What Teacher Educators Need to Know about Inquiry-Based Instruction

Alan Colburn

California State University

1250 Bellflower Blvd.

Long Beach, CA 90814

e-mail: acolburn@csulb.edu

Abstract

This presentation, specifically for teacher educators, defines inquiry, reviews research about the topic, and discusses classroom implementation of inquiry principles.

Introduction

The science education community has embraced no idea more than that called "inquiry," or "inquiry-based instruction." Developing an inquiry-based science program is the central tenet of the National Science Education Standard's teaching standards. Project 2061's Benchmarks for Science Literacy discusses scientific inquiry multiple times, including a section specifically devoted to the topic.

Still, inquiry is ambiguously defined while nevertheless hailed sometimes as *the* way to teach science, a method that addresses all important educational goals. The purpose of this presentation, based on my literature review of *JRST* articles about the topic, is to clarify participants knowledge about one of today=s biggest educational buzzwords. The paper addresses three aspects of inquiry-based instruction important for any teacher educator to understand. As a preservice teacher educator myself, the paper is keyed specifically to people teaching methods courses or science courses for preservice teachers.

I will:

(1) provide operational definitions for inquiry-based instruction,

(2) review what research says inquiry is and is not effective in accomplishing,

(3) recommend articles for those interested in examining the research base supporting

inquiry-based instruction, and

(4) discuss how teachers can gradually move from classical to more inquiry-based instruction.

Defining Inquiry

Perhaps the most ambiguous thing about inquiry lies in simply defining the term. Historically, discussions of inquiry generally fall within two broad classes. People get confused when they see the dichotomy between inquiry as describing what scientists do, on the one hand, and as a teaching & learning process, on the other hand. Authors of the National Science Education Standards seemed to recognize this dichotomy:

AScientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry *also* refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world.@ [emphasis added] (p. 23)

This paper focuses on inquiry as teaching technique, which I am calling inquiry-based instruction: the creation of a classroom where students are engaged in (essentially) open-ended, student-centered, hands-on activities. Students investigate natural phenomena, using their background knowledge and experiences. The things students do include posing questions, solving problems, and creating answers or tentative generalizations.

Even with this definition, teachers, researchers, and publishers have still historically referred to several teaching methods as inquiry-based instruction. These include the Suchman model, structured inquiry, guided inquiry, open inquiry, and the learning cycle.

Following Staver & Bay (1987), in structured inquiry activities students are given a problem to solve, a method for solving the problem, and necessary materials, but not the expected outcomes. Students are to discover a relationship and generalize from the data collected. In guided inquiry, students must also figure out a method for solving the problem given. And in open inquiry, students must also formulate the problem they will investigate. Open inquiry most closely mimics the actions of "real" scientists.

What Research Says about Inquiry-Based Instruction

Turning to research highlights, over the last generation many researchers examined learning from a Piagetian perspective. The researchers generally accepted these conclusions: (1) Inquiry skills often require some form of hypothetical-deductive reasoning as in Piagetian formal operations, and (2) students capable of using only concrete operational thought cannot develop an understanding of formal concepts. Thus, students lacking formal operational thinking abilities for a topic being studied in class will have a great deal of difficulty understanding inquiry-based activities related to the topic. The more familiar the activity, materials, and context of the investigation, the less likely students will have this difficulty.

Students more easily learn observable ideas via inquiry-based instruction (especially the learning cycle) than ideas considered theoretical. For example, inquiry-based instruction is likely to be effective for showing many students that chemical reaction rates depend on the concentrations of reactants. Students can even investigate how reaction rates depend on concentration. On the other hand, inquiry-based methods are poor as a means toward helping most students understand how scientists *explain* the phenomena, via the kinetic-molecular theory.

Most studies I examined supported the collective conclusion that inquiry-based instruction was equal or superior to other instructional modes for students producing higher scores on content achievement tests. Several studies concluding no significant differences in content achievement between groups were not focusing on content as the main outcomes measured. These studies generally concluded inquiry was beneficial for achieving one or more non-content goals, while simultaneously not hurting students' content achievement.

As I mentioned above, though, inquiry-based instruction is probably most effective in developing content achievement when the content is more concrete than theoretical. Some authors whose studies I examined recognized this point and stipulated in their articles that the content students were studying (and being tested on) was specifically concrete.

To help all students benefit from inquiry-based instruction, the science education research community would presumably recommend:

$ orienting activities toward concrete, or observable, concepts

$ emphasizing activities centered around operational questions, questions that students can answer directly via investigation (which goes a long way toward insuring activities are oriented toward concrete concepts)

$ emphasizing activities using materials and situations familiar to students

$ choosing activities for which the teacher believes most of his or her students already have the necessary prerequisite skills and knowledge to succeed. The range of student abilities in any given location is usually quite large.

