Grounding Inquiry-based Teaching and Learning Methods in Physics Experiences for Prospective Elementary Teachers

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Abstract. In teaching inquiry classes in physics, I ask students to reflect on their learning in journals. One of the journal questions deals with student expectations of transfer of the inquiry techniques used in our class into their own classrooms when they become teachers themselves. I report on students' answers to this question over a five-year period, which gives insight into how much or how little the students think the techniques are worth to themselves as both students and prospective teachers.

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I. INTRODUCTION

Children have natural curiosity. But after a few years of school, children seem to become less curious. Elementary and middle school teachers are required to know so many things about so many subject areas, they have little likelihood of becoming science experts. Perhaps it is because of this that many teachers discourage their students from asking questions of them and of nature. Teachers' lack of subject-matter confidence in science may lead them to interpret students' questions about content as a questioning of the teachers' authority.

I teach three inquiry courses in physics for undergraduates, each of which is adapted from and based on the research of the Physics Education Group at the University of Washington [1]. Many prospective teachers on my campus take these physics courses, and their prior experience is that *teaching* means *telling*. They are unaware that any other way of teaching exists. They have learned to, and therefore they expect their students to learn to, cram, memorize, and immediately forget.

Physics by inquiry attempts to break this cycle by providing an alternate experience for prospective teachers. The course emphasizes the scientific approach to nature—providing experiences from nature, discussing those experiences, proposing models that explain those experiences, evaluating the models by doing more experiments, etc. Because I rely on student experiences,

and the students themselves set up the experiments, they have personal, kinesthetic knowledge of their subject.

I believe along with Zull [2] that the role of concrete experience must be supplemented by reflection for learning to occur. I build on the familiar learning cycle, Fig. 1, which Zull argues is effective as a result of its reflection of the structuring of connections among areas within the brain.



FIG.URE 1. The learning cycle

The rest of this paper is organized as follows. In Sec. II, I describe course conditions. In Sec. III, I exhibit a selection of typical answers to one journal question, in Sec. IV I discuss the results, and in Sec. V I summarize the results of our investigation.

II. COURSE ORGANIZATION

Ohio State University offers its own version of three physics by inquiry courses: Properties of Matter, dealing

with mass, area, volume, density, and concentration; Electric Circuits, dealing with current and potential difference in the context of arrangements of batteries, bulbs, and wires; and Optics and Astronomy, dealing with single and multiple sources of light, shadows, and effects of the motion of the moon and sun. OSU uses the *Physics by Inquiry* books [3] as course textbooks. Typically, under 100 pages of the text will have been covered by the end of a one-quarter (10 week) course.

Physics by inquiry courses are taught in a way that encourages students to cooperate (students must work in groups.) It tries to assure student mastery of the topics. The syllabus they are given the first day of class shows students that only about half (53%) the final course grade comes from examinations. The remainder of the grade is based on attendance (which is important for both understanding and group success), homework, reworked pretests, and journals.

The courses are taught with concept mastery in mind (while complete mastery is not always gained, the average course grade is near a B+). The research basis of the materials is the elicit-confront-resolve model of learning. Most students come with ideas, which are brought forward by asking students to make a prediction (the question being determined by research on student thinking about the subject to elicit student answers inconsistent with reality), by doing an experiment that shows that the actual working of nature is discrepant from the expected student response, and by helping students build a model that encompasses the experimental results, resolving apparent discrepancies. Models are continually revisited and form the basis of student reasoning on the topics.

One important feature of the course is a complete lack of any lecture. Teachers interact with students mainly through discussions with the individual groups at appropriate points, called checkpoints, in the book. (I proffer help as needed, of course.) Students are led to construct their own (group) understanding of the phenomena being studied. The discussions follow from questions the instructor bases on the material covered since the previous checkpoint. Reflection is supported in several ways: group discussions, questioning at checkpoints, reworking of pretests, and the journal.

III. JOURNAL QUESTIONS ON INQUIRY

As noted above, the journal is an important component of the course. In it, I solicit answers to both content and course-related questions. The journal topic for week 6 provides information on students' likelihood of using inquiry themselves when they become teachers.

