Yale-New Haven Teachers Institute

Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
1995 Volume V: The Geological Environment of Connecticut

Dewey and Chemistry: The Water Cycle Revisited

Curriculum Unit 95.05.02
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Thirty years ago when I took AP Chemistry, I cannot remember ever having a lesson in Chemistry. What theory I had was given standing around the front bench. Theory was explanation to justify why we were doing the laboratory work for that day. There were no chairs or tables, except for the electronic balances kept behind paneled glass. Coming back to High School, we have come full circle. Labs are the explanation to justify the paper work and theory for the lesson. Previously I had never thought of Chemistry as theoretical—but it was the hay day of kitchen chemistry when photographic memories were a blessing. Much of what I learned then is not in High School books anymore. Memory now plays a small part. Chemistry is more like Physics—theory learned with mathematics.

Chemistry was exciting and dangerous. Now its danger is recognized as more insidious and liability incalculable. Contemporary intellectual elegance in Chemistry and technological advances have streamlined and made redundant the endless chemical analyses and titrations of a former era. However I feel we are left with a crisis. The swing from kitchen to computerized chemistry has emptied the motivation and drama from Chemistry.

My curiosity at what has happened in these intervening years was piqued by working for a short while in a hospital chemistry lab. The chemists had been trained in the 1950>s, were miserable and burned out. All of them bewailed the loss of direct experience of chemistry in their jobs. All they did was read off computer data and checked the smooth functioning of the machinery. What contact they had with chemistry was merely abstract. The laboratory director encouraged them to think about what they were doing but when I asked questions, no one was interested. As Kafkaesque as this may seem, I feel it has parallels to the situation in too many chemistry classrooms. Students work out of mass produced paperwork, software, books, symbols and with occasional experiments that have a predictability of cybernetic flowcharts that control for expected flaws or intended products [1]. As much as we call it chemistry, like that medical chemistry lab it is surely not chemistry, albeit socially useful

In reading in educational theory, I became quickly aware of one major influencing factor. Behaviorism has all but swallowed up educational theory, either directly or by providing the vocabulary used or implicit models of thought, for example, the cybernetic engineering language and models of input and feedback applied to reasoning between teacher and student. I am knowledgeable enough in philosophy and knew a little of Dewey to be very troubled by this. As I read in Constructivist writings, I learned that I was not at all alone, but it was not until I started to read for this paper that I realized how very much bigger is Dewey's thought than

Constructivism and how much he anticipated the current problems in teaching science. Ironically, constructivists, writing largely out of the psychology of Piaget seem to have revived what was seemingly a failed experiment by Dewey's ardent followers in progressive schools. However, in this study of the four major tenets of Dewey (experience teaches; aesthetic-cogmtion-conation is a single integrated knowing process; knowledge is non-dualistic (science and morality are a single cloth) and a scientific metaphysics is radically non-authoritarian and democratic) I hope to show that Dewey goes further, goes deeper and offers a corrective to key suppositions in Constructivism. I also attempt to show its relevance for both the understanding of the nature of knowledge in Chemistry and its implications for teaching Chemistry. A unit of chemistry, the hydrological cycle follows to give a concrete examplc of how these principles have been applied in a General Chemistry curriculum of an inner city High School.

Experientia Docet: experience teaches

No doubt generations of teachers have believed in the cliche that experience teaches or experience is the best teacher. However either what is meant by the phrase is that experience is something you get after you leave school or it is identified with the learning gained by hands on activities. This is not what was meant by the three philosophers of America's only major school of thought, Pragmatism. Peirce is credited with the dictum 'experience teaches' but activity was not the primary mode of knowing—the aesthetic was. Dewey held to a modified form of this and William James, the third of the triumvirate, understood existence to be existential, which is not the same as doing. [2]

Unfortunately constructivists, as far as I can tell, follow this popular identification of 'doing' with experience-based education. It is true that Dewey invariably insists on the omnipresence of action in knowing, but often he means by active as used in the sense of active listening or in the sense used by Prof. Spence at Yale. In his lectures to an auditorium of hundreds of students he mesmerizes them with Chinese history. He lulls their imagination so that his audience enter past events as if they were there. He recreates history as an experience. Colleagues crititize him for doing a disservice to history because he supposedly plays on subjectivity rather than offers analysis that the distance of time offers to the historical perspective. Spence does generate extraordinary passion for his subject, but the passion also generates a plethora of analytical voices. An otherwise deadly dull and seemingly irrelevant subject, in his hands, has become one of the fascinating campus subjects and full of important multidisciplinary questions [3] . He also disproves those constructivists who think that knowledge cannot be verbally transmitted [4] . His words are telling (transmit) because in telling historical events the listener actively enters these events as if they were the listener's own experiences and thus worthy of finding rational meaning. Reason has a substrate on which to act. It is not reasoning in a void as occurs when there is no clear reference point in the listener's experience.