There is a caveat to these recommendations, though. Evidence also suggests that students who are not challenged mentally will not develop their cognitive abilities as much as students who are challenged. Suppose, for example, a teacher had a group of students capable of, say, guided inquiry activities around a topic. Structured inquiry will not affect the students cognitive abilities nearly as much as guided inquiry activities. At the risk of sounding like Goldilocks, if the activities are too challenging, a student will not learn content effectively. On the other hand, if the activities are too easy, the student will not develop better thinking skills. Maximum learning probably occurs when the activities are "just right"--cognitively challenging, but still doable. This implies, at least in theory, a classroom where students may not all be doing the same version of an activity at the same time.

Recommended Articles

This section of the paper is for teacher educators interested in having students read original research supporting inquiry-based instruction, but looking for suggested articles. In writing the section, it was difficult for me to decide which articles to include. The task is made more difficult knowing that instructors will select articles for different purposes.

Researchers have examined inquiry-based instruction for decades. As such, people have studied the topic via a variety of research techniques and viewpoints. One advantage of this is being able to show students how researchers employing very different methods nevertheless arrived at similar conclusions. Few ways could be better at demonstrating the value of an instructional strategy, so I selected studies employing a variety of methods.

Whenever possible I selected studies that were replicated. Replication is an important part of establishing scientific validity. In addition, the assumption is made that if a study design was published two or more times, there is a better than average chance that the design is valid--as judged by peers.

Use this section of the paper to select the types of articles that will best serve your needs. Few students would ever be expected to read all these articles!

The articles, obviously, are not a definitive list. Selections are limited to articles published in *JRST*, and even within that journal's pages, many fine research studies had to be excluded. Readers should certainly not interpret this section to imply the articles discussed below are the *only* articles about inquiry-based instruction worth examining. In addition, space prohibits all but the most general discussion of each article. My apologies ahead of time to any authors who believe I missed important points when mentioning their work.

Non-empirical discussion about inquiry-based instruction Readers looking for definitions, philosophy, or editorials, may wish to begin with Gagne (1963). Gagne was influential in the development of alphabet soup curricula, especially SAPA. "The learning requirements for enquiry" appeared in *JRST*'s first issue. Twenty years later Finley (1983) critiqued the same issues from a newer perspective. Read and reflect on Gagne first, then see what Finley had to say.

In addition, Rutherford (1964) made the distinction between inquiry as content and as technique. The former essentially refers to studying about the nature of scientific inquiry. The latter refers to using inquiry methods as an instructional strategy (what I am calling inquiry-based instruction). The distinction was reiterated by Kyle (1980), and continues to be important.

Finally, Staver & Bay's (1987) article examining textbooks does a nice job of defining different types of inquiry-based instruction (structured inquiry, guided inquiry, etc.).

Longitudinal study Scott examined pupil abilities after exposure to a particular inquiry method of instruction. The author examined students' classification abilities over several years, reporting the results in three articles (Scott, 1966; Scott, 1970; Scott, 1973).

Teacher behaviors and student outcomes *JRST* published several related studies using interaction analysis techniques to examine inquiry-based instructional settings. Shymansky & Matthews (1974) was among the first. The basic idea behind the study was to code teacher behaviors (with the teacher providing more or less structure to hands-on lessons) for five weeks, and then code student behaviors for five weeks. Students were also given a process skills test. The study was replicated by Penick & Shymansky (1977), and expanded upon by Penick, *et al.* (1976) and Penick (1976). Vinelli, *et al.* (1979) also carried out a study along the same lines. Crocker, *et al.*, performed very similar studies, though they examined the resulting data via slightly different perspectives (Crocker, Bartlett & Elliott, 1976; Crocker, Amaria, Banfield & Sheppard, 1979).

Comparisons of different instructional methods (including inquiry) and sequencing on student outcomes Zingro & Collette (1967-1968) did this with six groups of college students. The study's methods were straightforward, the authors used a battery of assessment measures, and were able to present more analysis in their conclusions than some similar studies.

Schneider & Renner (1980) compared conventional instruction to the learning cycle, which they called inquiry instruction. The authors examined students' science achievement. The authors specifically addressed only science content requiring no more than concrete operational thinking abilities. Saunders & Shepardson (1987) replicated the study.

