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Comparing Traditional and Inquiry-Based Science Classrooms

A TRADITIONAL CLASSROOM

Traditional high school science classrooms usually look different from inquiry-based classrooms. That is not to say that traditional classrooms are any better or worse than inquiry-based classrooms; it just means the behaviors of the students and the teacher, as well as the appearance of the physical environment of the classroom, are different. There are instances, such as the first week of school, or when making an expository presentation through direct instruction, or when presenting an imposing amount of information in a short amount of time, that a teacher might prefer a more traditional or teacher-centered classroom. In a traditional classroom setting, students usually sit in straight rows of desks (assigned by the teacher) and learn through rote memorization. Students attentively listen to the teacher, who is standing in the front of the room or behind a demonstration table "imparting" information, while passively taking notes from the blackboard or overhead projector. The recitation may be followed by a question-and-answer session in which students are presented with queries that summarize the lesson and evaluate the students' understanding of the concept presented. The lesson is structured around "teacher talk" and student responses. A single textbook usually guides the teacher's presentation and provides additional readings and questions for further discussion and homework.

In teacher-centered classrooms, demonstrations are often used by the teacher to arouse interest or reinforce a concept that was previously introduced. The demonstration also enables the teacher to model a particular phenomenon and provide all the students with an observable experience from which an explanation or a discussion may follow. Discussions are also an important aspect of traditional science classrooms; however, in teacher-centered classrooms, the line of communication is too often an interaction between the teacher and one student at a time. Toward the end of the unit, the teacher provides the students with a cookbook-type laboratory to verify that the information presented on previous days' lectures is correct. At the end of the lesson or unit, students' understanding is evaluated through an objective-type test containing true/false or multiple-choice questions.

The walls of the traditional high school science room probably show a periodic table of elements, commercially made pictures of scientists (no self-respecting science classroom would be without a picture of Albert Einstein), and safety posters to remind students of the proper conduct for laboratory behavior.

If inquiry is so publicly touted, why do we still find a large percentage of high school science classrooms to be so teacher-directed? The answer to the question may lie in the relative ease of expository teaching, the standards and assessment constraints that teachers face, and teachers' previously held beliefs about "good" teaching and learning. According to Jorgenson and Vanosdall (2002),

> despite the increasing numbers of schools and districts that are embracing inquiry-based science instruction, the vast majority of our public schools still rely on the traditional "drill and kill" model of teaching science: students study textbooks, watch videotapes on various topics, answer the questions found at the end of the chapter, and perhaps observe an occasional demonstration performed by the teacher. Ultimately, they display their knowledge on a paper-and-pencil test. (p. 603)

THE ENVIRONMENT OF AN INQUIRY-BASED CLASSROOM

Inquiry-based classrooms are quite different. We can differentiate the characteristics of traditional and inquiry-based classrooms by examining three areas: what the classroom looks like, what the students do, and what the teacher does.

To begin with, inquiry-based classrooms are often described as student- or learner-centered. That doesn't mean that traditional classrooms cannot be student- or learner-centered; however, there are some common features usually found in inquiry-based environments. In these classrooms, we usually find a culture that is friendly and facilitating. The atmosphere promotes an effective learning situation by making the students feel that their teacher and peers value their ideas, thoughts, and opinions. The classroom provides a positive socialization promoting active involvement along with inter- and intrapersonalization.

In inquiry and student-centered classrooms, we often find the following:

1. "What if . . ." and "I wonder . . ." questions posted throughout the room
2. Concept maps and graphic organizers displayed on the walls
3. Evidence of student work displayed and celebrated throughout the room
4. Students' desks arranged in a "U" shape or in groups of two, three, or four
5. Separate learning centers for extension investigations, as well as individual and small group work

6. A collection of fiction and nonfiction books, science magazines and journals, and other primary sources of information on the shelves
7. A box or a crate for student portfolios and reflection journals
8. A daily schedule that accommodates extended or multiple-period investigations through block scheduling or double periods
9. Materials and supplies readily available in bins or containers with areas set aside for storing projects and extended investigations
10. Videotaping equipment available for recording student presentations and analyzing students' performance
11. Computer resources available for accessing Internet sources and containing supplemental software to review or reinforce science topics
12. Classroom sets or collections of multiple textbooks for in-class usage and/or student sign-out