The success of science is surely that of Spence where analysis is centered in an experience that is open to all to be entered into. Reason is made subject to a clear reference point in experience. When science is science there is no room for creating fanciful castles in the air, to paraphrase Kant (used in the context of metaphysics). The all important and practical question is what exactly constitutes an experience? There is no easy answer and Dewey spent a lot of time and ink trying to adequately answer this question. When the question becomes one's own question, then in Dewey's mind, we have come to the central enterprise of philosophy, and most imparticularly to the central issue in a philosophy of science [5] . From this vantage point he combated the popular ideas of science of his time that he felt had fallen prey to the long history of absolutist and rationalist philosophies. He considered himself a naturalist but fellow naturalists typically had the idea of experience similar to that of Locke's tabular rasa in which mind was thought to passively absorb experience on a blank slate, images encoded by Pavlovian conditioning and similar mechanisms [6]. Though Dewey abandoned Idealism, he maintained that mind is an active, imaginative and intelligent entity that searched for satisfaction, fulfillment and meaning. Though intelligence was characteristic of human thought, mind was part of human biology and an integral part of its environment and never should be understood apart from this interaction.

The central experience event in Chemistry is the experiment and the experiment, according to Dewey, is the key to arousing the intelligent mind to real thinking, imagination, fascination and enthusiasm. Reason is on certain ground because it is disciplined by the reality of an experience. In this sense, it is the experiment that teaches [7]. Applying this insight to the classroom, Dewey held that it was inappropriate to use an experiment as an attention getter, an entertainment device to 'titiltate', or a way to exemplifying text or supplement to theory. Chemistry is the experiment. None of its facts, as Dewey makes clear in his metaphysics, have any validity outside or beyond this context. We may not hypostatize measurements or facts to absolute status. No amount of usage of SI units makes measurements any thing but relative. All facts are subject to change if only because their meaning is given by an evolving understanding and context in flux.

Instrumental knowledge—affective, conative and cognitive

If the starting place for all philosophy is expenence, the starting place for epistemology (how do we know what we know) is an analysis of the unitary act of feeling, thinking and willing. Dewey used these three modes of knowing—the aesthetic, reason and willing—from traditional philosophy but turned them into something rather different. He intertwined them into inseparable aspects of knowing [8]. The aesthetic (not art from art museums but the root source of senses that constitutes the basis of awareness) cannot be subjective since reason cannot function except from within the aesthetic. It provides the consummation and goal of thought and thus must be the primary modality. Action is the drama that reason acts in as it makes connections from within the particular experience in process to the wider world of experiences [9]. That one can reenter experiences from the past does not mean iat either experience nor reason transcend time (an argument advocated by rationalists). Because of this organic analysis of experience in which reason is guided by the aesthetic he called himself an instrumentalist.

The significance to chemistry is that he offers a multi-dimensional mode of knowing that defies definitions of chemistry in terms of either volumes of information/facts to be known or sets of procedures to be demonstrated or the study of the behavior of the elements. Chemistry includes these definitions but we must acknowledge that experience from which these are derived is bigger still and so chemistry is in reality a philosophy of the elements.

The implication for teaching is to recognize that students learn using all these modalities and the the teacher teaches to these modalities, not merely because students have a variety of preferences in learning styles, but because reality necessarily is understood through a variety of modalities—any one of them is insufflcient. Reality, itself, is multi-dimensional.

Here constructivism and Dewey are in agreement. To quote Dewey (writing earlier than Piaget)—"Education is a continuous process of the reconstruction of experience." [10] "Intellectuality is not an end in itself but a means to intelligent ordering." [11] The scientific method is not a technique "but a way for getting at the significance of our everyday experience of the world in which we live." [12] The problem of traditional education is that it "ignores the internal situation.'' [13] "What is ignored is not the titillation of mere doing but the act of imaginative entering into an event." [14]

To summarize, we may say that there are three aspects of knowledge that go to make up a single world of meaning. First, the self may change its own thinking in response to the object of knowledge (aesthetic-feeling). Second, both self and object may interact so that both are changed in the knowing process (interactive-conative). Third, the self may remain unchanged but change the object of knowledge and reduce it to its parts (analytical-rational). The way these three aspects come together will be described below in Dewey's metaphysics.

Overcoming all dualisms—integrating morality as intrinsic scientific process

A casual reading of Dewey quickly reveals that a driving passion of his was to locate human beings within nature, to integrate ethics with science, in short to overcome the Cartesian dualism or split of body and mind. The philosophical origins in Greek (or Indian) thought are not important to dwell on. Dewey analyses succindly (and in in my mind convincingly) that the split is alive and well in science. Indeed it is epitomized in British Empiricism and American behaviorism. For example, Santayana described reality as a machine—the self or mind is a ghostly shadowy glow emanating from the body which is also just a machine. The self is a name tag. The mechanistic model is most apparent in the soences—and chemistry supremely so. In split thinking, the mind of the scientist is independent of truth—or should it be contaminated by mind, then truth will have been contaminated. Objectivity is out there. Subjectivity is inside. Values are inside. Knowledge is definable independently of values. Values belong to feelings as knowledge belongs to reason. Science gains absolutes and these absolutes are definable mathematically and independentlv of time. Feelings and the aesthetic are time bound and unreal. Morals are only certain if founded on some authority outside of ourselves.

