TOWSON'S PHYSTEC COURSE IMPROVEMENT PROJECT, YEARS 1 AND 2: RESULTS AND LESSONS LEARNED

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Abstract

The goal of Towson University's Physics Teacher Education Coalition (PhysTEC) project is to improve a field experience course for elementary education majors. The improvements are focused on (1) making the different sections of the course more uniformly aligned with the course goals, (2) increasing the amount and quality of inquiry in the undergraduate interns' science lessons, and (3) helping the interns more fully understand and appreciate inquiry-based science instruction. The project team, including a full-time teacher-in-residence, engaged in a number of activities to improve the course: the re-establishment of clear course goals, the teaching of certain course sections by the project faculty, and instructor and mentor teacher workshops. Data collected from teaching observations, end-of-semester surveys, and course assignments revealed that the project was generally successful. As a result of our project activities, when compared to baseline data, the interns spent more time teaching (and less time observing), the interns more frequently taught modified science lessons (rather than teaching the official lessons as-is), and the interns' science lessons focused more frequently on scientific investigations and the communication of ideas (rather than scientific demonstrations, lectures, and the verification of ideas). Additionally, the interns' attitudes and beliefs about science and science teaching shifted in a more positive direction. Lastly, the project team has learned numerous lessons about large-scale course reform with respect to effective course structure, different forms of inquiry lessons, realistic course goals, course coordination, and attitude and belief outcomes for the field experience interns.

Introduction

The goal of Towson University's Physics Teacher Education Coalition (PhysTEC) project is to improve our "Teaching Science in Elementary School" course (SCIE 376), which is a required field experience course taken by elementary education majors. SCIE 376 provides elementary education majors the opportunity to participate in an early teaching experience (i.e., a teaching experience that occurs before student teaching) in which they teach science once per week to their own small group of elementary children. The novelty of this project lies in our inclusion of a full-time teacher-in-residence in the project team, the deep-rooted focus on inquiry that underlies our project efforts, and our unique approach to early teaching experiences – a key component of which is the placement of multiple interns in science classrooms.

This article is a companion piece to our original ASTE proceedings paper on the description and results of our Physics Teacher Education Coalition (PhysTEC) course improvement project (Sandifer, Lising, & Tirocchi, 2006). Here, the structure and format of the field experience course is explained more fully, our data have been updated to include results from year two of the project (2005-2006), and our list of project outcomes has been expanded to include lessons learned by the project team about effective course structure, different forms of inquiry lessons, realistic course goals, course coordination, and attitude and belief outcomes for the field experience interns.

Expanded descriptions of certain aspects of our project – including our institutional context, course goals, and the activities of our teachers-in-residence – can be found in the original paper. Abbreviated descriptions are provided here.

Background and Context

The PhysTEC Project

The Physics Teacher Education Coalition (PhysTEC) project is a nationwide project sponsored by the American Physical Society, the American Institute of Physics, and the American Association of Physics Teachers that has the goal of improving science preparation for K-12 teachers. At each of the PhysTEC sites around the United States, science faculty, education faculty, and a full-time teacher-in-residence (TIR) work together to implement local teaching reforms that emphasize interactive engagement and a student-centered approach to learning science. At Towson, the PhysTEC project team consists of Dr. Cody Sandifer and Dr. Laura Lising, two full-time science education faculty in the Department of Physics, Astronomy and

Geosciences, and a full-time elementary TIR. The 2004-2005 TIR was Ms. Lisa Tirocchi, a Baltimore County Public Schools elementary teacher; the 2005-2006 TIR was Ms. Elizabeth Renwick, a Baltimore City Public Schools elementary teacher.

SCIE 376: Course Overview and the Need for Improvement

Prior to student teaching, elementary education majors at Towson University are required to complete a "math and science" semester, which is a semester solely dedicated to content and methods related to math/science instruction. One of the courses taken during the math/science semester is our science field experience (SCIE 376), which is the course that serves as the focus of our PhysTEC project. SCIE 376 is structured to help preservice elementary teachers (hereafter referred to as "interns") learn and practice methods of inquiry-based science teaching and engage in self-reflection and improvement.

There are six to eight sections of SCIE 376 offered each semester; each section meets once per week for four hours at a Baltimore City or Baltimore County public elementary school. Course activities include an hour of teaching time, coaching from the classroom mentor teacher, lesson planning under the supervision of the course instructor, and methods/content discussions and activities. The planning sessions and methods/content activities are conducted in a central meeting space (e.g., an unused classroom) provided by the school.