STUDENTS IN AN INQUIRY-BASED CLASSROOM

Like the classroom culture, students in an inquiry-based classroom demonstrate different behaviors and habits of mind from their counterparts in traditional classrooms. In an inquiry-based science classroom, high school students will do the following:

1. Show an interest and imagination in science by acting as researchers/investigators and viewing themselves as scientists
2. Engage in diligent investigations from their self-generated questions
3. Reflect on and take responsibility for their individual learning
4. Persist in asking questions to clarify and confirm the accuracy of their understandings
5. Work and communicate in thoughtful groups
6. Utilize higher-order thinking skills to solve problems and make judgments about their work
7. Consider skepticism and alternative models or points of view
8. Use unbiased data and evidence to form explanations
9. Connect new knowledge to prior understandings
10. Make decisions as to how to communicate their work
11. Demonstrate their science understandings and abilities in a variety of forms
12. Act as "reflective friends" through peer evaluation to seek other opinions and assess the strengths and limitations of their work

Students Acting as Researchers

Like the heart pumping blood, commitment, curiosity, and imagination pump questions throughout the learners' thought process. When students act as researchers, they take on a new role in an inquiry-based classroom. Action research leads students to using integrated process skills such as identifying variables, writing hypotheses, designing experiments and investigations, constructing data tables and graphs, and analyzing relationships between variables.

Having students act as researchers is a challenging endeavor for both the students and the teacher. For students to take on this new role, teachers must assume a new role too. Teachers must believe that students have the skills and interest to carry out their own investigations and generate their own ideas. When students act as researchers, they start taking responsibility for their own learning. That means students are given the opportunity to raise their own questions on a topic of their choice. Many students prefer answering their own questions to solving someone else's problems. It also means students can make decisions about their own work: how they will collect data, how they will organize the data they collect, and how they will communicate their findings to the rest of the class. By planning and designing their inquiries, students begin to use higher-level thinking skills, such as analyzing and evaluating, to guide the design and course of their investigations. Teachers will also begin to find that they need to provide fewer answers and more support to students. This support may include guiding the students to a location to search the Internet for a particular topic, suggesting they call a local expert on the topic, or recommending primary sources for the students to review.

According to the *National Science Education Standards,* in order to challenge students to accept and share responsibility for their own work,

> teachers [should] make it clear that each student must take responsibility for his or her work. Teachers also create opportunities for [students'] own learning, individually and as members of groups. Teachers do so by supporting student ideas and questions and by encouraging students to pursue them. Teachers give individual students active roles in the design and implementation of investigations, in the work with their peers, and in student assessment of their own work. (NRC, 1996, p. 36)

Students Working in Groups

According to the American Association for the Advancement of Science (1990),

> the collaborative nature of science and technological work should be strongly reinforced by frequent group activity in the classroom. Scientists and engineers work mostly in groups and less often as isolated investigators. Similarly, students should gain experience sharing responsibility for learning with each other. (p. 202)

There are many instances when students should work individually and other times when collaborative group work is most appropriate. This decision is often left to the discretion of the teacher, depending on the objective and nature of the lesson being studied. Group work can help students learn from each other, share and challenge their ideas, and distribute the work in an equitable fashion. This way, students learn to construct knowledge together and build positive peer relationships. Group work also allows students to build self-confidence while working collaboratively in a group to complete a common goal. Having students work in groups, however, always requires consideration of gender and cultural equity, as well as the interests, needs, and abilities of the group members.

According to Adams and Hamm (1998),

> cooperative learning is more than having students cooperate in a group activity or project. There is a set of strategies that encourage student cooperation while learning in a variety of settings, disciplines, and different grade levels. The process involves promoting positive interdependence by dividing the workload, providing joint rewards, holding individuals accountable, and getting students actively involved in helping each other master the topic being studied. Creative social engagement is paramount. (p. 2)

In high school settings, group work often becomes louder than traditional seat-time work. Because students are expected to communicate, debate, and move about the room while working in groups, classroom management techniques become essential. Students need and want rules of conduct to be established. They want to know the limits of classroom behavior. Problems often occur in inquiry-based classrooms when the teacher fails to effectively communicate group work expectations. The teacher can enhance the effectiveness of classroom rules by having students participate in deciding what rules need to be enforced while doing a scientific investigation. The students can agree to the rules and post them in the classroom. Classes can consider adopting rules of conduct by citing the positive behaviors that are expected (starting with the word *Do*) rather than rules written in a negative tone (starting with the word *Don't*).

