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Education: On Developing Engaging Science Curriculum for Secondary Students: Doing science as science is done

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Abstract:

Developing scientific habits of mind in secondary students begins with engaging curriculum. This paper examines how to set the context for developing curriculum for life science students in secondary schools (grades 9-12). The model presented is currently being used to train future life science teachers in a graduate program at Brown University, Providence, RI and was developed by the author who spent thirty years as a science teacher in public schools before joining the faculty at Brown University.

Introduction:

Jean Henri Fabre, a 19th Century French naturalist and teacher, once wrote: "Because I have stirred a few grains of sand on the shore, am I in a position to know the depths of the ocean? Life has unfathomable secrets. Human knowledge will be erased from the archives of the world before we possess the last word that the Gnat has to say to us.....".

I often think that perhaps the "best curriculum" a science teacher could possible create for their students in secondary life science classes is to reacquaint them with nature and our world. As children, we all have a natural curiosity about nature and life. Many, however, seem to outgrow the need to explore the natural environment and catch bugs or frogs...something I have been most fortunate (at times, to the chagrin of my family) not to outgrow.

Christopher Joyce (former editor and founder of the U.S. Bureau of the British Journal, NEW SCIENTIST, stated in an timeless article, years ago; "during our evolution from knuckle-walkers to mall-builders, we forget that we have spent most of our time as hunter-gathers living in and from nature".

There has always been a love (biophilia) - fear (biophobia) tension that has existed between "us" and nature. We enjoy the serenity of a pastoral or forest setting but have a fear of snakes or invertebrates. In developed countries, we resoundly state "Save The Rainforests" as we continue to purchase mahogany. In the United States we explore the tension between logging and the right for the spotted owl to exist while we all forget it is the habitat that we need to preserve...not just one cute species we may identify with.

So... in teaching future life science teachers in how to develop curriculum my fundamental goal is to think about how they may reacquaint their students with nature and help them see the connections and choices they can make as one species in and among the living parts. What follows are the steps I use in how to develop curriculum.

Getting Started:

What "story" can I create that will get the students excited and involved?

This really involves being playful with the content to get the right context. I feel it is most important to get the students going and messing about with a good story or question before delving into any content. The story or question needs to create cognitive dissonance for the students...it has to be something they can relate to but causes them to question their own understanding of it (and often it may be counter-intuitive). Once students are engaged in the *context*, the content becomes meaningful to them and they are ready to learn it by *applying it to this context* in order to solve the story or question. I truly believe that the role of the teacher needs to be one that causes students to be initially confused, but engaged, rather than one of knower of all knowledge.

Sample Questions which Create Dissonance:

1. The topic is Seasonal Changes:

Autumn: plants and animals are getting ready for winter our most harsh season. Most of our birds migrate, deciduous trees drop their leaves, and many animals hibernate. Why do bats, bears, deer, moose become pregnant in the Fall only to carry their young through this harsh season?

2. The topic or content area is Biotechnology:

How do we define (biologically) an "individual"? After the students brainstorm answers, I show them slides of a beech forest and ask them how many individuals do they see? They count the trees *but* many of the beech trees are the same individual

connected by a common underground root. This is followed by a slide of a living two-headed garter snake...each has a functioning brain....this is followed by showing them a redwood burr that has sprouted new growth. Although the "sprouts" are new, the burr is 600 years old. I ask the students "how old" is this plant / individual?

3. The topic is Genetics:

The essential question when we begin to study the human genome project; "Because we can, should we?"

4. The topic is Ecology:

Ask the students to inventory, by trophic level, the aquatic invertebrates they find in a local stream. The resulting Food Pyramid is often inverted....contrary to what they learned in biology and have read in the text. I then ask them to figure out why it is in fact inverted.

Building student confidence and establishing checkpoints:

It is very important to make sure that students are moving along and not feeling overwhelmed, frustrated, or totally lost. Several years ago when I was teaching secondary biology one of my students who was an exchange student from another country quickly let me know how she was doing by saying; "This is NOT science, in my country science is dogmatic!".

