Areas of Science Education and Its Reform

Area 1: Explanation
Perhaps nowhere in science education is there more room for improvement than this area. A scientist would not dream of having her/his ideas and notions about the world be either wrong (and not corrected) or ignored (in the sense that my ideas are not what is important to the advancement of scientific understanding). In both cases, we say poppycock. Why, then, do many brush student explanations aside as irrelevant to the world of scientific understanding? The reason is simply that educators, in a rush for efficiency, have devalued student explanation of concepts as a valid method of doing much else besides assigning a grade at the end of a unit.

Reformers talk about how explanation comes in many forms. From dialogues (between students, as well as students and teacher) to probing specific, known misconceptions, forcing students to explain themselves is what shows us the depth of their understanding. The notions of a continuum through which students will be assessed (not just pass/fail, but novice-to-master), along with a constant focus on the big picture relationships between concepts and ideas are where many teachers find the most solace in their personal approach. It is a struggle for any teacher to put both of these aspects into lessons, but the rewards are staggering.

Area 2: Interpretation
The role of interpretation in science is clear. There is little room for advancement of knowledge when a dogmatic mind-set gets in the way or when a lack of historical understanding prevents us from seeing feast or famine when one is obviously more evident. The story behind science is an incredible thing, full of mystery and intrigue, as well as determination and incredible human feats. Students rarely get to appreciate this story but from a very enlightened perspective. Many do not learn to truly appreciate science until the “story” of it all is examined.

The idea of using a more narrative strategy is not a new thing, but equally not well defined in the minds of educators. This instructional idea is usually first approached as a way to improve student interest, as well as to make assessments more unique and tailor-made to each particular student. For example, assigning a paper on the life of Isaac Newton is not nearly as challenging as writing a letter from Newton to Sir Haley about the accomplishments he felt most proud of in his life. The fundamental difference between the two is one of uniqueness as well as motivation. Like all good things, the narrative form of assessment must be used sparingly in science, probably as a summative form of assessment on the whole, lest it become old hat to students or lead students to think that science is merely a human interpretation of stories.

Area 3: Application
The most obvious facet of science education (and, oddly enough, most readily so to non-science educators) is that of application. Since we base importance of applications on how readily we use the knowledge and skills in our lives, and science is the study of how the natural world works, there is little wonder as to why this is so. Indeed, we do not use Shakespeare’s Hamlet nearly as much as we do the rules of simple addition, but neither do we use the law of sine to nearly the extent we employ some basic understanding of inertia. Using application as a framework for determining absolute worth is a slippery slope for all subjects, but it must be heeded as a means for sorting the important curricular issues in any single area of knowledge.

This facet is discussed in many different lights. Through use of role-playing, simulations, or problem solving that relates to real-life situations, a science class can become one of the most applicable that any student ever takes. Couple these activities with concrete rubrics and internalization of (and adjustment for) feedback and we have a powerful method for teaching the subject. It is very important that we focus constantly on assessment of the understanding, and not necessarily the performance outcomes themselves. For example, you may have students at work making videotaped presentations for projects in biology, but it is important to constantly remind them that form does not necessarily precede function in terms of importance. This is especially difficult in the climate of ‘production value’ (simply watch some of the television from 20 years ago and compare that to today’s programs) that students are now growing up within.
Area 5: Self-Knowledge

One goal for many teachers is for students to achieve the status of self-directed learner. This may be a farsighted goal for some students, but it is definitely achievable for many. All it takes is the willingness to try and, as is often the case, the successful modeling of self-assessment by the teacher to give the students the impetus to spread their wings. When a teacher assesses a student’s performance, it is nearly always from the perspective of the student climbing the ladder toward the teacher’s heightened position. It is very difficult for teachers to effectively regress back to a time when they did not know a specific concept or understand some idea. And so, it is accordingly difficult for a teacher to judge the student’s progress in a meaningful way in many areas.

By having a student that is comfortable and familiar with the notion of self-assessment, we are effectively allowing that student to stop at certain points of the learning process to ask, “Now that I am at this point, how does my perspective and frame of reference differ from where I was before?” It is less about the answer, and more about the growth process. This growth is the remarkably easy to use as a motivator as students progress, only becoming easier to point out as time passes.

