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Challenges to Inquiry Teaching and Suggestions for How to Meet Them

Abstract

Inquiry has been cited as an essential goal of science education for decades. While terminology has evolved over time, the notion that students need to apply various analytic and thought related skills in order to better learn underlying scientific concepts and processes, remains central to science education. This article looks at four major challenges facing teachers as they implement inquiry based teaching—including measuring the quality of inquiry, using discourse to improve inquiry, pursuing the goal of teaching content through inquiry methods, and learning how to effectively manage an inquiry classroom. An analysis of each of these issues, along with implementation strategies, is provided.

Introduction

Inquiry, in different guises and with different terms, has been cited as one of and often the principal goal of science education for decades. In the 1930's and 40's, it was common to find articles that spoke of developing "the habit of scientific thinking" (Blair and Goodson, 1939) and others that defined elements of the scientific method (Keesler, 1945). Still others focused on developing scientific attitudes like objectivity, replicability, and the value of controlled experiments.

In the 1960's the lines of research coalesced, even though the notion of breaking the whole into minute pieces remained. Inquiry was called science process skills, a set of discrete characteristics of the scientific process. Scientists observed, described, inferred, measured, and hypothesized. They identified and controlled variables, designed experiments, and drew conclusions. The belief was that if students practiced and mastered the distinct skills, they would naturally put them together to solve problems.

Key words: Inquiry, science, teacher education, professional development

We have come a long way since that time. We no longer try to break the whole into distinct parts. Instead, the *National Science Education Standards* describe inquiry as "the diverse ways in which scientists study the natural world and propose explanations based upon evidence…" (NRC 1996, p. 23). A subsequent publication, devoted entirely to the conceptualization of inquiry, set out its essential features—basically a description of how you would know inquiry when you see it (NRC, 2000). These essential features describe what the learner will do when inquiring, including:

- Engaging with a scientific question,
- Participating in design of procedures,
- Giving priority to evidence,
- Formulating explanations,
- Connecting explanations to scientific knowledge, and,
- Communicating and justifying explanations.

But as any science coordinator or professional developer knows, achieving the holy grail of increasing student understanding via inquiry learning depends on teachers who understand it, fully and completely, as a function of their disciplinary knowledge. Research indicates that teacher understanding of inquiry, including its many pedagogical and curricular nuances, is still problematic (Flick and Lederman, 2004). This article focuses on major impediments or challenges that the authors often see when helping teachers to understand and implement inquiry in their classrooms.

Challenges related to inquiry

Below are four challenges that teachers incur when implementing scientific inquiry in classrooms. We, then, describe some of our efforts in addressing and overcoming these challenges.

- *Challenge 1: How can we measure the quality of inquiry as implemented in the classroom?*
- *Challenge 2: How can teachers use discourse and discussion to encourage more effective inquiry-based learning?*
- *Challenge 3: How can we get teachers to think of content and inquiry as not mutually exclusive, but rather aspects of the same goal?*
- *Challenge 4: How can we help teachers learn to manage an effective inquiry classroom?*

How can we measure the quality of inquiry as implemented in the classroom?

K-12 science teachers reported that they devote on average 37.3% of their time to inquiry during typical lessons—higher for elementary teachers and lower for high school teachers (Marshall, Horton, Igo, & Switzer, 2009). Despite the perception by classroom science teachers that inquiry is regularly occurring in the classroom, the quality of this inquiry tends to be confirmatory or activity centered in nature where the teacher explains a phenomenon or concept and then directs the student in how to work with the concept via a prescriptive activity. While this approach may be appropriate when mastery of a skill is of primary importance such as learning how to perform a titration or how to use a microscope, it is not appropriate when trying to get students to develop critical thinking skills through investigation. Teachers can, however, improve the quality of inquiry being facilitated in the classroom if they are provided a mechanism to transform their instructional practice. The support necessary to help scaffold teacher transformation usually includes a combination of approaches (e.g., curricular, professional development, learning communities, administrative), but for lasting success, it needs to be clear, focused, and sustained over time (Supovitz & Turner, 2000).

Measuring inquiry through EQUIP.

