THE SCIENCE TEACHER AS STUDENT: COMPETENCY TAKES TIME

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Science teachers are often surprised and frustrated when their students fail to quickly grasp content that may to the teacher seem basic. If it were possible for the educators to recall their first attempts to learn simple laboratory procedures or background knowledge, it might give them a more sympathetic understanding of what their students are experiencing. However, more recent learning can provide an illuminating lesson. The following examples may help illustrate what I mean.

I give professional development workshops in science inquiry to teachers at international and English language program schools in Asia. The activities I provide are the same, but the similarities usually end with the type of response I get from the teachers. Due to the nature of the school environments and teacher backgrounds that are described prior to my visits, I expect there to be differences so I am not surprised at the processes I observe and how vastly the activities differ from school to school as the teachers go about their investigations.

I generally begin the workshops with a "Nature of Science" activity that was described by William McComas, professor of science education at the University of Arkansas, who designed an open-ended exploration of sunflower seeds to illustrate how scientists work, saying to workshop participants only, "Find out everything you can about these seeds" (McComas, 2014).

In my workshops, many of the teachers quickly set about exploring: they use measuring devices, compare findings, think of ways to test their ideas, find and describe patterns, and have to be stopped after 20 minutes as their curiosity and creativity keeps them going. Other teachers can be and often are more reserved, making a few measurements and only cursory observations, and not always recording them. This group in general does not venture from their tables, and ends the investigation in less than 10 minutes, despite my overt attempts to encourage them to make more observations. So when I asked the latter group if they had found out all they could about their seeds, and they all nodded, I said, "Great! What is the average length of the seeds?" Nervous glances and giggles usually follow. "Oh, okay, so maybe not everything," I reply to further laughter. The teachers then resume their investigations with renewed enthusiasm at being released from the restraints of what they are "supposed" to do.

The ensuing discussions are also usually very different. While the exchanges between participant groups in “active” science faculties are lively and rich in contrasting strategies and findings, the discussions of participants of the more reserved faculty are less so. This is, in part, no doubt due to their cultural backgrounds: The first type of science faculty member are nearly all western and have already designed science curricula to embrace science inquiry; their purpose in attending the workshops is often to find ways to improve their inquiry teaching and make their curricula more inquiry- and project-based, and more integrated as STEM activities. The more reserved faculty have all been from Asian countries and are the products of a very different type of science education, which shows up in their teaching as lecturing, “cook book” labs and test taking (this, however, is not applicable only to Asian educators, as many from the west are also traditional). Yet, they were very interested in learning about inquiry and its strategies, and are just as creative and excited by inquiry once they have the opportunity to experience it.

I had similar experiences when teaching students at international schools in Thailand compared to teaching inquiry lessons to students in Thai government school honors programs in science. Although both student groups were primarily Asian, and mostly Thai (The Thai school student population was 100% Thai), the same sort of observations were made as with the teachers, that is, the international school students made far more observations, asked many more questions, gathered more data and used critical thinking to design unique ways to gather information. Despite the less rigorous investigations made by students at the government school, they were no less enthusiastic than students at the international schools. Indeed, they relished the opportunity to explore. It had been the way they had been taught, and had certain expectations as to how a student is “supposed” to act in the classroom. Science is an active endeavor, and students are creative problem solvers if given the opportunity!

Do these observations suggest that the less active teachers and students are in some way less talented or less capable than their peers in the other groups? Could it be that they are less interested in science or perhaps less academically inclined? I am certain that most educators would not draw such conclusions.

Despite my anecdotal observations, I am well aware that even teachers are not able to learn something new and practice it in a polished methodology in a short amount of time. Teachers new to inquiry science (or more recently, science “practices”) cannot be expected to design an inquiry lesson or come up with good questions without first using it incrementally in the classroom, and certainly cannot do it by *reading* about it: they have to be directly involved as a learner first. Just as important, the students also cannot be expected to use the skill sets that professional teachers employ every day for years, which is why teachers are often frustrated by students not understanding concepts or memorizing content in a few short days of 50 minute periods.

Michael Clough, associate professor of science education at Iowa State University, explains that educators need to realize, as do science students, that "theory must precede observation" (Clough, 2011). "Students cannot," says Clough, "be compelled to see what the teacher sees." Clough uses the example of the student novice who sees a cell under the microscope, whereas the teacher sees an air bubble. Students simply do not have the experience, or theoretical knowledge to identify a cell under magnification when first using a microscope. Only after having multiple opportunities to use the scientific equipment are they able to observe with a critical eye (Clough, 2014). In other words, direct hands-on and frequent experience is essential for becoming competent and confident in using scientific skills.

Science teachers learning new skills needed to effectively incorporate inquiry in their classrooms must be done incrementally with increasing amounts of time given to investigations. It is also a good idea to schedule meeting times to discuss their experiences and receive feedback and suggestions from an experienced instructor. This is necessary if teachers are ever to become masterful at teaching inquiry, or any other methodology skill.