The questions are posed as follows: "For the following four questions only, imagine you are an elementary or middle school teacher. (1) What physics concepts taught so far in this class could be taught in your classroom? Would you teach the concepts the same way you learned them or modify their presentation depending on the age of the students? If you modify, how would you do that? (2) How would you adapt the structure of the material to work in a time period of about 45 minutes each day? (3) Would you use the same inquiry method of teaching as the instructors are doing right now? Why or why not? Would it be necessary to modify the teaching method also? (4) How would vou keep elementary or middle school students on track in a group effort? How would you determine whether the group is functioning, and how strict you should be with students who are disrupting the group and/or falling behind?"

In this paper, I consider the student responses only to the underlined parts (treated as one question) contained within the larger set of questions. I categorized the responses into the following six categories:

- •ves
- •yes, but ... [something more than the "inquiry" as used in our class, but without major changes]
- •yes, but have some lecture
- •have students do some experiments, but teach mostly by lecturing, giving demonstrations
- •probably not, absolutely not
- •don't know (what the student would do if a teacher).

In addition, I noted whether students said they would plan to do experiments or referred to experiments or demonstrations in their response.

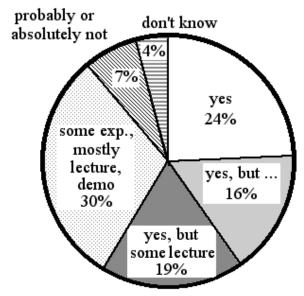


FIGURE 2. Student responses to whether they plan to use inquiry in their own future classes.

The responses of the 251 students included in this preliminary study fall into categories as shown in Fig. 2. About one-quarter plan to use the unmodified inquiry method, while one student in six plans to use the method, with slight modification, in teaching in the future. Only about one-tenth of students are adamantly opposed to using the method. To provide more context, selected student statements that fall into each category are provided below. The range of the answers gives a sense of student thinking that the summary table cannot.

Yes

"I can't think of a better way to teach science in general. Hands on experience is something I think would promote student interest as well as learning."

"I would use the same class structure as we are using now. It gets REALLY frustrating at times ... BUT I'm learning a lot because of the way that the class is set up." "I realize now why it is so important to communicate in a simple, clear, and precise manner; it is easy to get lost, lose interest and understanding when the person explaining or demonstrating throws in everything and the kitchen sink and most of the babble ..."

"I think using the inquiry method could be just as effective on younger students as it is on college students, so I would probably use it."

Yes, But ...

"The way it is taught in class seems to be one of the most effective but I think I would step down on some of the more complex parts (such as math)."

"I would let the students learn on their own to a certain point but as previously stated i [sic] would try to help the students as much as they needed."

"I would use the inquiry method but I wouldn't allow students (groups of students) to work at their own pace."

"I think I would not lecture, but give some guidelines and something to think about before they perform the experiments."

Yes, but Have Some Lecture

"I think we would work as one big group instead of more than one since they will probably be less likely to get work done and understand concepts on their own or just working with each other."

"I would modify the material, I would leaev [sic] it to major concepts only, and I wouldn't put as much emphases on a complete understanding, as I would on just knowing the material."

"I would do it much the same way done in this class but probably demonstrate a few things in each section first before turning them loose." "Students enjoy demos or lab but they need to be structured and expectation set from the beginning and the paper work to keep track would be tremendous."

"I would discuss the main points of the concept but still have them try it. I feel that experimentation is still a good method."

Have Students Do Some Experiments, but Teach Mostly by Lecturing, Giving Demonstrations

"Just teaching them the basic idea of how these things work and having them perform some exercises to see the ideas in motion would suffice."

"I would still use prediction but by raise of hand or group discussion. Then perform the experiment, check against predictions and discuss reasons for results."

"I don't think that I would require them to do as much thinking on their own, I would definitly [sic] help them out a lot more."

"... the teacher would have to just tell the students what certain things are ..."

"... less inqury [sic] and more demonstration, allowing the students to tell what happened ..."

"I need to give them information instead of let [sic] them think because they are too young for that method."

