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What Matters in Science Teaching

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Abstract

The question of identification and implementation of the essential qualities of great science teaching is the stimulus for spending millions of dollars for educational research and tremendous amounts of time. Good educators understand that much of this time and money is wasted, or at least, used unproductively. Anyone who has had a career in education for more than a few years can identify the latest trend. These trends alternate from one side of the pendulum to the other, with very few positive advances made.

However, not all is lost. There are answers to the question of what matters most in teaching. One does not even have to be a great teacher to realize the essential ingredients of great teaching. [4] Teachers must use what has been learned about the brain's functioning, particularly the Reticular Activating System or RAS. [5] Such things are easy to implement in training teachers, and science teachers in particular. However, other problems are more intractable. For instance, building public commitment to schools and teachers in the face of increasing taxes, thinking about evaluation rather than just giving tests, and developing student self-discipline and love of learning are huge hurdles. [3]

This author – with more than thirty years' experience as a secondary classroom teacher in the public schools of Texas, more than four years' tertiary experience at the university level and more than twenty-three years' experience as a co-author of internationally used science textbooks – has pointed out more than once that if science proceeded in the same way that educational research does, there would be a cold fusion reactor in every science laboratory. In this paper, we endeavor to go beyond the hallowed halls of tertiary academia and beyond the narrow vision of educational researchers whose main goal is to propose a new trend or a new set of standards. Instead, we distill three decades of classroom experience to detail the essential qualities that produce excellence in science learning.

1. Introduction

Everyone wants great teaching and great teachers in every classroom. With all of the time and money spent during the past century on identifying the essential qualities of great teaching, one might think that there were solutions to all the problems. A quick check in any school, however, provides ample evidence that there is still a great deal of difficult work to do. If education practitioners ever achieve that goal, this work must occur first.

All it takes is a walk down any school's science hallways to observe great science teaching. In those classrooms that contain great science teachers, one will find the employment of a myriad of techniques. One quickly notices that the techniques employed are as diverse as the styles and personalities of the individual science teachers employing them. The problem is not in identifying excellent teaching, but in replicating great teachers.

Not only is it impossible to replicate a great teacher, but the stark and unfortunate truth is that not everyone even has the capacity to be a great science teacher. Sometimes I think the best that we can hope for is to have competent science teachers in the classroom. That is a goal achieved by providing a background in the best practices of teaching, early and continuous staff development and professional collaboration between teachers. These skills and techniques are what I call the "nuts and bolts" of competent teaching, and excellent teachers have a command of these.

2. Skills and Techniques, the Nuts and Bolts of Excellence

Teachers must use what has been learned about the brain's functioning, particularly the Reticular Activating System or RAS. [4] Such things are easy to implement in teacher training classes and staff development opportunities. In addition, there has been a tremendous amount of educational research and anecdotal evidence about what techniques make for excellent science teaching. I have time here to mention only a few.

One foundational skill is to provide methods for students to explore the significance of science in their lives. "Covering the material" must be less important than allowing students to question and discover meaning. This requires effective hands-on inquiry involving steps that build students' investigative

skills such as observation, data organization, explanation, reflection and action. Such inquiry allows students to destroy their own misconceptions and naïve understanding.
Excellent science teaching makes science meaningful by developing thought, problem solving, curiosity, skepticism and openness to modifying understanding. It builds on concepts rather than introducing random facts and disconnected topics. It integrates reading, writing, speaking, and math. [5] Facilitation, collaboration, and independent exploration make up the majority of what happens in the excellent science teacher's classroom. [2] Rather than being the "sage on the stage" who gives all the information, the excellent science teacher keeps students engaged with objectives that relate to a good curriculum.
Perhaps most importantly, there is a modicum of time given solely to assessment. More usually, there is continuous formative assessment so that it is almost invisible to the casual observer.

3. The Excellent Science Teacher

So, what makes a teacher excellent? Fortunately, it doesn't require an excellent science teacher to identify an excellent science teacher. [4] No particular teaching technique identifies the excellent science teacher. In one classroom, the teacher may primarily lecture and in another classroom, the teacher may be a guide, helping one student after another. However, in every case, students engage with the teacher in the learning for that day. Engagement is not the key to excellent science teaching. It is, however, one cut on the skeleton key that makes up excellence.
Michael Johnson, a friend of mine in Texas, is not a science teacher. He is an author, a horse lover and a keen observer of people. Michael has observed that the best teachers are leaders who see themselves as their brother and sister's keeper. He points out that they are positive, passionate people answering a call. They look for the gifts, talents, skills, and abilities in others and help them become aware of their gifts. They do not waste their time, nor allow others to waste their lives. They love their work. They combine strong interpersonal skills with humor to connect with others. They are lifetime learners. They persist in their high expectations. They know and use the most powerful motivator – encouragement. They change lives. I cannot argue with what Michael says, but I believe there is more.
One doesn't need to spend millions of dollars on research to identify the essential qualities of great science teaching. One teacher produced this short list: has a sense of humor; is intuitive; knows the subject matter; listens well; is articulate; has an obsessive/compulsive side; can be subversive; is arrogant enough to be fearless; has a performer's instincts; is a real taskmaster. [4]
Excellent science teachers teach more than their science curriculum objectives. They are the ones who do not focus on the facts of a lesson, but on how to help students think. Their students identify them, sometimes decades later, when, with admiration, they tell others about the one teacher who inspired them. The excellent science teacher is a maestro who inspires his audience as he conducts a symphony with such precision that it appears effortless to those in attendance. This is what the great science teachers do day after day, year after year, generation after generation. No amount of educational research will ever find the key to reproducing them.

