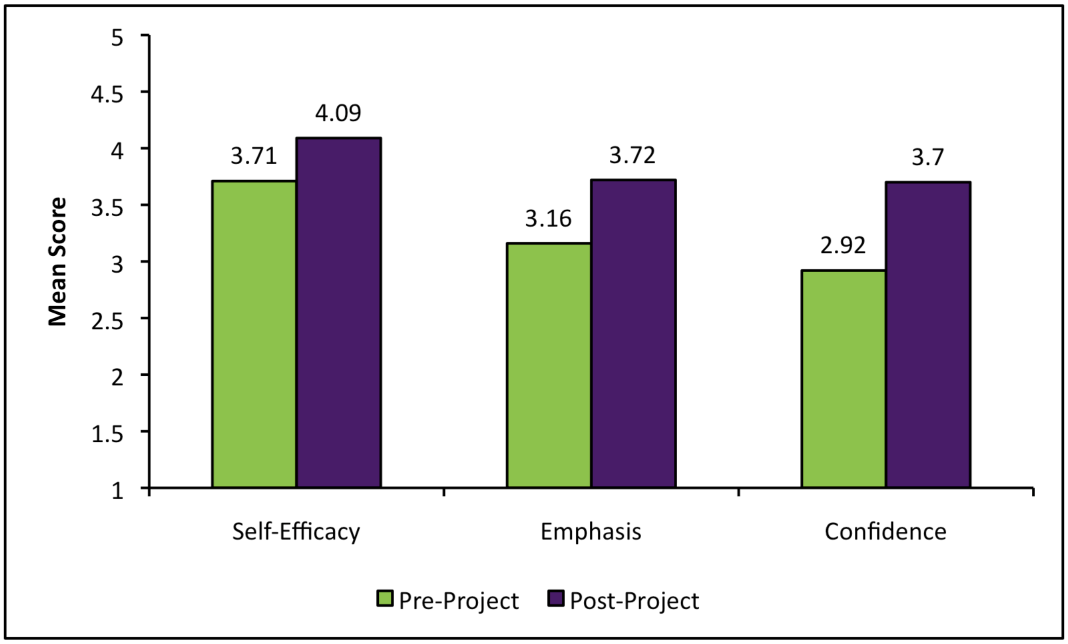
The impact of the project on teachers' beliefs and behaviors regarding science instruction was measured using the Perceptions of Science Teaching Practices survey. Teachers completed the survey online in September 2011 and April 2012 in order to measure their changes in beliefs and behavior as a result 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	3.71 (0.48)	4.09 (0.38)	6.95***	1.34
Emphasis	3.16 (0.57)	3.72 (0.52)	6.87***	1.35
Confidence	2.92 (0.70)	3.71 (0.58)	6.95***	1.63

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

Changes in Teachers' Science Teaching Beliefs and Behavior



Teachers' monthly 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. Two teachers wrote:

> *What a great experience this was for me. I have never been excited about teaching science until this year. I have not been very good at evaluating my students or creating assessments that really tell me anything before this year. I feel much more confident teaching my students science and feel that if I can use probes like we were taught or even use pre/post assessments I can learn much more about what my students are learning.*

> *Project Pi r2 has rekindled my confidence about teaching science! It has been inspirational! Through its many facets (professional development sessions, outreach programs, formative assessment, the scientist visits) it has enlarged and broadened my science knowledge base and help me re-visit, re-energize, and re-attach to the excitement I have for teaching science.*

The reflections also indicate that teachers implemented in their classroom many of the resources and activities provided during the professional development. The implementation of these inquiry-based activities likely contributed to some degree to the increase in emphasis teachers' placed on reform-based instructional strategies. One aspect of inquiry-based teaching that was particularly emphasized during the project was formative assessment. Teachers participated in a different formative assessment activity (different in content and format) every professional development session. While many teachers were already aware of formative assessment to some extent, the teachers' reflections indicate that the project made them more aware of the ways in which student knowledge could be assessed.

Impact on Student Learning

The impact of Project Pi r2 was determined mostly using the student content knowledge instrument described in the "Evaluation Methods" section of this report. Teachers' monthly reflections were also used to evaluate the project's impact on student learning.