1. Ask the students to report to the whole class on their findings thus far (mini-symposia)...often they will suggest options to each other and help clarify in "real student talk". The common brainstorming that occurs often initiates new ideas for others to follow or try while engaging all students as “co-investigators” and adds ownership to their research.
2. Provide the students short articles to read (and discuss them) that are germane to the investigations they are doing. The questions and comments from students often clue the teacher in to who is having problems as well as how you might be able to assist them.
3. Short term assignments such as labs., fieldwork presentations, field journal entries allow the teacher an opportunity to both gage and guide a student along. To me, this is what the purpose of assessment is all about...giving students feedback to adjust their performance as they go versus a "final grade". This also allows for student growth and confidence in gaining knowledge and skills as they develop their scientific literacy.

"Mid-Course" (Unit) Corrections and Updates

I found as a secondary science teacher that as I go along in a unit, it is important to make changes. The initial story or essential question pre-supposes that the students have some prior knowledge and understanding of the concepts about to be covered. As the study unfolds, it becomes clearer to me what the students do know and what misconceptions they may have. Consequently, in planning curriculum, I try to think about "the when and where" I need to add degrees of difficulty (challenges) and/ or supportive pieces that may include a short topic lecture (for some or all), a reading for background, or a quick "hands-on" skill building practice session.

One anecdotal example from a field problem that I give my tropical ecology students while in the field (Mexico):

Essential Question: Can bromeliads be used as an eco-indicator of environmental stress?

(Bromeliads are epiphytic plants related to the pineapple and are home to many invertebrates and some vertebrates living in and on them.)

The students, already knowing how to use a species diversity index as a tool for eco-indicators, quickly devise an experiment to test this. They collected bromeliads from several different habitat....detailing the abiotic conditions in which they found that bromeliad. They dissected each bromeliad and identified by taxon the organisms they found and mathematically determined the species diversity index.

Once they completed this and presented their findings at our end of the day field symposia (just before dinner) they were feeling quite smug about their work. Indeed, they had done a very good job and "concluded" they knew everything there is to know about epiphytic bromeliads. They were in need of a challenge....not so much about the natural history of bromeliads but about good science and the ability to keep on searching for new meaning and understanding.

I congratulated them on their work and then posed a challenge question to them:

"Which came first, the trees that depend upon bromeliads or the bromeliads that depend upon trees?"

That spurred on new discussion, inquiry, and argumentation. How does knowledge originate? I am convinced that it does not come about from giving students unproblematic givens but from questions, problems, and argument. Knowledge is derived.

When is it time to call it "quits" on a topic, unit, or project?

Although I have left this for last to write about, it is in fact the first question I answer before I plan a unit. On my planning sheets, I outline the skills and knowledge that I want incorporated in this unit.

- Terrestrial Succession & Interpreting Land History requires the students to present their findings using a scientific "Poster Session" format.
- Symbiosis requires that the students learn how to do active research using on-line technologies and presentation software culminating in a technology presentation.
- Winter Adaptations is designed around the learning log and requires students to problem solve, interpret data, while taking annotated notes on references that they are reading.

Once I have identified what skills and knowledge I want the students to be working on (and this includes the reasons for why I want them to be included in this unit....what does this connect to?), I use as a resource an action verb list to get me thinking of ways of both presenting to and assessing students. I put the action verb (such as: evaluates, distinguishes, contrasts, connects, distinguishes, etc.) in front of or after a specific skill or piece of knowledge to help me think of activities for presenting, getting kids to "do it", or for how to assess students' work.

This really does not take that much time and has helped me create engaging curriculum for secondary life science students. The curriculum is never perfect but it pushes me and I hope my students to go a bit deeper into the substance. I now use this model with my Masters of Arts in Teaching graduate students who are learning to become science teachers.

Author Biography:

Daniel Bisaccio was a classroom teacher for thirty years before joining Brown University as Director of Science Education five years ago. As a classroom teacher, he was awarded the Presidential Award for Excellence in Science Teaching by the National Science Foundation and the President of the United States as well as numerous other awards in teaching. His work with students has been recognized by the Smithsonian Institution, the United Nations Convention on Biological Diversity, as well as in several scholarly books on education reform.