Conducting Water Chemistry Analyses Transforms Information into Ecological Knowledge

Margaret B. Bogan¹ and Michael D. Bogan²
¹Florida Gulf Coast University
²Florida Institute of Phosphate Research

- Teachers performed wet chemical water analysis following soils and forestry techniques, plant identification, macro/micro biotic stream analysis, taught with expert pedagogy. The biology and chemistry of the Earth and teaching thereof became a functional interconnected unit.

The Program
Six groups of 20 in-service teachers participated in 10-day environmental education institutes in NE Alabama, funded by the US EPA and Alabama Eisenhower Foundation. Federal and state agency specialists and in-service lead teachers instructed participants in soil analysis, forestry study techniques, terrestrial plant identification, macro and micro biotic stream analysis, the chemical analysis of water and the Native American relationship with Earth. These professionals were chosen as community resource consultants useful as expert guest speakers in the secondary classroom.

Research scientists were employed to instruct in wet chemistry data collecting techniques and reporting the health of free flowing streams. Groups of 6-8 teachers participated in water chemistry studies at any one time. The HACH Fish Farmers Kit was used to determine stream temperature, dissolved oxygen (DO), nitrite (NO₂⁻), ammonium (NH₄⁺), carbon dioxide (CO₂), bicarbonate (HCO₃⁻) and carbonate (CO₃²⁻). Teachers constructed intellectual bridges among the natural sciences, the nature of inquiry teaching and teaching about the environment (1).

Program Day 1-4: Teacher Participants established heterogeneous groups based on the Gregorc Mind-Style instrument. Each “home team” designed a crest that best represented the team as professional educators. During the first five days of the program, “crest” teams worked together on all activities. Activities were designed to invite teachers to work in a classroom setting (inside and out-of-doors) where the responsibility for learning was on the learners (2). Teachers became active learners experiencing the teaching/learning event from the perspective of the student and the teacher. They performed plant ID/vegetative analyses on multiple quadrats through numerous communities along a common transect line, dug pits to investigate soil layers in addition to experiencing and processing environmental ethics awareness readings using expert pedagogical strategies.

Program Day 5: Teacher teams were mixed so each home team had a member on a specialty water chemistry analysis research group. The “It’s a Puzzle” or the jigsaw teaching strategy was implemented (3). The dissolved oxygen team collected data on stream DO₂ levels at several designated stations along the stream; the hardness team collected data on stream hardness at several designated stations along the stream, etc. Reports on each chemical parameter were delivered to the home teams. The entire class then participated in an open discussion.

During the early part of the first five days of the program, teachers referred to each academic discipline in environmental science as its own entity. Teachers reported single bits of factual information in “Today I Learned,” statements, e.g. “the alkaloid on the skin of the common gray tree-frog tastes bitter.” On day five of the program, two integrated areas in environmental science were studied together, water chemistry and the biotic community of the stream being tested. Teachers began to weave threads among the information gathered during the preceding days of the program, and inter-relate the natural sciences towards fashioning an understanding of environmental health. The voice of the teachers and the expert will be used to elucidate “what the teachers...
learned and wanted to learn” during the instruction in water chemistry analysis (4).

Research Method
Storytelling is an excellent way to capture the ambience of the learning environment. In a constructivist paradigm, the story not only unfolds from the mouths of participants, analyses stresses emergent learning and understanding (5). The language of this paper is often first person descriptive to facilitate the developing understanding of the interrelationships between the:

- Activities performed
- Hands-on discovery learning experience
- Paper format of HACH kit directions
- Group practice
- Reflective practice
- Philosophical approach to learning in this program.

Data were collected from three major sources, two end-of–day conversations and a nightly reflective journal. Each individual responded to the, “Today I learned” prompt. These statements were recorded on a microphone. Each home team then generated 5-Questions that came to mind as a function of having experienced the events of the day. These were presented for in large group open forum. In addition, each participant kept a nightly reflective journal. All data triangulated and are reported as the exact words of the teachers. Comments made during discussion or heard during group conferencing are also presented.