After decades of accumulated results of studies on the efficacy of science inquiry, the U.S. National Research Council (NRC) has identified five Essential Features of Science Inquiry, which are research-based strategies to be used in maximizing student learning (NRC, 2000):

- The learner engages in scientifically oriented questions.
- The learner gives priority to evidence in responding to questions.
- The learner formulates explanations from the evidence.
- The learner connects explanations to scientific knowledge.
- The learner communicates and justifies explanations.

Teachers who have misconceptions about inquiry (e.g., it is "discovery" or "free exploration") are often surprised to learn that they do engage their students in inquiry, even though it may be considered "incomplete inquiry", that is, using some, but not all of the essential features of inquiry ("full inquiry"). Incorporating as many of the essential features as possible into a lesson boosts student interest and critical thinking. Robert Yager, Professor Emeritus of science education at the University of Iowa, quipped, "If every science teacher would use hands-on activities just once a year, it would revolutionize science education" (1991). Even in the 1990's, these strategies were well established by research studies as effective in helping students learn science concepts. Teachers regularly report to me that as I discovered, they found their students to enjoy science much more when engaged in inquiry. Additionally, scientific inquiry employs aspects of STEM education, since science study regularly incorporates mathematics, innovative design (engineering) and technology.

In today's atmosphere of test-driven curricula, it is generally necessary for teachers to guide the initial activity in order to fulfill curriculum requirements. However, I have found that with good teacher questioning, the initial exploration often stems from student-formulated questions about the topic.

Schools around the globe continue to stubbornly resist the opportunity for students to learn ways to be independent learners, and develop critical thinking skills, problem-solving techniques and creative ways to apply knowledge to real world situations. Yet nearly all have some sort of school motto that alludes to those as goals. In my experience, it is clearly not reasonable to expect a teacher who does not have these experiences to teach students to develop them. If a school does not offer teachers opportunities for sustained professional development over the school year or longer, one can hardly be surprised if students are unable to think outside the box, which is being demanded by increasing numbers of universities and companies.

The model from which I offer the standard two-day workshop on science inquiry is in actuality a three year program designed by a team of science and technology consultants, including myself, at a regional state agency in the state of Iowa in the U.S. In that model ("Capacity Building"), teams of science teachers and an administrator from each participating school spend 12 full days in professional development workshops over two successive academic years, and then three days in their classrooms the third year teaching lessons they designed with support from agency consultants. It was felt that it was the minimum amount of time necessary to fully implement inquiry teaching effectively. Other Iowa agency teams in math, science and language arts developed similar programs.

In offering the two day workshop, I caution participants that it is but an introduction to teaching inquiry science, and it is not expected that participants become experts immediately. However, there are some things that can be done to begin to find success and build confidence and competence in teaching science inquiry:

1. Proceed slowly. Choose an activity that lends itself to science inquiry and decide how best to begin it. Then, once that is done, continue until you feel it is necessary to stop. Don't worry about completing the activity, taking up the full class time, or incorporating all of the Essential Features (you might only use one).
2. Make a video of your teaching and review it, using the Essential Features and knowledge of inquiry skills modeled in the workshop. It is a powerful and humbling experience, and it will improve your teaching.
3. Know your limits, and also those of your students. Don't push too hard for a full inquiry. Instead, make that your ultimate goal. It could take all year.
4. Remember Clough's adage: "Theory must precede observation". If you are experienced in science inquiry but your students are not, expect them to

acquire inquiry skills gradually. Likewise, if you find that your students are more experienced in inquiry than you (it happens), let them help you learn!

5. Practice, practice, practice!

Science inquiry is a powerful methodology that helps students become independent learners and critical thinkers. If one is patient but persistent, the classroom eventually becomes an exciting hub of activity, one I enjoy walking into and not be able to find the teacher right away because s/he is right there in the thick of inquiry with the students!

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Biosketch Questions

Pre-service teachers/former teachers/non-teachers:

What are your current educational or professional activities?

Science Education advisor for the Institute for the Promotion of Teaching Science and Technology (IPST), Ministry of Education, Thailand, and Editor-in-Chief of IPST's English language textbooks and professional publications;

Science education workshop provider with East Asia Region Council of Schools (EARCOS).

Describe any past teaching duties.

Classroom science teacher (grades 4-12) in California, Iowa and Maine;

MS & HS science teacher at international schools in Brussels, London, Kuwait City and Bangkok;

Higher education curriculum & instruction faculty at University of Northern Iowa and education faculty at College of the Atlantic;

Biology instructor at DMACC (Iowa);

Science consultant at Heartland AEA (Johnston, Iowa);

Adjunct professor at SUNY Brockport, Iowa State University, Drake University and University of Iowa.

What recognitions/awards, if any, have you received for your teaching? **Conservation Teacher of the Year (Iowa), Beryl Buck Foundation award for innovation in technology (UNI), Outstanding teaching assistant award (U of Iowa)**

What science or science education organizations do you belong to? **ASTE, NSTA, SESD (Science Education for Students with Disabilities)**

What other articles, if any, have you had published or circulated? **27 total, including 3 in ISTJ.**

What else might readers like to know about you relating to your work in education that we could include in your biosketch? **I split my time between Bangkok and Maine. I am also a free-lance photographer.**

May we include your e-mail address within the article for readers who wish to write you with questions? **Yes.** If so, what e-mail address should be included. **jsscience@yahoo.com**