One mechanism that can help support teachers to improve the quality of inquiry-based learning facilitated in the classroom is the Electronic Quality of Inquiry Protocol (EQUIP) (Marshall, Horton, Smart, & Liewellyn, 2008). EQUIP provides a reliable, valid measure of the quality of inquiry being facilitated and is focused on four major pedagogical constructs—instruction, curriculum, discourse, and assessment (Marshall, Smart & Horton, 2010). The descriptive rubric associated with the instrument allows teachers, instructional coaches, administrators, and researchers alike to measure and discuss what occurred or has been occurring and then allows individuals to chart tangible, intentional steps that can be undertaken to improve the overall quality of instruction (Marshall, Smart, & Horton, 2010).

Each of the 19 indicators, that comprise EQUIP's four constructs, is designed to measure a critical aspect associated with the quality of inquiry that occurs during a lesson; each details four possible levels of performance (Pre-inquiry—Level 1, Developing Inquiry—Level 2, Proficient Inquiry—Level 3, and Exemplary Inquiry—Level 4). EQUIP was written and validated so that Level 3 is the target for high quality inquiry. Further, our preliminary data suggest that the quality of inquiry (measured by EQUIP) is an excellent predictor of both student science content and process knowledge (measured by Measures of Academic Progress test; NEA, 2004).

In helping teachers to transform their practice to higher quality inquiry-based teaching, we have found that it is most helpful when teachers target 2-3 indicators (e.g., *Order of Instruction* or *Questioning Level*) at a time to improve. This allows them to be more focused and intentional about the improvements until the new skills become automated in their practice. As one begins using EQUIP, it is helpful initially to establish a baseline of teaching performance. This can be done by videotaping and then scoring the lesson later, by having a peer teacher or instructional coach observe a lesson and then score the performance, or by working with a team of teachers to analyze and score the lesson (similar to a lesson study with EQUIP used to focus the discussion).

The scores when used in conjunction with the rubric help articulate what occurred during the lesson. For instance, a Level 1 tends to be a more traditional, teacher-dominated lesson where students tend to be passive recipients of information. Level 2 is very commonly seen among teachers and is where students are busy working with activities related to the concept, but students largely are not required to think deeply about the material. These activities tend to be dominated by more prescriptive forms of learning where students follow a predetermined series of steps after the concept has been already told to the students. By Level 3, students are asked to question, theorize, and apply ideas. The concept is often embedded within the investigation instead of preceding the investigation, and students are commonly more involved in the entire planning, collection of data, and sense making portion of the learning. Level 4 occurs when the teacher is able to facilitate learning experiences where the students successfully and consistently engage in rigorous, content-embedded inquiry learning experiences that challenge high level, developmentally appropriate thinking. Achieving Level 4 is not always the desired goal, because there are times when the teacher needs to assume a more active role in guiding and scaffolding the learning experience.

Two of the 19 total indicators are discussed below to illustrate how an indicator can help make teaching practice more focused and intentional.

Order of instruction.

First, the *Order of Instruction* indicator, within the Instruction construct, challenges teachers to facilitate learning that provides opportunities for students to explore ideas before formal explanation occurs. In so doing, a Level 3 score is earned. In contrast, a Level 2 performance is earned when the teacher asks students to explore after receiving explanation and the teacher does most of the explaining. By realizing the difference between a Level 2 and Level 3, most lessons can be adapted by reversing the order of instruction. This seemingly small change often results in higher student engagement, and what previously was a lengthy lecture often becomes review as students help to create the knowledge through explanations of results and conclusions. This intentional change in instruction can with practice allow teachers to transform the typical curriculum that is provided by book companies or available via the Internet.

Complexity of questions.

The discourse that is facilitated is critical for engagement and active learning. As such, the *Complexity of Questions* indicator provides guidance into the interactions that are facilitated in the classroom. A Level 3 is earned when questions challenge students to explain, reason, and/or justify their thinking. In contrast, a Level 2 is earned when the questions focus mostly on one correct answer with some open response opportunities provided. Simply by asking more 'why' questions and fewer 'what is' questions the teacher can begin to change the interactions in the classroom. Level 3 instruction increases the degree of rigor in the class and requires students to be thoughtful about their work, their responses, and their overall reasoning.

The highlighted indicators provide two examples of immediate, intentional steps that can be taken to improve teaching practice. It should be pointed out that just as it takes time to learn how to teach more effectively, it also takes students time to adjust to new ways of learning. So, in order to encourage student success, be sure that changes are made gradually to allow students time to acclimate.