Leonard and others performed three studies examining the effects of different types of inquiry activities--essentially structured vs. guided inquiry (Leonard, Cavana & Lowery, 1981; Leonard, 1983; Leonard, 1989). The studies looked at both college and high school students. The 1983 study was replicated by Hall & McCurdy (1990). The 1983 study's straightforward design, combined with an experimental group of college students taking general biology, makes Leonard (1983) and Hall & McCurdy (1990) particularly valuable articles to share with colleagues in science departments.

Westbrook & Rogers (1994) also examined the effects from different types of inquiry activities, with ninth grade students. In this case, the researchers examined different types of learning cycle activities (roughly equivalent, however, to structured, guided, and open inquiry). They found student reasoning abilities improved only with learning cycles featuring guided and open inquiry type activities.

Studies comparing student or teacher attributes when looking at the effects of inquiry-based instruction Shymansky & Yore (1980) selected college students on the basis of concrete or formal thinking ability, plus field dependence or independence. Yore (1984) also examined how students with different cognitive abilities performed in an inquiry-based setting. In this latter case, the study focused on fifth graders.

Sunal & Sunal (1985) found significant correlation between formal thinking abilities in teachers and their teaching ratings. Moreover, the ability to *recognize* differences in concrete and formal teaching styles was *not* related to teaching performance.

On a more affective note, Kyle, *et al.* (1988) found elementary students liked science significantly more after a year of inquiry-oriented lessons than more classical instruction. This study is of note because all the teachers involved had widespread support from their school district, including extensive inservice training.

Meta-analyses The early 1980's brought a number of meta-analyses of research studies. Those most closely associated with inquiry-based instruction or curricula described by some as being inquiry-based include Lott (1983), Sweitzer & Anderson (1983), Shymansky, *et al.* (1983), Weinstein, *et al.* (1982) and a re-examination of an earlier meta-analysis by Shymansky, *et al.* (1990). Although commonly cited, the results from these studies are actually rather mixed in deciding how effective inquiry-based instruction is for particular outcomes. Authors of the studies seemed to agree that much of the problem lies in poorly defined terms and studies that are vague in some respects.

Path Analysis Germann's (1994) path analysis examined direct and indirect relationships among variables affecting process skill acquisition. The author found students' cognitive development and academic ability (as measured by standardized tests) had the greatest total effects on science process skill acquisition. Knowledge, language preference, parents educational backgrounds, and student attitudes toward science were also quite important factors.

Examinations of curriculum materials Some studies focused on curriculum materials, rather than teachers or students. Germann, *et al.*'s (1996) study is particularly recommended for the detail with which the authors laid out their criteria and methods. However, Staver & Bay's (1987) study examining elementary science texts and Pizzini, *et al*.'s (1991) studies are also both recommended. In each case, though, the results were quite similar--regardless of grade level or subject area examined, few activities were found that could be classified as inquiry-based.

Observational Study In preparing this paper, my *JRST* review only covered through the mid-1990's. The mid-90's through the present has seen a rise in the number of observational, qualitative research studies. Thus, the most recent studies of this type are not addressed here. However, Roth & Roychoudhurry's (1993) study is still a good starting point for an example of this type of research. They examined how students developed higher order process skills within an inquiry-based context.

Helping Teachers Move from Classical to Inquiry-Based Instruction

Inquiry-based instruction often represents a new, different, and complex classroom situation for teachers and students. Both need the time to gradually make a transition from the more classical confirmation type activities and lectures, to more open-ended activities characteristic of inquiry-based instruction. The key point is to make teaching changes slowly, not continuing on with something new until teacher and students alike feel comfortable. Both should be successful!

A good place to start is by taking away premade data tables that accompany many lab activities. Have students figure out for themselves what data to record, and how to record it. Initial confusion will eventually give way to success! Several authors of research articles discussed their observations that students initially resist open-ended instruction, but after several weeks grow to either like it, or at least understand its value.

Once students are used to recording their own data, the teacher can move on to further activity modifications. Parts of the procedures students are given can often be deleted, for example. Students make decisions that can have small effects on the outcomes of the activities, while still allowing them to learn everything the teacher would like them to learn, and still using the materials the teacher had planned on using. Teachers can also experiment with having activities come before lectures (or direct instruction). This simple change--keeping everything else as already planned--can open up all sorts of wonderful things in the classroom, because of the discussions possible between students and teacher before going on to formally introduce new content.

For more information about how to gradually make classical science activities more inquiry-based, see Colburn (1996, 1997) or Colburn & Clough (1997).

Finally, even when following suggestions like those above, maintaining an inquiry-based classroom is extremely difficult. It is my hope that these suggestions, coupled with extensive research support, will help convince teachers and teacher educators of the great value, promise, and fun of inquiry-based teaching.

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