In the years leading up to our PhysTEC project, instructor and student complaints about SCIE 376 had been steadily increasing. Discussions with instructors and interns revealed that the different sections of the course were no longer uniform (in terms of the number of science lessons taught per intern, the number of interns per classroom, feedback on the interns' science teaching, and the degree to which each section focused on inquiry), and also that there was a general lack of communication about the goals, structure, and logistics of the course. A critical issue was that, at the beginning of the project, it was unclear as to whether the interns' science lessons in the elementary schools were inquiry-based, or were instead more traditional types of science lessons.

Given these problems, the mission of our PhysTEC project became clear: to improve SCIE 376 using methods that would be effective, sustainable, and measurable. Our subsequent course improvement efforts, along with our project results, are found below.

Project Activity: Course Improvement

In the past, the only resource provided to new SCIE 376 instructors was a sample syllabus. This proved to be an insufficient means of instructor support – one which typically resulted in a state of affairs where the different SCIE 376 course sections varied tremendously in terms of their focus on inquiry, their teaching and observation expectations, their methods activities and course assignments, and the degree to which the interns were satisfied with the course.

After becoming aware of the lack of uniformity across sections in SCIE 376, the project team engaged in a number of course improvement activities, including the re-establishment of clear course goals, the teaching of certain course sections by the project faculty, course instructor and mentor teacher workshops, and the creation and distribution of a resource CD-rom for course instructors. The following sections describe each of these improvement activities in detail.

Updating of Course Goals

Early in the reform process, the project team created an updated list of course goals for SCIE 376 to guide our improvement efforts. The updated course goals required that the interns in each section of SCIE 376 should (1) begin to understand and apply inquiry-focused theories of science teaching, (2) become exposed to content and teaching standards, (3) teach science as often as possible, (4) receive in-depth feedback on their teaching, and (5) engage in self-reflection and make steps toward improvement.

Our notion of inquiry teaching and learning is aligned with the approach taken by the National Science Education Standards (1996, pp. 52 and 113), which defines inquiry learning and teaching through a series of "emphasis" summaries that contrast inquiry-based teaching with more traditional teaching methods. At Towson, we have further distilled the NSES inquiry approach into our own three core principles of inquiry:

1. **Figuring Out**. Students are figuring out science concepts and underlying mechanisms *on their own* whenever possible. ("Concepts" are differentiated from facts and terms, and "mechanism" is defined as *how* something is happening.)
2. **Active Learning**. Lessons are activity- and discussion-based (sometimes hands-on, often cooperative, *but always minds-on*), rather than lecture- and reading-based. These lessons require clear, common sense, contextualized, and non-obvious questions that the activities and discussions seek to answer.
3. **Ideas and Good Reasoning/Making Sense**. Lessons focus on ideas and reasoning (making sense of things) rather than memorization of right answers and vocabulary words. Here students are developing and applying evidence-based reasoning skills, where evidence consists of everyday experiences, experimental data, common sense, and prior knowledge. ("What do you think, why do you think that, and how do you know?")

Restructuring the Field Experience Course

After trying a number of different teaching formats for our field experience course, the project team has now settled on a single teaching and planning format that is (ideally) used in all sections of SCIE 376. In this format, the ~13-20 interns in any given section of SCIE 376 are spread across a small number of classrooms in a single school; ideally, between four and six interns are placed in each science classroom. During the allotted teaching time, the classroom is broken into four to six groups of elementary students, with each small group being led through an inquiry-based science activity by a single intern. The same interns that teach shoulder-to-shoulder in a classroom also plan their lessons together, with the result that the lessons that are taught concurrently in the different intern groups are nearly identical – although there is certainly room for variation and creativity from group to group if the interns so desire. Occasionally, if appropriate, the interns might also alternate between small-group and whole-class instruction within a single lesson. For example, in a particular lesson, each intern might guide her own group through a discussion or experiment, at which point the different student groups might then share their ideas or results with the entire class; the lesson might then conclude with the students returning to their own small groups to make sense of the data or discussion with the help of their "teacher" (i.e., that group's permanently assigned intern).

Another key component of our course format is the fact that the interns are not expected to create lesson plans from scratch. Instead, for the first three or four weeks, the course instructor typically provides the interns with inquiry-based lesson plans (or lesson plan outlines, minimally) for the interns to flesh out and implement. These lesson plans tend to consist of official school lessons that have been modified by the instructor to be more closely aligned with our principles of inquiry. After the first few weeks, once the interns have grown more comfortable with inquiry-based teaching, the course instructor stops distributing lesson plans to the interns; from that point forward, the interns are expected (with the help of the instructor) to analyze each upcoming activity from the official curriculum, modify the official activity to make it more inquiry-based, and then implement the modified version of the official activity.

