

Helping Preservice Teachers Implement and Assess Research-based Instruction in K-12 Classrooms

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Abstract. The Physics Education Group at the University of Washington offers special physics courses for preservice teachers. The three-quarter sequence helps prospective teachers develop an in-depth understanding of some of the important basic concepts they will teach. The guided-inquiry pedagogical approach provides them with an opportunity to learn as they will be expected to teach. As a result of the course, preservice teachers also come to recognize some conceptual and reasoning difficulties commonly encountered by students. A culmination of their experience is a teaching *practicum* in which the preservice teachers apply what they have learned to instruction in middle or high school classrooms. Observations of the preservice teachers as they design, teach, and assess their lessons contribute to our understanding of the type of preparation needed for them to be able to teach physics and physical science by inquiry.

INTRODUCTION

The Physics Education Group (PEG) at the University of Washington offers special courses in physics and physical science for both preservice and inservice science teachers. A primary purpose is to provide teachers with an opportunity to develop an in-depth understanding of topics relevant to K-12 instruction and to do so in an inquiry-oriented manner consistent with how they are expected to teach. For inservice teachers, this process occurs during a six-week NSF-funded Summer Institute and an academic-year Continuation Course. During the academic year, the PEG also offers similar courses for preservice teachers. This paper focuses on the courses for undergraduate physics and mathematics majors who anticipate becoming middle or high school teachers.

PRESERVICE COURSE: OVERVIEW

During the academic year, students interested in teaching physics or mathematics enroll in a three quarter physics sequence at either the 200 or 400 level [1-3]. The sequence for which a student registers depends on whether the student will teach at the

middle school or high school level and on his or her physics and mathematics background.

Throughout the academic year, the preservice teachers investigate various topics in physics and physical science. As they work through *Physics by Inquiry (PbI)*, developed by the PEG, they complete carefully sequenced experiments and exercises designed to guide them in developing an in-depth understanding [4]. Common conceptual and reasoning difficulties are specifically addressed. Working in pairs, the students progress at their own rate, keeping careful notes of their observations, data, and answers to questions posed by the curriculum or that arise during their study. The notebooks reflect the inductive and deductive reasoning through which they developed basic concepts and learned to apply them. At pivotal points, the instructional staff probes student progress through semi-Socratic dialogues. Student understanding is also assessed via exams, homework, and papers in which students must provide thorough explanations of reasoning.

In addition to helping students develop the in-depth content understanding that is imperative for success in the classroom, the courses encourage students to reflect on instructional strategies they experience [1]. A special focus is on the inquiry approach that has

proved effective in helping students develop a coherent conceptual framework and in eliciting and addressing common student difficulties [5,6]. The paper assignments, in particular, are designed to help the preservice teachers examine and articulate how their conceptions developed through the experiments and exercises they performed. During the course, the preservice teachers begin the process of translating their own learning experiences into effective classroom practice. The culmination, which takes place in the third quarter, is a teaching *practicum* in which the preservice teachers design, implement, and assess a lesson for middle or high school students.

TEACHING PRACTICUM

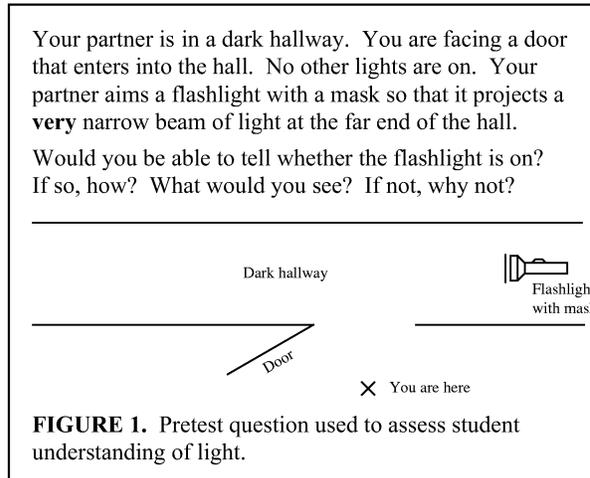
After developing their own understanding of several topics, the preservice teachers have an opportunity to teach a topic they have studied. They try to provide for middle or high school students learning experiences similar to those they have had themselves. The *practicum* is designed to serve as a context in which the preservice teachers can:

- recognize the value of identifying initial, current, and final levels of student understanding
- experience the iterative process of curriculum development
- gain practice in teaching by guided inquiry, and
- reflect on teaching and learning as processes of inquiry

These goals are accomplished through four phases of the *practicum*: preparation, adaptation, implementation, and assessment/reflection. The topic varies from year to year. For specificity, the discussion below is in the context of the 2004 *practicum* on geometrical optics.