How can teachers use discourse and discussion to encourage more effective inquiry-based learning?

In some disciplines like mathematics the quality of discourse in a classroom is a surrogate for level of thinking within the discipline. Science discourse can cause students to become disengaged from science if they are not accustomed to talking about science. But science discourse can be used as a way to encourage inquiry. In this section, we discuss how encouraging scientific discourse can promote inquiry-based learning. Science discourse creates its own set of challenges because of the specialized language necessary to understand the discipline. However, this language or set of words is necessary for students to truly inquire about science and with scientists. In general, school science requires students to integrate the practices of prediction, observation, analysis, and presentation with science reading, writing and language use (Lee & Fradd, 1998). This ability to 'talk science' has served as a gatekeeper to the sciences, preventing many students from having access to academic success and successfully engaging in scientific inquiry (Lemke, 1990). Instructional discourse or discourse initiated by the teacher in science classrooms often includes techniques for asking questions (e.g. small-group or whole-class instruction). Below we outline prominently used discourse techniques with suggestions for incorporating inquiry into them.

Providing feedback.

First, we encourage teachers to examine their questioning techniques. Teacher-questioning techniques are a central component to leading classroom discussions. Close analyses of classroom interactions expose unspoken classroom rules and previously unnoticed norms for classroom behavior. For example, most teachers use a teacher questioning technique called IRE (teacher initiation, student response, and teacher evaluation) sequences (Mehan, 1978). This format often can stifle discussion and induce passivity in students. In everyday conversation, a question is typically followed by an answer, without a follow-up evaluation. In this way, classrooms deviate from everyday conversation in having, overwhelmingly, a triadic structure. In this triadic structure, it becomes very difficult to encourage and teach the use of inquiry strategies. However, if teachers change the third move in this sequence from evaluative to feedback to become IRF (teacher initiation, student response, and feedback from the teacher) this creates an environment more closely related to everyday conversation. During this everyday conservation, students often begin dialoguing with each other. This student-to-student discussion in scientific discourse often promotes scientific inquiry as the dialogue and feedback is continuous and not predetermined by the teacher. Because the desire is that students will begin to inquire more readily, ultimately we are asking teachers to relinquish control of the discussions in order to encourage conversations and allow students to inquire during discussions. Teachers can promote inquiry through feedback and continuing the conversation.

Providing follow-up information.

Another way teachers can use IRF to promote inquiry in their classrooms is to change the third move to provide follow-up information to extend students' ideas, highlight the significance of students' contributions, and make connections to other experiences. Then, the teacher can help students devise a research problem, think about a variety of solutions, and reconsider their procedure—in other words, support the student in engaging in scientific inquiry. IRE sequences tend to occur when the topic is introduced in response to the teacher's questions, and when the discussion's purpose is to elicit scientific knowledge (Wells, 1993). However, when the student initiates the discussion or the discussion focuses on shared classroom experiences, the teacher and students offer both detailed and significant contributions to the discussion. Thus, triadic dialogue can serve an important non-evaluative interactional function allowing teachers and students to co-construct knowledge as well as create a space for teachers to formatively assess students' knowledge. When teachers are not just evaluative but also supportive, it provokes deeper thinking beyond simple recall. Thus, students begin to formulate hypotheses, make predictions and inferences, and draw conclusions.

Overall, scientific discourse can serve a function for eliciting information from students. However, the manner in which a teacher encourages scientific discourse affects students in a variety of ways and has the opportunity to create a space for inquiry. As Lemke (1990) points out, in content-centered classrooms, teacher-student interactions tend to occur mainly through IRE sequences that allow teachers to maintain an authoritative role and control every aspect of the conversation by asking questions and evaluating students' responses. However, these alternative instructional discourses mentioned above are critical as they allow teachers and students to adopt more equal interactional patterns in which authority over the learning of science is shared by both teachers and students. As a result, students are given opportunities to develop and maintain a sense of ownership and agency over their learning experiences; thus allowing teachers to promote better discourse and higher quality inquiry learning.

How can we get teachers to think of content and inquiry as not mutually exclusive, but rather aspects of the same goal?