Before the start of the internship, to obviate the need for week-by-week coordination between the course instructor, mentor teachers, and interns, the instructors and teachers carefully negotiate which specific activities and/or content units from the official school curriculum will be taught by the interns during the semester.

Finally, it should be noted that the interns are not expected to teach science lessons as soon as they begin the internship. To ease the interns into the course, the first one to three class meetings – which are four hours in length, just as they are for the remainder of the semester – are held at the university campus. These early meetings provide an opportunity for the interns to engage in preparatory activities that focus on inquiry-based science instruction, lesson planning, and the specific science concepts relevant to the interns' upcoming lessons.

Instructor and Mentor Teacher Workshops

Since Towson University offers as many as eight sections of SCIE 376 each semester, the course has a fairly significant amount of instructor and mentor teacher turnover. Any reforms of our field experience course therefore involve strong coordination between multiple course sections, some of which are led by relatively inexperienced part-time instructors and/or mentor teachers. The project team chose to remedy the coordination and communication problems plaguing SCIE 376 by creating professional development/training workshops for these new instructors and mentor teachers.

Towson's PhysTEC workshops were created and refined during the first two years of the project, and eventually took the form of half-day workshops for new mentor teachers and two-day workshops for new instructors. These workshops are now offered every semester, as needed. The goals of the workshops are to: help new instructors and new mentor teachers develop a better understanding of inquiry; clarify the roles and responsibilities of the university instructors and mentor teachers; clarify the format of the course; and hold open discussions about course goals, course logistics, feedback on the interns' lesson plans and lessons, and other issues of concern. A variety of brief presentations and interactive methods- and science-related activities are implemented in the workshops to achieve the workshop goals.

A critical aspect of the mentor teacher workshop is the inclusion of a time for mentor teachers to meet with the individual instructor assigned to their school; the purpose of these small-group meetings is for the teachers/instructors to negotiate section-specific issues relevant to each school site: teaching times, the content units and grade levels to be taught, and mentor teacher and instructor expectations. In the instructor workshops, time is also spent on the introduction and overview of the SCIE 376 resource cd-rom that is provided to each instructor. This cd-rom is an exhaustive teaching and curriculum resource that includes a course overview, a list of web resources, science education readings, videos of students engaged in inquiry-based instruction, 25 methods activities (each of which is explicitly linked to the national standards and course goals), and a variety of other support documents: a core syllabus, sample observation schedules, sample lesson outlines, and observation forms.

Project Results and Lessons Learned

The Results of our Course Improvement Efforts

Towson's PhysTEC team has adopted a multi-pronged approach to project assessment. Observations of the interns' science lessons give us the most relevant data concerning our project successes, since these observations allow us to look at the interns' actual classroom practice – thereby allowing us to gauge the degree to which we have been successful at fostering inquiry-based instruction at the field experience school sites. The observational data is complemented by survey data that allows us to obtain both multiple-choice and open-ended written responses concerning the interns' attitudes, beliefs, course activities, and suggestions for improvement.

Survey Results: Course Activities

A multiple choice survey was administered to all SCIE 376 interns at the end of the Fall 2004, Spring 2005, Fall 2005, and Spring 2006 semesters to ascertain the type of activity occurring in the different sections of the course, as well as to determine if there had been any course improvements after Fall 2004. The PhysTEC team had not attempted to make any curricular changes to SCIE 376 in Fall 2004 (except in Dr. Lising's section), and so the Fall 2004 results represent the baseline data for the course before any significant PhysTEC-related course improvements were instituted. The results of this ongoing survey are presented in Table 1.

Table 1

SCIE 376 course activity: Fall 2004 through Spring 2006

	Fall 2004 (89 interns)	Spring 2005 (108 interns)	Fall 2005 (75 interns)	Spring 2006 (93 interns)
Interns who observed their mentor teacher teaching 4 or more times	19%	18%	9%	1%
Interns who taught fewer than 4 times	28%	11%	0%	2%
Interns who indicated that their lessons were primarily official school activities implemented as written	20%	10%	20%	2%