Preparation phase: During the preparation phase, the preservice teachers continued to work through *Physics by Inquiry*. They also read relevant research literature on the teaching and learning of science [7,8]. Meanwhile, the students with whom they were going to interact were given a pretest by their teacher. (See Fig. 1.) The preservice teachers analyzed the responses to try to identify specific difficulties.

The following pretest responses were considered correct: “No [I could not see the light], because in order to be able to see something, light must first hit that object and then enter your eye.” and “Yes, when there is dust in the air the light would show the dust. It would look like a beam of dust.” Responses



considered incorrect or incomplete include: “Yes. Even the smallest ray of light will pierce the darkness.” and “Yes, you would see the slit of light in front of you almost like there was a rope or line.” Many students failed to articulate (implicitly or explicitly) that, for the observer to see light from the flashlight, the light must first strike an object (*e.g.*, a dust particle) so that the (reflected) light has an unobstructed linear path to the observer’s eye.

Only 35% of the secondary students who have taken the pretest (N=153) gave correct reasoning. (This result includes students given the same pretest the previous year.) It is interesting to note that these results are similar to those of preservice and inservice teachers who have taken the pretest. (See Table 1.)

Adaptation phase: Analysis of the pretest informed the preservice teachers of the need to help the students develop an understanding that light travels in straight lines and the ability to apply this idea. Therefore, the preservice teachers adapted a section of the Light and Color module from *PbI*. This section covers the linear propagation of light and also helps develop the idea that light is emitted in all directions from each point on an extended source. The preservice teachers, working in groups of three, formulated questions to use as verbal checkouts to evaluate understanding as the students worked through the materials. In addition, the preservice teachers designed post-test questions to assess student learning upon completion of the curriculum. Members of the university instructional staff assisted the preservice teachers throughout this phase of the *practicum*.

Implementation phase: After the adaptation phase, the preservice teachers were ready to venture into the secondary classroom. Each three-person group of preservice teachers was assigned 15 secondary students with whom they would work for 3

TABLE 1. Assessment of student learning. (The total numbers of pretest or post-test responses are given in parentheses.)

Population	Pretest		Post-test
	Fig. 1 % correct	Fig. 2 (or similar) % correct	Fig. 2 (or similar) % correct
Secondary students taught by preservice teachers	35% (153)	–	50% (42)
Secondary students taught by very experienced teacher*	–	–	85% (57)
Preservice math and physics teachers	55% (24)	35% (29)	85% (60)
Inservice K-8 teachers	30% (43)	30% (43)	90% (47)
Undergraduates in calculus-based introductory course with <i>Tutorials in Introductory Physics</i> [9]	–	20% (>2100)	80% (~360)

* The teacher had a Ph.D. in physics education research and had been involved in the design of *PBI* modules on light.

hours over 2 days. While in the classroom, the preservice teachers used their own learning experiences as a model for their instructional approach. Rather than answering students' questions directly, the preservice teachers guided students to use their developing understanding in constructing a model for light. The preservice teachers also moved around the classroom observing the students and listening to their conversations. Several preservice teachers commented that these observations were quite informative since they provided insight into the intellectual struggles of the students.

Assessment and reflection phase: A few days after completing the curriculum, the secondary students were given a post-test. The post-test consisted of several questions, some designed by the preservice teachers and others developed by the PEG. We have noticed that preservice teachers often find it difficult to design questions that effectively probe student understanding. By including well-tested questions, we ensure that all preservice teachers obtain results they can use to assess student learning (even if their own questions prove to be less effective). The questions also allow comparisons to be made between different populations (including various secondary student *practicum* groups). Below, we limit our discussion of post-test results to the PEG questions on geometrical optics.