Students Utilizing Higher-Level Thinking Skills

In a community of inquirers, utilizing exploration and discourse strategies stimulates students to think critically about the data and evidence accumulated during their inquiry. This motivates students to analyze and synthesize the data and to make judgments and evaluations concerning their evidence and conclusions. These types of thinking skills are far superior in developing scientific literacy than the lower-level, knowledge-type questions often repeatedly posed to students in traditional classrooms, where the recall of science fact is valued. In contrast, as students experience inquiry investigations, they use thinking skills that cause them to reflect about their work and pose logical arguments to defend their conclusions.

Students Showing Interest in Science

"Why do we have to learn this stuff anyway?" one 12th-grade girl asked in her physics class. "Because," the teacher responded, "it's going to be on the test." Have you been asked this question? It seems every teacher has, at some time in his or her career. From the point of view of the student, what does the question mean? Does it mean she doesn't like physics? Does it mean she doesn't like this particular lesson? Or does it mean she doesn't understand what she is expected to do? All we know at this point is that the student might not see the relevance of the content she's expected to learn.

Posing problems of importance and relevance to students is an integral aspect of inquiry and constructivist teaching (Brooks & Brooks, 1999). That does not mean that in inquiry classrooms the student decides what he or she wants to learn and when. Nor does it mean that we have to wait until the student wants to learn about Newtonian physics before the topic can be presented. It does mean, however, that in inquiry-based classrooms the teacher mediates relevance by engaging students in meaningful problem-solving investigations. According to Brooks and Brooks (1999), "The inquiring teacher mediates the classroom environment in accordance with both the primary concept she has chosen for the class' inquiry and her growing understanding of students' emerging interests and cognitive abilities within the concept" (p. 380). Making learning meaningful is another central theme in inquiry-based learning. Brooks and Brooks go on to say,

> It's unfortunate that much of what we seek to teach our students is of little interest to them at that particular point in their lives. Curriculums and syllabi developed by publishers or state-level specialists are based on adult notions of what students of different ages need to know. Even when the topics are of interest to students, the recommended methodologies for teaching the topics sometimes are not. Little wonder, then, why more of those magnificent moments don't occur. (p. 106)

In inquiry-based classrooms, students are engaged in investigations that interest them, through prompting and mediation from the teacher. As a result, students demonstrate open-mindedness and curiosity, and they gain an appreciation for and positive attitude toward science as well. Seeing themselves working as researchers and scientists does much to promote interest in science and encourages students to pursue further science courses in the years ahead.

TEACHERS IN AN INQUIRY-BASED CLASSROOM

The teacher's ABCs (attitudes, behaviors, and competencies) are paramount in inquiry-based classrooms. They set the stage for teaching and active learning. When observing inquiry-based high school teachers, we often see styles of presentation, organization, questioning skills, and even body language that differ from those observed in traditional settings. The following is a list of 40 attitudes, behaviors, and competencies that often accompany inquiry-based teaching. In high school classrooms, inquiry science teachers

1. use the *National Science Education Standards* and statewide standards to guide their long-range instructional plans;
2. select learning experiences that align with the national standards and the students' interests and abilities;
3. create a classroom culture that encourages positive scientific attitudes and habits of mind;
4. provide opportunities for metacognitive strategies;

5. stimulate and nurture students' curiosity;
6. limit the use of lecturing and direct instruction to occasions when the lesson cannot be taught through hands-on or inquiry-based instruction;
7. demonstrate flexibility by balancing and mediating their preplanned lessons and questions with the activities and directions prompted by students' questions;
8. assess students' prior knowledge at the start of a lesson or unit of study;
9. use students' prior knowledge as a basis for introducing new concepts and accommodating the lesson plan based on misconceptions;
10. make learning relevant and meaningful by exploring student interests, taking student interests into account, and basing lessons on students' prior suppositions;
11. use counterintuitive demonstrations and discrepant events to pose contradictions and challenge students' previously held conceptions;
12. use inquiries and investigations to "anchor" new information to previously held knowledge;
13. initiate classroom dialogue and discourse by posing essential or starter questions, offering prompts, and demonstrating thought-provoking discrepant events throughout the lesson;
14. ask questions that require higher-level and critical thinking skills;
15. use wait-time (Rowe, 1974, 1987, 1996) techniques appropriately and do not interrupt students in the middle of their questions and/or answers;
16. rephrase student questions and responses so students can begin to answer their own questions;
17. plan lessons utilizing the 5E Learning Cycle;
18. refrain from divulging answers and pose prompts to clarify students' questions;
19. say "Thank you" or "Great answer" in response to student contributions and give positive reinforcement for student contributions and exemplary work;
20. ask follow-up questions to student answers rather than saying "Okay" or just repeating the student answer;
21. maintain appropriate classroom management during hands-on investigations by displaying rules in a positive sense, providing expectations and structure, and creating a safe and well-organized room;
22. establish everyday routines for group interaction and when retrieving and returning materials;
23. arrange students' desks for collaborative work in small groups;
24. focus the lesson on engaging and relevant problem-solving situations;