As demonstrated in Table 1, in comparing each subsequent semester's data to the Fall 2004 baseline data, our PhysTEC project continues to be extremely successful in (a) decreasing the number of times that the practicum interns observe their mentor teachers, (b) increasing the number of times that the interns teach science, and (c) increasing the number of lessons that are adapted lessons rather than unmodified lessons. For example, the percentage of interns who taught fewer than four times in Spring 2005 (11%) is significantly less than the percentage of interns who taught fewer than four times in Fall 2004 (28%), $\chi^2(1) = 9.2$, $p < 0.01$. Likewise, the percentage of interns who implemented unmodified activities in Spring 2006 (2%) is significantly less than the percentage of interns who implemented unmodified activities in Fall 2004 (20%), $\chi^2(1) = 15{,}2$, $p < 0.001$. The only exception to (c) occurred during the Fall 2005 semester; at the end of that semester, 20% of interns reported that their teaching primarily consisted of the implementation of unmodified science lessons. This anomaly can be explained by the fact that a 376 instructor during that semester deviated from the goals of the course and did not focus on the adaptation and modification of lessons.

Survey Results: Attitudes Toward Science and Science Teaching

In the Fall 2005 and Spring 2006 semesters, the SCIE 376 interns were assessed with Likert-scale items (strongly agree, agree, neutral, disagree, strongly disagree) about their attitudes toward science and science teaching. Table 2 and Table 3, below, show the data for these survey items. The interns' "strongly agree" and "agree" responses have been combined (under "agree") and the interns' "disagree" and "strongly disagree" responses have been combined (under "disagree").

One particularly interesting shift is the positive, statistically significant pre/post shift in the percentage of interns who like science, which occurred in both the Fall 2005 and Spring 2006 semesters. Another interesting result is the encouraging (although not statistically significant) pre/post shift in the degree to which the interns were scared by the idea of teaching science.

Finally, after a single semester of inquiry-based science teaching, interns from both semesters shifted significantly (toward smaller percentages) in their belief that the ability to do well in science is a natural ability.

Table 2

Attitudes Toward Science and Science Teaching: Fall 2005

	Pre (80 students)			Post (75 students)			
Statement	Agree	Neutral	Disagree	Agree	Neutral	Disagree	Chi-square
Some students have a natural talent for science, and some do not	47%	40%	13%	40%	28%	32%	7.8, $p < 0.05$
The idea of teaching science scares me.	19%	26%	55%	8%	20%	72%	5.7, $p > 0.05$
I like science.	61%	21%	18%	77%	17%	5%	6.7, $p < 0.05$

Table 3

Attitudes Toward Science and Science Teaching: Spring 2006

	Pre (109 students)			Post (93 students)			
Statement	Agree	Neutral	Disagree	Agree	Neutral	Disagree	Chi-square
Some students have a natural talent for science, and some do not	38%	38%	24%	1%	11%	88%	64.4, $p < 0.001$
The idea of teaching science scares me.	19%	25%	56%	9%	12%	79%	5.7, $p > 0.05$
I like science.	54%	29%	17%	74%	12%	4%	6.7, $p < 0.05$

Observation Results: Science Teaching at the Field Experience Sites

To assess the degree to which the interns' science lessons were inquiry-focused, our TIR (Ms. Tirocchi or Ms. Renwick, depending on the project year) conducted two observations per course section. For each observation, the TIR would choose an intern at random and then observe that intern's entire science lesson, during which time she would make notes about the intern's lesson and the elementary students' responses. A day or two within observing each lesson, our TIR coded her observations with a standards-based observation protocol that had been developed by the project team. This method of observation and data coding was used to collect baseline data during Fall 2004 (the semester immediately before course reforms were introduced), and to collect follow-up data during subsequent semesters. Because SCIE 376 interns are novices at science teaching, the observations were coded for intent toward inquiry as well as for success at implementation.

Tables 4-6 contain the "lesson intent" data that resulted from the observations of the interns' science lessons. Originally, each lesson characteristic was rated on a 0 (very traditional) to 5 (very inquiry-oriented) scale for each lesson. Ratings at the 0 or 1 level were relabeled as "traditional", denoting that the particular lesson characteristic was aligned with traditional teaching methods. Ratings at the 2 or 3 level were relabeled as "mixed", denoting that the particular lesson characteristic contained aspects of both traditional and inquiry teaching methods. Ratings at the 4 or 5 level were relabeled as "inquiry", denoting that the particular lesson characteristic was aligned with inquiry teaching methods.