The post-test question in Fig. 2 was given to the secondary students who participated in the 2004 *practicum*. A correct response requires understanding of the ideas that: light travels in straight lines and extended light sources may be treated as collections of point sources. The correct answer (see Fig. 3) can be obtained by treating the long-filament bulb as a continuum of point sources, each of which produces a crescent-shaped image on the screen.

Many of the preservice teachers were disappointed by the results from this portion of the post-test. Only 50% of the secondary students gave correct or nearly

correct answers (that is, responses in which extended sources were treated as continuous or discrete collections of point sources). In contrast, after instruction that uses *PBI*, preservice teachers typically perform at the 85% level on similar questions. See Table 1 for results from comparable post-test and pretest questions from various populations.

A mask that contains a small crescent-shaped hole is placed between two long-filament bulbs and a screen as shown below. Sketch what you would see on the screen when the bulbs are lit. Explain.

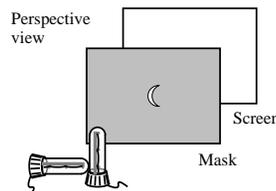


FIGURE 2. A post-test question used to assess student understanding of light after instruction.

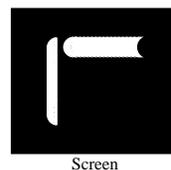


FIGURE 3. A correct response to the post-test question shown in Fig. 2.

The secondary students' post-test results provide an excellent opportunity for the preservice teachers to analyze remaining student difficulties as well as to reflect on their own insights into teaching and learning by inquiry. The reflection is formalized in a paper that the preservice teachers write. The paper includes:

- an analysis of the student post-test data

- an evaluation of the effectiveness of the adapted curriculum, including proposed revisions
- a reflection on pedagogical issues, and
- a description of interactions with students

The paper also provides insight into the usefulness of the *practicum* for the preservice teachers. In the 2004 *practicum* papers, many of the preservice teachers stated that the questions they had asked at pivotal points as students worked through the curriculum failed to probe student understanding adequately. They realized that the questions they had designed prior to working with the students had not been effective in guiding them to their own understanding of the material. Several preservice teachers also became aware that, during the Socratic dialogues, they often “heard from the students what they wanted to hear rather than what the students actually said.” These insights helped the preservice teachers recognize that teaching by inquiry requires not only a deep understanding of the content, but also pedagogical skills to support inquiry learning. One preservice teacher commented:

“When I spoke with [students] who really understood the material, I got to learn how other people think about physics. When I was talking with [students] who didn’t understand, I had to reach inside of myself for different ways of leading them to their own understanding.”

CHALLENGES AND CONCLUSION

The *practicum* is a relatively new component of the PEG courses for preservice teachers. We have evidence that this is an important experience for K-12 teachers. For example, we worked with an inservice high school teacher whose students were studying astronomy. Although she had worked through materials on astronomy in the preservice course (without the *practicum*) and could account for the phases of the moon, she did not recognize the careful consideration that must be given to curriculum adaptation and implementation. Failing to recognize the need for a coherent curriculum that explicitly addresses common difficulties, she eliminated some crucial experiments needed for a logical progression of ideas. Only 30% of her students (N=78) were able to identify the role of the sun/moon angle in the moon’s phases, a disappointing result since 35% had correctly identified the role of the angle in a pretest. The *practicum* allows PEG members to guide and advise prospective teachers throughout the adaptation and implementation process. Thus, preservice teachers, in

collaboration with staff, can examine the instructional materials critically, search for gaps in the logical progression of ideas, and identify common difficulties not explicitly addressed in the draft curricula.

Courses that focus on content, but that are taught in a manner consistent with how teachers are expected to teach, play an invaluable role in preparing prospective teachers to meet the challenges of the K-12 classroom [1]. The incorporation of activities such as the *practicum* into preservice physics courses enables prospective teachers to gain practice in adapting, implementing, and assessing guided inquiry lessons. Such opportunities provide preservice teachers with a chance to reflect on the inquiry approach, both as a learner and a teacher, in a way that helps them draw upon their own learning experiences when working with secondary students.

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