One often hears teachers complain that they cannot implement an inquiry classroom because they have so much content to cover. With the pressure of high-stakes testing and curriculum standards sometimes emphasizing breadth instead of depth, teachers struggle with the amount of content they need to cover. Often times, this struggle leads them to rely on direct instruction to more efficiently convey scientific knowledge to students. However, these methods of instruction reinforce the idea to students that science is in its "final form" (Duschl, 1990). Rather than learning scientific principles in an isolated and superficial manner, science teachers must learn to use strategies to facilitate student understanding of both inquiry and content knowledge.

Linking scientific content and inquiry.

While the *National Science Education Standards* (1996) call for teachers to help students acquire content knowledge as well as utilize the methods of science in a complementary way, in the typical science classroom, we still see science process skills being taught in isolation. Often times, teachers devote the first couple of weeks of instruction to learning about the scientific method, making observations and inferences, designing controlled experiments, and measuring without ever requiring students to apply these skills to develop an understanding of science concepts later in the school year. One reason for this problem could stem from the way standards are interpreted. Many states include a "scientific inquiry" standard for each grade level. Some teachers may view the standards as a sequential list of topics to be covered, therefore they teach inquiry in isolation from scientific content. Textbooks designed to align with state standards may only serve to reinforce this separation. Another reason for the division between inquiry and content could be due to the model teachers experienced in their own science courses; for example, at the college-level, most science courses separate lecture and laboratory sections. Regardless of the root of the problem, doing inquiry requires engaging students in combining process and critical reasoning skills to develop an understanding of scientific concepts.

Evidence-based explanations.

One strategy teachers might use to help students develop an understanding of both inquiry and scientific knowledge is to help students develop evidence-based explanations. Students should work like scientists and conduct investigations that involve "the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence" (p. 12, AAAS, 1993). Essentially, we advocate changing the order of instruction so students explore a concept though investigation first and then begin to apply the appropriate scientific principles to explain their understanding.

To encourage students to develop scientific explanations based on data, teachers can engage their students in a three-step process (Luft, Bell, & Gess-Newsome, 2008). First, students should develop scientific questions or identify problems to be investigated. To address this question or problem, students should be encouraged to make a claim. After they develop a claim, students can begin to collect evidence to support their claim. This step requires that students apply many scientific processes while they are studying a topic, such as asking questions, identifying variables, designing experiments, constructing data tables and graphs, and sharing ideas within groups. Finally, students should be supported as they make connections between their claims and the evidence they have collected. During this process, students are analyzing relationships and making evaluations about their evidence and conclusions; in addition, they must apply and be able to explain the appropriate scientific principles. The benefit for the students in developing scientific explanations involves having a more accurate view of the way science works, developing a stronger understanding of content knowledge, demonstrating better problem-solving skills, having a better ability to apply inquiry and showing more interest and curiosity in science (Shymansky, Hedges, & Woodworth, 1990).

Developing appropriate assessments.

In order for students to show their understanding of both inquiry and science content, teachers need to revisit the way they assess their students. While traditional assessments (e.g. multiple choice tests) may provide insight into student understanding of content, they do not usually indicate students' understanding of the processes necessary to do science or students' application of that knowledge. To truly understand what students both know and can do in the science classroom, teachers need to add a variety of assessments to their repertoire. The use of performance assessments (e.g. having students demonstrate how they go about lighting a bulb with a battery, bulb, and wires) allows students to engage in a research question or solve a problem. Plus, it provides teachers with opportunities to examine students in action and scaffold them in thinking critically about science investigations. Performance assessments can be informal or formal and may include classroom discourse, student demonstrations, and the development of models. While there are multiple types of performance assessments that can be used, they must all address issues of students' ability to apply inquiry, critical thinking skills, and knowledge of science content (Hein & Lee, 2000).

How can we help teachers learn to manage an effective inquiry classroom?

One of the greatest concerns for teachers in implementing inquiry-based instruction is the fear of losing control—control of instruction, control of students, control of the class. Unless teachers address this fear, they will likely continue to rationalize their unwillingness to implement inquiry instruction instead of asking what is best for students and then working to achieve that goal. After all, management issues are the main reason that people leave the teaching profession (Barmby, 2006). With knowledge and effort, however, this fear can be addressed and overcome.