Table 4

Number of Interns' Lessons Demonstrating Science Content (Traditional) vs. Investigating Science Content (Inquiry)

	Baseline (11 lessons)	Spring 2005 (14 lessons)	Fall 2005 (10 lessons)	Spring 2006 (14 lessons)
Traditional	9	4	2	4
Mixture of Traditional and Inquiry	0	5	4	7
Inquiry	2	5	4	3

Table 5

Number of Interns' Lessons Focused on Getting an Answer (Traditional) vs. Developing an Explanation (Inquiry)

	Baseline (11 lessons)	Spring 2005 (14 lessons)	Fall 2005 (10 lessons)	Spring 2006 (14 lessons)
Traditional	8	5	4	1
Mixture of Traditional and Inquiry	1	0	2	10
Inquiry	2	9	4	3

Table 6

Number of Interns' Lessons Focus on Providing Answers (Traditional) vs. Communicating Science Ideas (Inquiry)

	Baseline (11 lessons)	Spring 2005 (14 lessons)	Fall 2005 (10 lessons)	Spring 2006 (14 lessons)
Traditional	8	3	3	2
Mixture of Traditional and Inquiry	1	5	3	9
Inquiry	2	5	4	3

Note: This category of analysis did not apply to one lesson in Spring 2005, which is why the total number of lessons does not match the number of observations for that semester.

In our baseline semester (Fall 2004), as illustrated in Tables 4-6, observations of the interns' science lessons revealed that, in most cases, the lessons tended to be activities that focused on verifying science content and obtaining answers through the use of text, demonstrations, or lecture. Very little about these lessons approached evidence-based inquiry into scientific ideas and scientific phenomena. In contrast, the teaching in later semesters focused much more frequently on the investigation and analysis of science content, public communication of science ideas, and scientific discussion and explanation.

For example, setting a minimum acceptable threshold of "mixed" (a mixture of traditional and inquiry-oriented methods) for each lesson characteristic, we see that only 2 out of 11 lessons in Fall 2004 (the baseline semester) focused on investigation and analysis – whereas 10 out of 14 lessons in Spring 2005 ($\chi^2(1) = 7.0$, $p < 0.01$, when compared to baseline), 8 out of 10 lessons in Fall 2005 ($\chi^2(1) = 8.0$, $p < 0.01$), and 10 out of 14 lessons in Spring 2006 ($\chi^2(1) = 7.0$, $p < 0.01$) focused on investigation and analysis. Similarly, only 3 out of 11 lessons in Fall 2004 (the baseline semester) focused on communicating science explanations – whereas 10 out of 13 lessons in Spring 2005 (one N/A lesson omitted; $\chi^2(1) = 8.3$, $p < 0.01$, when compared to baseline), 7 out of 10 lessons in Fall 2005 (not statistically significant), and 12 out of 14 lessons in Spring 2006 ($\chi^2(1) = 8.8$, $p < 0.01$) focused on communicating science explanations.

Lessons Learned

After two years of weekly meetings, lively discussion and debate, the collection and analysis of project data, and thoughtful reflection, the project team has reached a number of conclusions that are potentially relevant to faculty attempting similar reform projects. These conclusions, which have been dubbed "lessons learned" by the project team, are presented below.

Lesson #1: The multiple-interns-per-classroom model for early teaching experiences works well.

There are a number of different reasons why, from the instructor's perspective, placing multiple interns in the same classroom works well. The primary benefit to the instructor is that each section of the early teaching (field experience) course can be located in a single school, which means that the instructor is able to see every single intern during each class session. Having contact with interns during each session is important due to the fact that face-to-face coordination and support tends to be more convenient and effective than email or phone contact – especially when requests for support often come at the last minute (i.e., just before instruction). Email and phone contact is more common in field experience courses where interns are placed one or two per classroom; in these situations, unfortunately, the instructor is less able to provide the last-minute words of advice, conceptual clarifications, and friendly assurances that increase the likelihood of the interns' science lessons being successful.

Beyond the logistical benefits provided by the multiple-interns-per-classroom model, we also find that most of our interns have learned something new by the end of the course: that group lesson planning is a valuable, worthwhile process. Each class session, during the allotted time for group planning, the members of each group become *de facto* peer mentors: they share lesson plan ideas, engage in formal and informal teaching discussions, and provide motivational, pedagogical, and content-related support for one another. Evidence for the interns' appreciation for group planning is most visible in their summative course reflections, a portion of which is often dedicated to the interns' recognition that group planning is helpful – although the interns often wistfully recognize that this sort of group support may not be present during their upcoming student teaching semesters.

Support concerns aside, there are also pedagogical reasons for having interns plan lessons in small groups. Group planning offers a natural context for the interns to have substantive debates about teaching theory, philosophy, and practice that are connected to actual teaching experiences with children. Given the abundance of research that shows that teachers' stated orientations toward teaching often do not translate into practice, combined with the research that shows the importance of practice-centered professional development, the interns' group planning is a crucial part of their pedagogical training. In our experience, the differences of opinion and interpretation that get glossed-over during a discussion in the university classroom come out in sharp relief during group planning sessions, making the way for further progress.