Why analyze student work?

There must be a good reason for teachers to grade papers, talk with students and give tests and quizzes. After all, if they didn’t do these things, what would separate them from the role of college professor? As it so happens, there are some good reasons that teachers analyze student work, and these reasons allow the teacher to learn about the student as well as his or her own teaching ability.

Teachers who analyze student work are able to fine-tune their lessons so as to deepen student understanding. For example, students in a physics class might have never spent any time creating scaled diagrams of any type. By figuring this out in the pre-assessment, it could not only prevent wasted time that would ensue from the assumption that they could make the diagrams, but it could also give the teacher an opportunity to plan an introductory lesson involving the primary skills of creating such diagrams. Analysis of student work also allows teachers to compare student understanding with specific standards or goals (i.e., MEAP and SAT). This is simple and straightforward. Not exactly what you would expect in terms of teaching for understanding, but a reality for any teacher in our goals-driven, accountability-minded world.

My Experiences with White and Gunstone (based on their 1992 work, Probing Understanding)

Not only does using multiple methods allow the teacher many different “avenues of attack” for a particular subject or concept, but it also allows students a much-needed breath of fresh air when dealing with assessment. As White and Gunstone admit about concept mapping, too much of a good thing can permit the good thing to lose value and meaning to students and teachers. So, as I read and pictured and practiced teaching for understanding, it became clear that I could not simply include one small part of these methods over and over. Instead, I needed to use as many tools as I could in order to see how students respond to them as well as to vary the methods by which I assess.

Concept mapping is one method of assessing that I seldom have used; not because I see no purpose in its use, but simply because I have never had the mechanism explained to me in a meaningful way. After reading the chapter, I have seen a much greater implementation area for this tool. With my biology class, I had them concept map the functions of a cell, and was surprised to see how many students caught right on. I had often thought that most were linear thinkers, but as the events showed in my two biology classes, this is not necessarily the case.

The use of poignant, observation-based activities in science education always seems to be in the mold of the “lab.” Students are given a procedure and told what to look for/predict, and then told to write about it. Somewhere in the entire shuffle, value is often lost. This is not because the procedures themselves are flawed, or
because the lab does not allow students to see something of real importance to the subject matter. It is usually because the students can’t see the forest (the actual phenomenon and/or concept occurring) for the trees (the mind-numbing procedure, the over-emphasized structure, and the prefabricated, pre-directed questioning). I have tried to do less of what are typically called labs (for the sake of labs) and more of what White and Gunstone call POEs (Predict-Observe-Explain) so that students will be forced to face their own understanding and rationalize it in a real way (real to them), and allow me to peek in on their understanding (or misunderstandings, as the case may be). In biology, placing a pre-shelled egg in a beaker of distilled water allows me to test students’ understanding of osmosis. When they are simply asked to predict based on what they know, then observe what happens, it is a powerful realization when they come to the conclusion that their knowledge has some basis in fact. Furthermore, by asking them to explain the prediction-outcome relationship, it deepens their attachment to science as a study of reality.

Interviews are perhaps some of the most powerful and power-draining techniques I could imagine as a teacher. To sit down with individual students for several minutes at a time and question them on an individual basis regarding their understanding of concepts is, on one hand very appealing. How better to get to know the student, as well as to allow your assessment to be completely formative and individualized? However, it also scares me. How in the world could you afford the time (always the killer for any good idea) to spend with individual students when there are only so many hours in the day and exactly this much material to cover? Here is where my feelings of reform come to the forefront. If we are expected to assess, measure and direct teaching to fit learning, then how can we do this when some of the best methods available are out of the question due to something so modifiable as time. If this is the case, we simply have to alter our educational model so that time is not a factor in teachers’ concerns over assessment. This does not get rid of the more insidious reason against using interviews, however. Few teachers would admit that they aren’t interested in interviews simply because they are not willing to put forth the effort, but that is very much the situation. Sadly, interviews (definitely, in science) may be a non-possibility due to time constraints, but they do not need to happen on a regular basis. Like all the other techniques mentioned, using them where they are most effective is the key. As for interviews, I can imagine conducting simple interviews (even informal ones) at the beginning and end of each unit, so as to chart (in a minimalist sense) the progress made by each student toward understanding.