We have found teachers' receptivity to inquiry instruction rests, at least in part, on their success, or lack thereof, in managing the classroom effectively. Classroom management is undoubtedly one of the most critical aspects associated with effective instruction and learning. Poor management can destroy any chance for meaningful learning—including inquiry. To address issues of classroom management that impact inquiry instruction, we will discuss three essential keys to creating an appropriate affective classroom for inquiry learning and strategies for organizing the physical classroom for effective instruction. The three keys for creating an appropriate affective classroom include: building a solid presence, creating strong relationships in a respectful environment, and setting high expectations.

Building a solid presence.

A commanding classroom presence carries a firmness, fairness, confidence, and "withitness" that allow the classroom to operate safely and respectfully—thus allowing and encouraging learning to take place. Though these qualities tend to improve with time and experience, they can also be learned so that novice teachers can establish a commanding presence and quickly pass the "tests" that their students will inevitably send their way. A teachers' firmness is often necessary in helping set reasonable boundaries for guiding classroom interactions. Treating students with impartiality and equity means addressing the unique needs of each learner, which requires that all are treated equitably Thus, successful teachers avoid playing favorites and focus on meeting the needs of all learners in the classroom. Confidence in teaching, a self-assurance that gives teachers comfort with the subject and the activity at hand, can be developed or enhanced through an examination of the strengths and weaknesses in their teaching practice. Possessing a strong understanding of science content knowledge is a great step in building confidence in science teaching; however, it should not overshadow teachers' understanding of the pedagogy necessary for teaching science, their relationships with their students, and their reflections on their teaching. "Withitness" is a global understanding of what is transpiring in the class at a given time; the awareness develops when teachers show they care about their students, their students' learning, and the content that they teach.

Creating strong relationships in a respectful environment.

We know that the needs, the abilities, and the goals of our students are all unique, so our career is a personal one that requires a professional rapport with and understanding of each student that we encounter. Thus, our task as teachers includes facilitating the development of a caring and respectful learning environment. Many battles are waged because of respect, or a lack of it. But a common mistake is to think that respect is given and earned in the same way. Respect is typically culturally dependent. In some settings, respect is commonly yielded up front—you are respected until you lose it. In other settings, particularly those in which the teacher is not a member of the dominant culture, respect often must be earned. Thus, if you possess little background in cultural understanding of your setting, it is easy to become frustrated when students do not bestow you with immediate respect (Marshall, 2008). Even though gaining respect may take more time in some settings than others, there are still things that can be done. Let the students know that you have general expectations regarding decency and civility that all must adhere to. Students don't have to agree with everyone in the class, but the teacher must set expectations that students should listen to each other, hear each other out, and find appropriate ways to dissent when appropriate.

Setting high expectations.

Expectations can be co-created with students. When students feel they have a voice and ownership in their learning, they are more likely to engage in learning and defend it when scoffed at by peers. One means of setting expectations is to have students set short and long-term goals. Long-term goals may be about their performance in the course overall. Short-term goals may have to do with what they will try to achieve today. Goal setting has become particularly popular in middle school settings and provides one strategy to narrow the achievement gap. Having students focus on clear goals each day helps them both to organize and prioritize, which are two very difficult things for many students. Encouraging students to set their own goals and meet those goals on a day-to-day basis provides an ongoing challenge for students and may minimize boredom. Many of the so-called "trouble makers" are not malicious, but rather bored students in need of challenges that are provided by both goal setting activities. Many discipline problems are a student's call for help rather than a calculated attempt to sabotage the class. A respectful classroom environment that provides both goal setting and goal meeting opportunities to support inquiry learning will provide multiple opportunities for student success.

These global management issues can help teachers transform their classrooms and improve the quantity and quality of inquiry. There are undoubtedly other issues that remain that include making gradual changes with students, managing cooperative learning environments, learning how to question effectively in an inquiry classroom, working with diverse learners, and pacing so that learning is maximized (Marshall & Horton, 2009). Although all of these could not be addressed here, we hope this article will start many conversations and encourage further reading into the pertinent issues for teachers and schools.

Conclusion

While we understand the challenges addressed in this article do not constitute the entirety of all the challenges that science teachers face when incorporating inquiry-based learning, we believe that these challenges represent some of the largest impediments to teaching with scientific inquiry. We hope teachers will be able to utilize our ideas for incorporating more effective inquiry in their classrooms and that they will be able to address these critical challenges.

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