Expert Report
The environmental side of analytical chemistry has occupied most of my 30 year professional career. I’ve discussed water chemistry and the practice of determining analyte identity, concentration and technique many times with groups of varied backgrounds. The title of this article suggests that the authors’ will present information about the chemical analysis of water. What really took place in these outside classrooms is much more about the nature of science; inquiry, asking how and why and what if; and integrating information into knowledge (6).

How Do These Parts Fit Together
Each time I begin teaching I think of James Burke, author of Connections expressing the thread that must run through all of our professional careers as people interested in spreading information, causing knowledge (7). James Burke’s Connections are devoted to bringing diverse information to focus on a single topic. He weaves the details together in a tapestry that covers the point of the dissertation. It is my opinion that many who desire to promulgate knowledge, practice this weaving.

In this vein, I ask us to look at some rhetorical questions about interconnections. This is how I started my lesson:

“How many of you have had the opportunity to:
- React cyanide for disposal (8)
- Clean up spilled table salt
- Sweep up dirt from the floor?

Each act is a waste disposal problem. Each requires the same thought processes and consideration to select the appropriate method of performing the task: safety, containment, and disposition (9). To determine the most appropriate disposal methods, you make many subjective and knowledge based decisions. You made many decisions that may have been erroneous because your knowledge of the situation was limited. Because of the particular situation, you might have assumed that the dirt on the floor did not contain any toxic or hazardous materials. However, Love Canal is real and the dirt on the floor was contaminated; and Love Canal has a large-scale environmental impact. Due to lack of information, even the experts were not sure how to handle this disposal properly (10, 11).

Consider the following five topics.
- Studying the release of high pressure gas from a small orifice
- Performing the pararosanaline reaction to determine NO3+
- Examining how gravity affects a falling object
- Studying the redox properties of NO3+
- Considering the oxidation products of explosives.

At first glance these topics may seem to be fairly loosely related. However, in criminal forensics, determining gunpowder residue and gunpowder residue dispersal patterns depends on all of these topics. Seemingly simple topics require understanding many diverse knowledge bases and their correlation to garner useful information. After all, information is the essence of scientific investigation.

A single piece of datum, such as the quantity of NO3+, is enigmatic. The process of acquiring this datum can be even more unfathomable. We ask: Why collect the datum and how does that datum relate to others like it? Are other data describing a quantity of NO3+ really related? Does the aggregate of NO3+ quantities convey information? Are there
ways to evaluate this aggregate of data to elicit information or delineate a story that is interesting?”

The previous discussion relates to the title topic because the teaching of water analysis techniques is not just the reiteration of a scheme for carrying out a series of chemical reactions in a manner that is reproducible and accurate. Useful water analysis is the compilation of many facts and seemingly unrelated data to structure a coherent and comprehensible whole. This whole dictates what can live in the stream, how well “it” can live in the stream, what needs to be done to clean up a “dirty” stream and or what policy needs to be developed or conscience and ethical stance practiced, so that the stream does not become polluted again.

**Water Chemistry Stream Analysis Teaching Events**

Study sites were selected, specific procedures in the HACH Fish Farming water chemistry kit described and small groups were formed. The pedagogical strategy served to facilitate individual interdependence within each group (interdependence is an underlying principle of ecology). Discussion acquainted teachers with the operational procedures necessary for measuring several chemical parameters in the field. The plan included introducing the portable analytical kit, describing the techniques and allowing the teachers perform the tests with environmental samples. Our English, Math and Art teachers learned technique while our science teachers learned or enhanced their technique. During data collection, teachers began to realize, to think about the ramifications of and to ask questions about the environment and teaching.

**Teacher Reports**

Data collected from three qualitative sources will be used to present the teacher-participant view of their learning experiences on the “Water Chemistry” day of the 10-day program. These include Reflective Journals, “Today I Learned” statements and “Five Questions.”

**Reflective Journals**

Sample reflective journal writings show teacher thoughts about the events of the water chemistry day (12).