"I don't think that it would be necessary for me to use inquiry with my students because it might be too hard for them to think of things on their own, however if they understood the concept well enough then I would go into some inquiry"

"I just don't think it feasible, so it would become a demonstration in front of the class asking questions and having the students assist me as one large group to figure out the answers, having me perform a couple of the different ideas."

Probably Not, Absolutely Not

"I think that the inquary [sic] idea is a joke. I do not feel that is benificail [sic] at all."

"I would teach them the concepts through lectures and class demonstrations."

"I would not use the same inquiry method of teaching as the instructors are right now. Why, because it would be too compilicated [sic] for the students."

"I would not use the inquiry method. I would probably just instruct while they tried doing it themselves at their desks, and then asked them questions as a class, like why do you think that the candy had the same mass of the square nut?"

"I do not think that elementary kids could find these things out on their own."

"I wouldn't use the inquiry method.....just because it takes too long for a class of 30 YOUNGER students to grasp. I would teach with experiments as well as lectures and explanations."

IV. DISCUSSION

The time spent in the course plays an important role in student responses. I have noted that the fourth or fifth week is the nadir-many students seem frustrated and ready to call it quits. After this, though not on a predictable schedule, many students change their minds and come to see things differently. A student writes "Some days I really hate going in for class. But lately I have felt better and have actually enjoyed it. I liked it more when I felt as if I had really found out something ahead of where we were. I don't know if it happened later in the quarter because I was more used to how it all works or if I am just understanding it more." Ideally, we would like to have two quarters to influence the students, but many students (those we don't reach before the end of the course) opt out of a second quarter. Time also plays a role in coming to terms with the experiments, as it should. It takes time to assimilate new ideas, which come rapidly in the physics by inquiry courses. An example of this effect is seen when one student writes "When I look back at some of the experiments we did, I think to myself 'why did I have such a difficult time grasping the concept?"."

About one-quarter of students say they would apply the inquiry method when they become teachers, and another 16% are interested in using it, but with minor modifications. On a final evaluation in the journal, one student writes "I feel inquiry based instruction is very open. We learn everything by doing it ourselves, and if there is something we have a question on, it is usually figured out by thinking up an experiment to try it out. There are no study and answer kind of sheets, or tell all formulas." I regard this student's answer as a great success for the course. She has taken responsibility for her learning. She appeals to experiment as the final arbiter of answers about how nature works. She recognizes she can design an experiment herself to address her particular questions about nature.

About one-half the students say they would partly or mostly lecture, and almost 10% were completely turned off by inquiry (at least as I have practiced it here). Even those who are convinced have mixed feelings, as exemplified by this student's comment in the final journal: "I know what the course is designed to do, and I think to an extent it works, but since it is so different from how we're traditionally taught, many people got frustrated and may not have gotten as much out of the class as possible. This type of curriculum stimulates those who learn in a different manner than by hearing or reading. Many people learn best with a hands-on process. This stretches those who learn in other ways. You are

right in that we will always remember this course. I am still debating as to whether I liked it or not to be honest."

V. SUMMARY

It appears that many preservice teachers believe that elementary-school children are too young to be able to think or to solve problems. An awareness of barriers such as this can help science methods instructors identify ideas about teaching and learning that need to be addressed or confronted in their classes.

I find that 62% mentioned doing experiments or having students do experiments in their future classes. Since physics by inquiry classes so emphasize experimentation, it may not be a surprise that students would mention it in the journal.

During the past year as part of the first journal, I have asked students what they had thought teaching was before entering my course. Virtually all responses refer to lecture, as in, for example "One of the usual ways ... is being lectured. Most of the time I spend my time in class writing notes as fast as I can, and never really getting the time to process what I am being taught because its impossible to do both," or are vague references to ideals: "Teachers need to guide children." If I assume that previous classes would have written similar responses, the results presented here imply that a number of students have changed their minds about what constitutes teaching by week 6 of a single ten-week quarter.

At the very least, I have demonstrated to students that there are alternatives to lecture, that teaching needn't always be telling. The proof of the effectiveness of this pedagogy will come only after these students become teachers, and these teachers' own students begin to arrive already functioning as inquirers in the classes I teach.

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