A final benefit of the multiple-interns-per-classroom model is that, in teaching science to a small group of elementary children, interns have the opportunity to get to know their student's thoughts and personalities in a deep and meaningful way – much more than they would in the traditional model where one to two interns are assigned to a classroom. Moreover, in only having to oversee four to six students, the interns can shift their instructional focus from classroom management to other instructional issues more directly relevant to inquiry-based teaching: the elicitation of students' prior knowledge and experience, data collection, and the students' use of evidence-based reasoning to come to consensus on scientific conclusions and explanations.

Lesson #2: All inquiry lessons do not look the same, for a variety of reasons.

Early in the first year of the project, it became apparent that inquiry-based science lessons can vary widely in their intent and structure, and yet still adhere to the basic principles of inquiry that were created by the project team. Certain inquiry lessons might consist entirely of open-ended, evidence-based discussions, while others might hold to the more typical predictexperiment-discuss-conclude lesson plan format. The choice of whether use a particular lesson format is, in part, driven by the lesson topic. It is difficult to structure a hands-on experiment about the properties of outer space, for instance, so another type of activity (e.g., design a functional space suit and share the design with the class) might be more appropriate for this topic. However, an instructor's choice of format is also partly informed by that instructor's philosophical and personal stance toward inquiry instruction. One instructor might prefer to let students arrive at concepts almost entirely on their own, for instance, while another might tend to step in more frequently to provide explicit guidance. Similarly, to one instructor, it might be acceptable on occasion for a lesson to end at the point where a scientific rule has been established (e.g., some metals are attracted to magnets), whereas another instructor might be uncomfortable with ending a lesson at that point, and might therefore ask her students to move beyond the rule and consider a possible mechanistic explanation for the phenomenon under investigation.

Given the fact that instructors will structure their inquiry lessons to match their own particular teaching goals, and that certain topics lend themselves more readily to hand-on investigations than others, it can be very difficult, if not impossible, for educators to agree upon a single "best" format for inquiry lessons. Continuing along this line of reasoning, it is likely not reasonable to expect inquiry lessons across all sections of a field experience course to be identical in format. On the other hand, it *is* reasonable to expect that interns' science lessons will adhere to the same general principles of instruction – whatever those agreed-upon principles might be for a particular institution. This suggests that an important first step of course reform of a field experience course is for the instructors to explicitly define the expectations for teaching that will guide all of the course activities. By participating in discussions about the interns' teaching expectations, beyond reaping the benefits of increased coordination, the faculty may also experience the same secondary benefit that we experienced in our project team: the further development and refinement of our own personal philosophies, teaching goals, and understandings of inquiry and inquiry instruction.

Lesson #3: Expecting the interns' science lessons to be almost completely inquiry-based across all course sections is an unrealistic goal.

Just as we can't expect a first-year college student to leave an introductory physics class with an expert understanding of the laws of mechanics, we also cannot expect an intern to develop a full and complete understanding of inquiry-based instruction in a single semester. Inquiry-oriented instruction is an unfamiliar, complicated, and often unpredictable endeavor that challenges even the most experienced science teachers. For this reason, course instructors and program directors should be wary of setting their personal bar for course success too high – if nothing else, for the sake of their own instructional satisfaction. Although we hope that our field experience interns make significant strides toward understanding inquiry, we now accept the reality that some interns will exit the course with a philosophy of science teaching that mixes traditional and inquiry instruction (often unknowingly) – and that this is an acceptable outcome. Put another way, the project team has grown increasingly aware of the limitations of a 16-week semester as a timeframe for engineering a complete reconstruction of the interns' teaching philosophies, which is why we now no longer expect all of our interns' science lessons to be inquiry-based across all class sections.