“I enjoyed the chemistry behind the chemical testing. The why’s if you will, behind the recipes. I also learned the chemical substances released by trees besides O2 and CO2 & antbug stuff. I also learned the “scum” and oily areas are caused by the decomposition of plants releasing hydrocarbons and not pollution. It never occurred to me nature could release nasty looking stuff. I want to share this with my students. This idea that nature can surprise you or how our own schemes can prevent us from seeing other options.”

This individual developed an understanding of the rationale for doing water analyses. (S)he also identified that plants can “take care of themselves”, that plants have biochemical protection mechanisms to ward off insect infestations. Notice that this person passes a value judgment on the “look” of plant decay by-products. Another participant takes the thought a bit further.

“Mike told me many things that were new to me. I always thought that all oily spots you see in lakes were due to boats leaking fuel. …I had never been taught that as plants decay they give off or should I say decompose into some hydrocarbons that appear as that oily matter on the water’s surface. I also did not realize that trees release hydrocarbons (with some oxygen attachments) through the leafy tips & that this is what can cause a crown fire to spread so quickly. He also said that trees can give off poisonous chemicals to protect them from harmful insect infestation when they have been “warned” by an infested tree of what was happening. It’s no wonder that the Native Americans can believe that they need to get permission from the plant to take its life. We don’t think about plants having the ability to communicate with each other. It gives them a more human-like quality.”

The participant bridged the natural sciences with the social sciences with his/her “no wonder” statement, indicating the beginning of developing an understanding for Native cultural perspectives on humankind’s necessary relationship with other Earth beings (13).

One participant overcame his/her fears of working in the out-of-doors:

“…I know from the start that I would be far less familiar with those procedures than Bette & Jane, so I volunteered for the dirty work so that I could do my part and still let the more apt perform the actual analysis. The more I think about crawling out there in the muck, the less I dislike having had to do it. I think… my resistance to doing it was a basic fear of the unknown. Whether or not I’d get sucked up to my waist, whether I’d jump into nasty things like moccasins or leaches [sic]. I think I am over that fear. Though I would probably carry a stick the next time [sic].”

Others waxed philosophically about the upcoming events of the new day.
Breakfast started our fifth day at Noname State Park. It was the day of reckoning: Water Quality Day. A day for which all awaited. Why is getting wet something that little kids and Big kids look forward to? Perhaps, it’s ancestral or it’s just because we are so closely linked to the sea; our mothers and the earth, or could it be that it is just “plain fun”? We journeyed down the mountain near the base of the falls. We tested several stream parameters under Mike’s leadership. He was a very competent scientist. After testing PH, temperature, alkalinity, Nitrate and ammonia levels, we cleaned up, shared our data with the other group working beside us, and started our ‘marvelous’ dinner.

Some learned how:

“The water quality – Again we felt like scientists. It was not new for me but it certainly was a great review – Mike was a big help with this – I like numerical data.”

Some asked how and connected what was done to teaching in the classroom:

2. How often are lakes and streams sampled for water quality?
3. If water quality is poor how and when are wheels set in motion to improve the situation.

Today I Learned:

These statements demonstrate that the teachers’ hearts are with the students. Teachers are learning content information previously unknown; finding a sense of wonder about their studies and realizing pedagogical content knowledge (14,15).

“While we were out doing water quality studies, I learned about the hydrocarbon production in trees, and (laughter) I’m just going to stop there. (Laughter)”

“Today I learned that, that shiny stuff and soap scummy stuff in the water isn’t necessarily pollution. It’s actually natural caused by the plants or caused by the micro-organisms breaking down the plants. And something else I learned is in terms of chemistry, I learned what chelate means. It means claw because if you have a chemical that looks like this. . . you can knock off the edges and add a new one and it claws it up. That’s chelate.”

Five Questions:

At the end of each day, each team designed five questions that came to mind as a function of having participated in the discussion. Topics ranged from hazardous wastes to showering with hard water to purifying water to drink while hiking, to septic tanks!