4. What's the Problem?

There are small problems of one kind or another in every school. They vary tremendously, but are most often easily solvable at the local level. However, other problems – big problems – are easily identifiable, but not easily solvable. If you require a list of the intractable problems of teaching science – or any other subject – in public schools, you've identified yourself as a teacher who hasn't been in the classroom for very long.
I have visited secondary classrooms in China, Japan, Mexico, Saudi Arabia and throughout the United States. There are some big problems in some of those countries that are not present in others. For example, in Japan I observed too much rote learning and not enough exploratory learning. This is an inherent problem stemming from the national curriculum. In Saudi Arabia, some science supervisors observed that teachers never engage students with real studies of the ecology and environmental problems around them. Although they are making efforts to change, as in all large bureaucracies, the changes come slowly.
The biggest problems in the U.S. are building public commitment to schools and teachers in the face of budget cuts, thinking about evaluation rather than just giving tests and developing student self-discipline and love of learning are huge hurdles. [3] Teachers are highly valued in most countries, but they have been devalued in the U.S., primarily because everyone has a school experience and, therefore, think that they know what it is that a teacher does and they could do it better. In the U.S., teachers, at every level, bemoan the increasing reliance on standardized testing, the direct result of

state and national requirements. In the U.S., assessment is more likely to be wielded as tool with which to evaluate the teacher rather than the student.

Another enduring problem in the U.S., and I suspect in many other countries, is the swing of the pendulum in the education community. During my years in the public schools of Texas, a new initiative (what I fondly refer to as a bandwagon) came about every three to five years. In the 1970s, there was a push for inclusion of drug information; in the 1980s a push for practical workplace teaching; in the 1990s, a push for community inclusion in the school. Since I retired from the public school classroom, I now hear of "flipped classrooms" and Common Core initiatives.

One might get the impression that the problems overwhelm us. We sometimes find it easy to convince ourselves that the hurdles before us are insurmountable. However, they are not. Each is solvable if we make it a goal and commit the resources to solve them.

Nevertheless excellent science teaching thrives – and is likely to continue to do so. It will continue because there are excellent science teachers, and the excellent teacher simply is not replicable.

5. Conclusion

The excellent science teachers I observe in classrooms every year leave me in awe. They labor in classrooms where they complete real awe-inspiring work on a daily basis. As Mark Twain said in his novel, *Puddin'head Wilson*, these teachers resist and master fear, even when they are fearful. Even excellent science teachers fear the unknown – unknown children, unknown ability levels, unknown previous experiences, and unknown hostilities.

William A. Ward suggested in 1873 in *Kenelm Chillinly: His Adventures and Opinions* that, "A mediocre teacher tells. A good teacher explains. An excellent teacher demonstrates. A truly outstanding teacher inspires." When I began my teaching career – more than 40 years ago now – I thought it was important that each student learn as much about biology, or physical science, or chemistry, or whatever I happened to be teaching, as possible. I thought it was important for them to know all the vocabulary and understand every concept to be a functional citizen. Facts were my friend. I wanted my facts and trivia to be their friend, too.

That paradigm changed dramatically through the decades. Now I'm not certain if it is important for a student to remember *any single fact* that I attempted to teach. However, I am now certain that it was most important *that we – my students and I – made a connection with each other*. For you see, I now realize that the connections I made with the students – and the students' connections to relationships among the concepts I taught – were most important. Eventually, I found that most of the "stuff" I taught wasn't as important as I'd believed. I found out that what students need most is the ability to find out about anything they need to learn at the time they need to learn it. What students need are designed experiences that provide meaning to the facts, that inspire understanding, and that result in learning at profound levels that last longer than mere memory of the facts.

Edward Bulwer-Lytton said, "The best teacher is one who suggests rather than dogmatizes, and inspires his listener with the wish to teach himself." For more years than I care to admit, I trekked to Big Bend National Park each spring, taking groups of my students there for the week. By providing the opportunity for students to learn about the desert and mountains there, an impression has been made on many students. How do I know? Any time I get to visit Big Bend in the spring now, I still see students – some who were in my classroom as many as 30 years ago – who have come back to that place year after year to experience and learn more. One student wrote in a letter to me recently "You didn't tell me about biology. You brought me to biology." Students like these don't have to tell me they were inspired. They don't have to say anything at all. Seeing them still involved in learning after all these years speaks volumes. That is what we want for all of our students. [1]

References

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