Another reason why "100% inquiry" has been abandoned as a realistic course goal is that the interns' science lessons arise from a complicated interaction between (a) the expectations of the university instructors, interns, and mentor teachers, especially as related to whether the interns should be teaching the official school science lessons "as-is" or whether the interns should instead be critically examining and modifying the science lessons, (b) the degree to which the university instructors, mentor teachers, and interns possessed a deep, shared understanding of inquiry-based science instruction, (c) the ability of the interns to put their inquiry teaching goals into practice, via their lesson planning and facilitation skills, (d) the practical constraints of elementary classrooms and the early teaching course, such as the availability of science materials and basic communication between the interns, university instructors, and mentor teachers, and (e) other contextual/environmental factors such as a school's general stance toward inquiry and the need to student prepare students for standardized tests. Noting that many of the these factors are instructor- and mentor-teacher dependent, a critical matter is the limited time with which the project faculty are able to spend with mentor teachers and part-time faculty (in the form of workshops, etc.) – especially given the turnover associated with the mentor teacher and part-time faculty positions. Consequently, it isn't clear to what extent the project team will be able to help each and every mentor teacher and Towson instructor develop a shared understanding of standards-driven, inquiry-based science teaching. Invariably, this lack of a shared understanding of inquiry by course instructors and/or mentor teachers will lead to inconsistencies in the degree to which the interns' science lessons are inquiry-based across the different sections of the course.

Lesson #4: Coordination across content, methods, and field experience courses leads to the highest potential for educational success.

Towson University uses a cohort system in its elementary education program, meaning that groups of undergraduates enroll in all of their courses together. A crucial aspect of Towson's elementary science education course structure is the fact that cohorts who are enrolled in the Teaching Science in Elementary School course (SCIE 376) are enrolled concurrently in an Earth-Space Science course (PHSC 303). Ideally, to provide the undergraduates with a coherent framework for science teaching and learning, cohorts have the same instructor for both courses.

The intent is that, in the Earth-Space Science course, the preservice teachers learn science content and reasoning skills through inquiry, while at the same time reflecting on and explicitly discussing the structure and value of inquiry-based instruction; the methods content from Earth-Space Science is then supplemented and reinforced with additional methods discussions in the practicum course, in which the interns are expected to teach science through inquiry at elementary school sites.

An advantage for full-time faculty is that they often have the same student cohort for both SCIE 376 and PHSC 303. Having the same cohort for both classes sets up a fluid situation where (a) the science content in the SCIE 376 interns' science lessons can become part of the course content addressed in PHSC 303, (b) the instructor can hold in-depth methods and planning discussions in PHSC 303 that, due to time constraints, might otherwise not occur in SCIE 376, and (c) the instructor can help the interns develop a deeper, more coherent understanding (and appreciation) of inquiry and science learning by having them make explicit connections between their teaching practices, their understanding of children's science learning, and their own science learning. These types of meta-connections are recognized by the educational community as being crucial aspects of successful professional development for teachers.

Unfortunately, by necessity, most sections of SCIE 376 are taught by part-time faculty who meet with their interns only once per week, at the school site – and so the types of spillover content/methods opportunities that occur when an instructor teaches both SCIE 376 and PHSC 303 are not possible. This makes teaching SCIE 376 for part-time faculty, and full-time faculty in a similar predicament, much more challenging.

Lesson #5: Given the proper course structure, support, and feedback, many interns will develop a new appreciation for science, science teaching, and inquiry methods.

Many interns enter their content, methods, or practicum courses with a disheartening set of attitudes and beliefs about science and science teaching: they don't particularly care for science, they lack confidence in their ability to teach science, and they imagine that their preservice and inservice science teaching experiences will consist of lectures and readings that will be enhanced, occasionally, with classroom demonstrations or science projects. That these same interns might change their core belief system and conclude instead that science is fun and interesting (or, better yet, fun and interesting to teach) is something that the interns and others might dismiss as highly improbable. Equally as improbable in the eyes of many interns is the idea that they might implement an unusual, unfamiliar form of science teaching – inquiry-based science instruction – and come to appreciate and value this new type of instruction. It has therefore been both a pleasure and a relief to discover that a carefully structured field experience can have a fairly significant impact on interns' initially negative impressions of science and science instruction.

Below are course reflections from interns who were enrolled in a section of SCIE 376 taught by a member of the project team (CS). The first four quotations are from a final exam questions where the interns were asked to reflect on the components of effective science teaching. The final quotation is from an end-of-semester assignment where the interns were asked to write words of advice for the interns from the upcoming semester.

> "At the beginning of the semester I, like all the other interns, came in with my own ideas about science classes. From my own experience in school I had an idea of a science class that was very traditional and in an old school fashion. I had the idea that science would be students working behind a desk, doing experiments where necessary and taking notes from the teacher's lecture. That was how I learned science in elementary and middle school and so I assumed I would be teaching it that way even though I had not enjoyed it very much. As the semester went on and shortly after the

first couple of classes, I realized that my view of a science class was not the best way to teach and not the way we, as interns, would be teaching science. I was in the class that taught Astronomy to 4th graders this semester and it was a great learning experience. Over my first lesson taught I quickly learned that my idea of telling the students what they should know and just trying to explain it to them was not the most effective way to teach the concepts. We were teaching the concepts about Earth's phenomena (day/night, times, etc) and at first I began by trying to tell the students what happened without asking them what they knew first. This was not a beneficial move for me to do because it did not encourage the students to critically think and share their ideas. I quickly revised that for the next part of that lesson and let them share their ideas with me whenever possible."