Teachers then posed general questions:

- How do you know when you’ve got a good survey?
- Is there a soil test that can test the health of the soil like the water test we did? Or top layer, lots of earth worms…You can do bio-indicators. There are a
lot of bio-indicators that you can use. Soil is more difficult to analyze because generally speaking the contaminants that would be a problem with soil are in even lower concentrations than are even in the water. And you have a maintenance problem. Water is fairly easy to isolate things. But the way you have to separate chromium and manganese from iron, it's a bit more difficult. It's not as easy.”

- What are the criteria for an accurate water ecology survey?
- What is sulfanic acid?
- Why did our minnow die? Did it drown? No, it's a fish. Lack of oxygen. Oh! Lack of oxygen. So, in a little of water, the oxygen is used up really fast? It may have. The handling may have shocked it? You may have crunched an internal organ.

**Conclusion**

The multiplicity of comments and questions generated by teacher-participants serve as a model to Burke’s treatise. The underlying ecological principal that all things are connected was reinforced. The process of conducting water chemistry analyses was the stimulus that transformed the information gathered during the first five days of the program into ecological knowledge. Teachers experienced a learning process and drew interconnections among what they knew, thought they knew, and were amazed to learn, about the ecosphere.

Numerous topics for discussion emerged during the two, 4-hour sets water chemistry technique training. The interrelationship between pH and buffering capacity is based on CO2, Mg++ and Ca++ levels in the water. Mud with a low pH usually equates to high sulphur compounds and anaerobic bacteria. The Ca++ content in the water determines the hardness of invertebrate shells. The entirety of chemical health of a waterway system is inexorably intertwined with the biological inhabitants therein.

The geology of an area determines the quality of land runoff into a stream. Plants are a result of the geology of the environment and a contributor to the nutrients released from soil. Incinerators introduce air pollutants and solid precipitation into surface water threatening ground water contamination. Water can be cleaned with clay runoff which is absorptive, unlike a quartz substrate.

Many connections were realized among the scientific disciplines. Plants became more complex than previously considered. Plant biochemistry, recycling of plant material by microbes and water chemistry became intimately interrelated through the teaching of water analysis techniques. A discussion of fire ecology (propagation and control) followed analysis.

Teachers’ interest was heightened as they began to draw the web between geological substrate, plant emissions and the complexity of chemicals found in stream water. A discussion about the rate of crown fire propagation developed further. The water cycle became the unifying dynamic connecting humankind, forest vigor, atmospheric/weather conditions, stream health, and biological inhabitants therein.

Data collection and sampling techniques were discussed. How does a researcher determine sampling locations in a stream? How do the preconceived notions that the scientist brings to the research control how (s)he collects samples and interprets data? How do these notions influence results?

Teachers expressed new formulations of classroom strategies which incorporated the teaching techniques in which they had participated. They wanted to use the group data collecting and handling schemes to increase dialogue and thought, creating interdependence and respect and to augment classroom projects. Teachers identified that hands-on activities stimulate both interest in learning and retention of material, (e.g. using Brock scopes for macro and micro invertebrate identification, HACH Fish Farming water chemistry, soil substrate analyses). They described implementing the procedures in which their students’ would sample local waterways. Inquiries were made concerning the role of teacher interest as a tool for generating interest in academic content. Several teachers now value the importance of implementing hands-on activities in their own classrooms. Field biology study techniques surfaced as new information for classroom curriculum design.

Although the initial intent of the activity was to teach the chemical analysis of water, participants grew in many divergent ways. Initially data collection, recording and analysis techniques were learned or enhanced. Teachers began to think about teaching with hands-on labs in the science classroom. Social Studies teachers developed a foundational understanding of the reasons for existing environmental policy and need for the development of policy based on state-of-the-art data analysis. Teachers became comfortable to ask questions tangential to the investigation. The biology and chemistry of the Earth became a functional interconnected unit. Teachers had fun playing science.

**References**