25. move about the classroom and rotate among the small groups throughout the lesson;
26. encourage students to design and carry out their own investigations;
27. kneel to make on-level, eye-to-eye contact when speaking to students in small group settings;
28. value students' responses and view wrong answers as an "open door" to their naive conceptions or misconceptions;
29. keep students on task by having them support and debate their data, evidence, and conclusions;
30. use instructional classroom time effectively and efficiently by beginning the lesson on time and using the entire period for instructional purposes, not as time to do homework;
31. integrate science content with process skills and problem-solving strategies as well as mathematics, technology, and other subjects;
32. act as a facilitator, mediator, initiator, and coach, while modeling the behaviors of inquiry, curiosity, and wonder;
33. use primary sources of information rather than, or in conjunction with, commercially published textbooks;
34. encourage communication skills such as speaking and listening;
35. moderate classroom discussions so all students can share their points of view;
36. encourage students to use concept maps, graphic organizers, and drawings of models to explain and demonstrate newly acquired knowledge;
37. assess student performance in a variety of forms;
38. monitor student progress continuously on a daily basis;
39. assist students in assessing their own progress;
40. keep current in teaching methods by joining a professional organization, such as
    - the National Science Teachers Association,
    - the National Association of Biology Teachers,
    - the National Earth Science Teachers Association,
    - the American Association for Physics Teachers,

    and reading appropriate journals, such as

    - *The Science Teacher,*
    - *The American Biology Teacher,*
    - *The Physics Teacher.*

For more information on the attitudes, behaviors, and competencies of an inquiry-based teacher, see Chapter 3, "Science Teaching Standards," from the *National Science Education Standards* (NRC, 1996).

BECOMING AN INQUIRY-BASED TEACHER

Many teachers will admit that the journey to become an inquiry-based teacher is a very personal experience. Each of us makes the journey in different ways by constructing our own paths to instructional renewal and reform. Regardless of the path one takes, the transition to becoming an inquiry-based teacher usually follows four distinct stages: starting at *the traditional approach*, next *exploring inquiry*, followed by *transitioning to inquiry*, and finally *practicing inquiry* (Llewellyn, 2002). At each stage, teachers will exhibit and demonstrate increasingly effective inquiry strategies.

Becoming an inquiry-based teacher will require creating and sustaining reflection practices and discourse with other teachers. As Sergiovanni (1996) puts it, "good teaching requires that teachers reflect on their practice, and create knowledge in use as they analyze problems, size up situations, and make decisions" (p. 151). For that reason, teachers need to develop a network to offer encouragement and support. Forming inquiry support groups allows teachers to share their lessons, accomplishments, and frustrations. A local college or university science education department can be a source for developing and facilitating a teacher study and support group. Finally, the school administration must demonstrate trust that teachers can make the appropriate curricular decisions to bring inquiry-based instructional strategies and change to the classroom level. Lack of support from peers and administration has discouraged many teachers from building their capacity to develop inquiry-centered classrooms.

Regardless of how you plan to begin increasing your ability to teach through inquiry, my best advice is not to do it alone. Seek out a friend or a group of people who share your values and beliefs about teaching. Ongoing conversation with colleagues will help enhance your skills and development.

Regarding the impetus to change your instructional practice, the most effective results occur when motivation stems from both an internal and an external locus of control. Combining motivation from internally (yourself) as well as externally (peer support groups and administration) sources, teachers will find the journey exhilarating and fruitful.