"This course has been my first real experience in the classroom, not just my first science experience. Therefore, my ideas about effective teaching have changed drastically from the beginning of the semester. [Then] I had nothing to base an educational philosophy on besides a few observations and the information that teachers had been filling my head with. I now have solid experiences to base a philosophy on. I have seen the effectiveness of hands-on activities [and] learned the problems that can come with lecture…I have always thought it good practice to do hands-on activities with students. However, before this semester I thought it was good to do hands-on activities to break up the redundancy of constant lecture. I did not think that it was possible for a hands-on activity to stand without lecture. Through this course I have learned about using discussion as an alternative to lecture."

"Before this semester science was not one of my favorite subjects. Through my teaching experience I learned that science can be very fun and interesting at the same time. Some ways to make science exciting and enjoyable is to relate material to different hands on activities. I received a lot of positive feedback from my students whenever we did activities. It made them excited to learn. Students loved to get involved in the activities and share their responses. After receiving my good bye letters from my students, I noticed that the things they remember the most were the demonstrations and how they are related to real life. Some of the best way for students to learn is to…explore, label, design, draw, create, and interpret data."

"In the beginning of this semester I assumed that teaching science was really easy. Give students the materials, do some experiments and show them the answers. Now that the semester is over I've realized that teaching science is a lot more involved than that. Before I just assumed that in teaching science it's all about teacher instructions. This semester has shown me that it's all about the students' inquiries and experimenting that really make teaching science effective… From this semester I've learned that students giving wrong answers is just as important if not more so as students giving correct answers. When a student answers incorrectly it gives the other students the opportunity to think about the answer and decide if it is right or wrong. I always try to give the students time to think about their answer and decide for themselves why their answer might not be right."

> "My first piece of advice to next semester's interns is: Science is more fun than you think. While I thought I would never like teaching science, I think science is now my favorite subject. Prior to this semester, science scared me. I think most people don't have enough clear exposure to the subject. My classes were never run efficiently enough, and as a result, science was confusing – something I didn't know how to teach, and something I never learned well enough. If you had the same experiences as me, this semester will change your mind about science. While you may be confused going into the classroom for the first week or so, you'll quickly adapt to teaching science as inquiry and love watching your students experiment and come up with conclusions."

Although one might assume that these particular reflections have been chosen for their particular take on SCIE 376, it must be noted that reflections of this type are not terribly unusual for interns from this course section. Thus, given that the sentiments expressed in the course reflections are also supported by the attitude and belief data from our end-of-course surveys, we can conclude that a significant number of SCIE 376 interns leave the course with a sense that (1) science teaching is fun, interesting, and worthwhile and (2) they are able to teach science effectively. And although the above reflections are from a handful of interns in a particular course, it is our belief that interns in other courses and other institutional contexts might experience similar change in heart based on their own early teaching courses.

Summary

The goal of Towson's PhysTEC project for the past two years has been to improve our elementary education program's early teaching (field experience) course by (1) making the different sections of the course more uniformly aligned with the course goals, (2) increasing the amount and quality of inquiry in the undergraduate interns' science lessons, and (3) helping the interns more fully understand and appreciate inquiry-based science instruction. We chose to accomplish these goals by working with a full-time teacher-in-residence on a number different project activities, including the implementation of instructor and mentor teacher workshops, the teaching of certain course sections by the project team, and the creation and distribution of a curriculum resource cd-rom.

Assessments of our project activities, which include teaching observations, course surveys, and course assignments, indicate that we have made significant progress toward reaching our project goals: the field experience course has become more consistent across course sections, the course interns' science lessons have become more inquiry-oriented, and the interns are developing a greater appreciation and understanding of inquiry teaching methods. In the remaining years of the project, Towson's PhysTEC project will continue to make progress towards our goals, document our efforts and lessons learned, improve our assessment instruments, and create additional resource materials for elementary science educators.

References

National Research Council. (1996). National science education standards. Washington, DC: National Academy Press.

Sandifer, C., Lising, L., & Tirocchi, L. (2006). Our PhysTEC project: Collaborating with a resident teacher to improve an elementary science field experience. Annual Proceedings of the Association for Science Teacher Education Conference.