Drawing models and samples of reality are absolutely necessary in both of my subject areas (biology and physics). In physics, it is the drawn model that allows us to affix scale and meaning to, what is mostly an otherwise mathematically abstract situation. In biology, it is our ability to draw and envision that permits us to venture into the microscopic realm of cells and molecules without a microscope. For evidence of the value of this tool, realize that the picture, which most students draw of the cell membrane, is quite indicative of their innate understanding of how that layered world operates. I continue to use this assessment technique, though I know understand that grading (in the traditional sense) is not really necessary for every outcome. Sometimes, a simple spot-check of important features and relationships is all that is required.

Though I was very impressed with the technique called fortune lines (having never heard of it in my life), I was also left quite confused at first as to how I could use it in my teaching. I did ponder this for a while, until the historical development of a specific concept was addressed in my class. With this topic, it would be an excellent tool for assessing students understanding. Historically (time-dependent), we can follow the importance (socially, scientifically, or both), the level of interest, or the development of some concept. It also occurred to me that using them in hybrid with POEs could be beneficial (chart the temperature over time of the water in a glass of ice at room temperature). Now I look forward to using fortune lines toward the ends of units to tie their importance all together for students, as well.

When relational (or Venn, as they are sometimes referred to) diagrams are used, it is often in a math class as a separate subject. Along side of concept mapping, these diagrams can be very effective in showing the associations students perceive between several concepts, or a group of ideas within one concept. In my teaching, I have had only a few experiences with them in classroom use (outside of teaching them in math classes). I have tried using in my activities and assessments in the future where there is a direct relation between two or more things that contains boundaries and overlapping meanings. For example the relationship between acceleration and force (effectively Newton’s Laws) are a great situational use that has hit home with many students.

Word associations are typically thought of as childish games, so it is little wonder that they are seldom seen in classroom assessment. They can be used a relatively quick, class-wide commentaries on the level of comfort and understanding of a topic, but the individual assessment can be difficult to derive from them.

Question production is discussed from the standpoint of how to get students producing their own interogatives, but I think each one of these strategies might easily be used on teachers. I know that coming up with meaningful questions on activities and assessments is often difficult. If students are given this task, they can help to
self-direct their own learning which starts them in the direction of inquiry-based learning. Teachers, and I am
definitely here, can also benefit from using different techniques in question production. Too often, teachers will use
the same method for creating test questions or laboratory situations. I was particularly fond of the strategy where
students are asked to create questions based on puzzling points in the material (what would you like to know?) or
things that don’t quite click in terms of how they relate. I have used this method before, and found that if I do not
follow up on it with allowing the students to investigate, one of two things happens. Either the students seek out the
answers themselves (which is somewhat rare when students are new to the strategy) or they will become irritated at
the course for not meeting their needs.

How I See Teaching for Understanding

Along the same lines as my personal life is my professional view of teaching for understanding. If I am to
allow my students the opportunity to come to the understanding and conclusions about scientific principles, then I
should provide an environment that nurtures the situations akin to what I need personally and what I see others
needing. In order to facilitate many learning styles, specific activities should be used and encouraged to enhance
and permit understanding in the many realms of intelligence. Sometimes students can address a concept much
better in one idiom than another. Also, sometimes students will think themselves incapable of performing feats of
understanding in one learning mode, only to find that when manipulated and reconsidered, they are quite capable
indeed. The major part of this idea in science education is collectively referred to as inquiry-based approaches –
students spend time as scientists, discovering the ways toward knowledge that work the best for them, and produce
explainable results.

Feedback is also a key. There is little room for the pre-planned lesson with no connection to the students it
is trying to teach. There must be some assessment of what is known prior to the lesson, and follow-up assessments
checking on the progress of the students. Furthermore, there must be a consistent and honest feedback loop helping
to strengthen lessons in the areas needed. In order to know when to go back (or to expand), you must be aware of
what is understood.