Teachers administered the student content knowledge instrument to their fifth grade 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. The test items were aligned with the content that teachers received during the project, and were also appropriate for the expected reading level and cognitive ability of students in the fifth grade. Eight teachers participating in the project administered the tests to a total of eleven fifth grade classes[10]. In addition, one teacher who did not participate in the project administered the test to one fifth grade class, which served as the control group for the student content knowledge analysis. In total, 144 Project Pi r^2 students and 23 control students were included in the analysis.

An independent t-test was conducted to determine if the mean gain in content knowledge was different between Pi r^2 students and control students. The results indicate that the mean gain in content knowledge observed for the Pi r^2 students ($M = 1.39$, $S.D. = 2.25$) was not significantly different than the mean gain in content knowledge observed for the control students ($M = 0.87$, $S.D. = 2.49$), $t(165) = 1.01$, $p > .05$. This finding demonstrates that the project was

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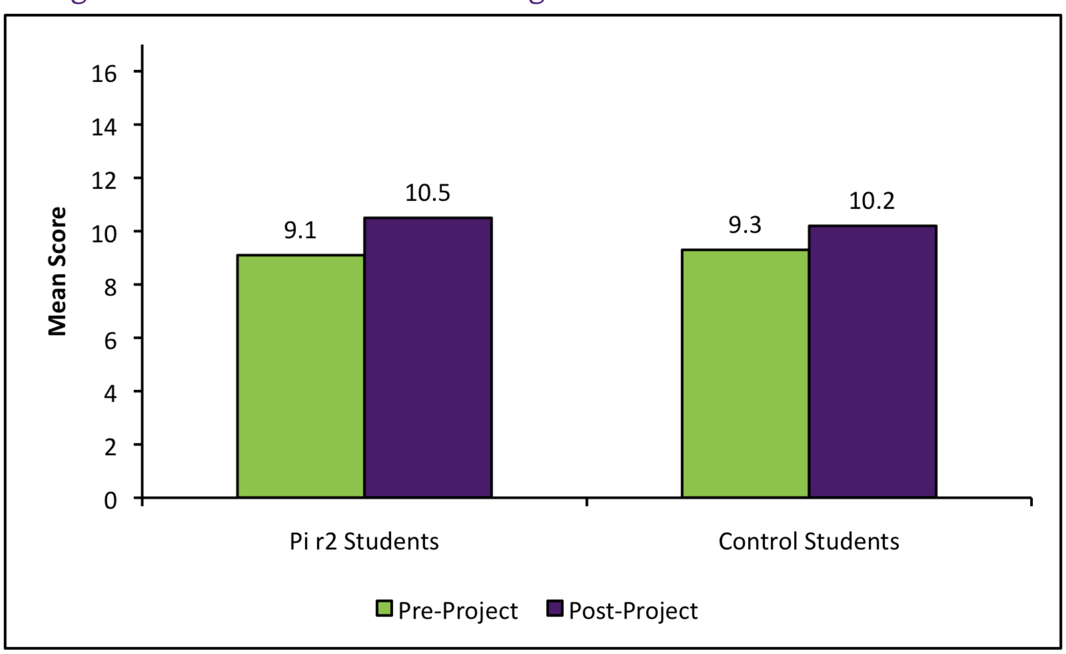
[10] Some of the teachers taught more than one class, and teachers were required to choose one class in which all six outreach programs were implemented. Some teachers, however, raised funds to pay for outreach programs to be implemented in their other classes. Therefore, all of the students who completed the content test (with the exception of the control students) engaged in six outreach programs during the school year.

no more effective at increasing student content knowledge than science instruction not altered by the project.

To follow up this analysis, two dependent t-tests were conducted to determine whether Pi r^2 students and control students as separate groups significantly improved their content knowledge. The results indicate that Pi r^2 significantly improved their content knowledge ($t[143] = 7.39$, $p < .001$), but the control students did not ($t[23] = 1.63$, $p > .05$). The follow up analysis suggest that Pi r^2 teachers were more successful than the non-Pi r^2 teacher at improving their students' knowledge. However, the initial analysis using the gain scores suggests that there was no difference in knowledge improvement between Pi r^2 and non-Pi r^2 students. The inconsistency between these two analyses perhaps points to the problem that occurred with recruiting control students. If more control students had been included in the analyses, the results would likely have been more consistent. Nevertheless, the results demonstrate that students taught by teachers participating in the project significantly improved their content knowledge. Whether or not those improvements are significantly greater than other students' improvements cannot be definitely concluded from the evaluation findings. The table figure below illustrates the students' change in content knowledge during the school year.

Changes in Students' Content Knowledge



Teachers' monthly reflections suggest that the project had a positive impact on student learning. Many of the teachers' reflections suggested that the project positively impacted students' retention of information. Two teachers specifically commented on the project's impact on student's performance on the Ohio Achievement Assessments. According to three teachers:

> *This outreach program brought those experiences to them and made them real and memorable. After taking the OAA tests this past week several of the students commented that they thought of the things we did with Imagination Station and making butter, to what they learned from Reed Steele and the scientist when they were answering the questions. They also thought of the follow up activities that we did in class. They said that they thought the test was easy because they felt prepared. I couldn't have hoped for a better response.*

> *We often would refer back to a program when discussing content or reviewing for the OAA. Students could recall information and even provide appropriate explanations of the content.*

> *Even months after the presentation of a speaker, my students would be able to remember the concepts that they learned. They often would refer back to a speaker when they read about or saw something that reminded them of the presentation.*

Teachers also commented about the value of the visiting scientists in relation to the impact those visits had on students' interest in science and science careers. Some of the teachers wrote:

> *And having some scientists come to our schools was just an incredible experience for the kids. Most of them had never met a "real" scientist and it offered them a look at a person who knew what he was talking about yet he was a human being! Some of the kids actually envisioned an Albert Einstein-type of person as we discussed the fact that a scientist would be visiting our class. To see that this person was normal and could laugh or joke yet be very smart and knowledgeable really hit home to a few of them.*

> *One of the great benefits of participating in Pi R-2 has been the opportunity to have scientists and outreach sessions in my classroom. The presence of the scientists in the*

learning environment increased student interest in science and helped students to realize real life applications for learning about science content.

Overall, the students were motivated and inspired. Some, if only to ask more questions and learn about new things and careers. It also helped to eliminate the misconception that all scientists have to work in a lab and collect data from vials and test tubes. It was definitely a positive experience for the students and I would love to have the opportunity to have more scientists visit the classroom.

When Dr. Yacobucci came to our class, the students were quite interested in the kind of work a geologist does. Many of them did not realize the wide scope that geologists cover and the cool trips and excavations that they take part in. Many of my students' perceptions of scientists was that they worked in labs and did research and frankly that it was boring. I believe that their interactions with a "real" scientist helped them realize that there is much more to being a scientist than lab work. I really do feel that my students were inspired by Dr. Yacobucci especially when she talked about how she always knew she would become a scientist ever since she was a young girl.

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. Teachers valued the teacher-as-student format of the professional development, specifically emphasizing its value in helping them to predict student misconceptions and potential obstacles regarding classroom implementation.

The outreach programs, including the scientist visits, were successful in engaging students in active hands-on learning activities, which according to the participating teachers, subsequently improved students’ retention of knowledge and overall interest in science. The outreach programs also effectively provided professional development for the teachers by providing a model of inquiry-based teaching that teachers could later replicate in their classroom.

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 (especially regarding physical science) as a result of their participation in the project. Teachers indicated that participating in the monthly professional development sessions and observing the informal educators during the outreach programs contributed to their gains in content knowledge. In addition to gains in content knowledge, teachers also improved their awareness and use of community resources, 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.

The evaluation findings demonstrate that students who were taught by teachers who participated in the project significantly improved their science content knowledge over the course of the school year. Whether or not the student gains can be attributed to Project Pi r^2 cannot be determined based on the evaluation data. One analysis demonstrates that control students did not significantly improve their content knowledge during the school year, while another analysis demonstrates that the gains in content knowledge are not significantly different between Pi r^2 and control students. Therefore, while one may accurately conclude that Pi r^2 students significantly improved their content knowledge, one can only presume that students' gains were due to the project activities. Future projects should further emphasize the recruitment of control students in order to more accurately evaluate the impact of the project on student learning.