The split thinker separates science from the arts—the natural from the human sciences. Dewey dismisses all such dualisms as the heritage of past philosophy—either from the absolutist or rationalist traditions, whether they be idealists or realists [15] . Here is not the place to detail Dewey's arguments but it is worth understanding how he resolves all dualisms.

One way is through action—here subject and object are united—both are changed in the situation. Experience constitutes primary reality—we cannot go beyond it. The knowing mind cannot go beyond an experience. The mind can abstract out of experience either by using rational (fixed, or 'being') or dynamic (flux or 'becoming') categories. These realms of being or becoming have no separate existence apart from experience (as per Aristotle). Unlike Aristotle, Dewey asserts that our truths cannot be more than symbols that connect the problematic with resolution of a problem.

As with constructivists, Dewey describes problem solving as initiated by dissonance or break down of equanimity or equilibrium. All thought is contextually based. It cannot be lifted out of context without distortion. For example, one can play games with the symbols of a chemical equation and come up with correctly balanced equations. These may or may not be useful analogies. Their predictive value is limited, rather like spelling rules in the English language. They do indicate orderly and ‘rational’ reiationships, but to strip them from qualitative or direct experiment distorts [16] . It gives them some ontological reality they do not have. Like rules of spelling they are merely guides. So theory is indicative of relationships just as a map is indicative of relationships but we do not confuse a map with reality itself—nor may we with theory. In fact theory is the subjective construct imposed by the mind upon reality for practical purposes whereas the feeling awareness of phenomenon is the objective reality that theory is subject to. What overcomes the object/subject split is action and doing—the point of Dewey’s pragmatism (the accuracy of a map is its ability to get us where we want to get to).

Hence Dewey places truth somewhere in the middle ground between the dualist split and can do so because reality is prior to our abstractions. He can also do this because he locates thought dynamically in a problem solving process of achieving consummation in the affect (the desired). All thought is biased to the affect i.e. the envisioned it seeks to gain or resolution of needs. Truth is thus instrumental to a felt goal. The goal is time bound and totally bound up with the thinking mind. The mind is not looking on but inside reality—every bit apart of the material order as the experimentai process [17] .

The pressing relevance to chemistry is the inseparability of science from morality. There are not two ways of thinking—one for science and one for morality (he would add religion or any other of the arts/humanities). Both begin with an analysis of experience, and concern ends and means, concern resolution of a problem, require reason, require vision, a pragmatic quest of how to achieve ends, a feeling for an intuited outcome, knowledge of past experience and depth of understanding from aquaintence with the many dimensions of the problem. What neither morality nor science need are abstracted laws that have come from some supposed Absolute or Rationalistic world. They both share a need for openness to expenence—past, present and expected future.

To achieve Delvey’s goals of unifying the moral and scientific quest so important in the environmental crisis of our times, we need to free science from its narrow focus and free it for a scientific method that is appropriate to the particular area of study. Graphs, charts, data may or may not be essential. Arguments for abortion cannot be divorced from data and is not dependent upon a reporting of Gallup poll statistics. The argument for abortion is given from what we feel, envision and want in the context of life as it is experienced. We are not limited by the present but, using reason, can resolve our problem by imagination, feeling and practical ingenuity. Dewey argues that these are the very skill and thought processes that go to make up scientific research and judgment. They do not exclude religious experience or belief in God, for such experiences and beliefs are subject to the same processes of thought and judgments (or at least could be so based or should be if they are to be compelling truths).

What Dewey achieved is not simply a philosophical grounding for the current fad towards inter and intra disciplinary studies approved of by constructivists. Dewey provides an intrinsic connection and one that can be taught in school. He makes the chemist responsible for grounding ethics in rational judgment as much as for grounding chemical formulae in rational judgment. Chemists may not shrug their shoulders and put environrnental ethics off onto some department of religion, philosophy or social studies. The processes of thought that enable chemists to create the wonders of human transportation are the same processes that can create the nightmares of human transportation. By locating reason in affect in the manner of Dewey, the chemist can act less blindly in the theoretical and praciicai aspecis of his or her craft.

4. Metaphysics, Freedom and Chemistry

The typical impression Chemistry books and courses give (me at least) is that all will be known in the behavior of elements, that can be known—it is just a matter of time. Drops of facts are filling up the ocean of knowledge. The rate of knowledge is piling up faster by the second as intemet brings global computers into a single storage system. Each fact is authoritative and the more we know the greater an authority we become. In the practical world of technology, however, what is here today is gone tomorrow. All those neat industrial and chemical processes once so important and upon which were spent so much heart achce and head ache learning were wasted efforts. We need a stoic approach to learning and think of career, financial or grade rewards.

Dewey attacked both conceptions as misguided. We have alluded above to the status of knowledge in science (or any subject). Experience is greater than any abstraction and our abstractions are always only true within a given instrumental context. Thought is a problem solving process. Laws give us connections like signs on a map. They are indicative of reality but always symbolic and partial. More fundamentally the point for Dewey is that science is a bulwark against authoritarianism. It is science that sets minds free. Science turns all certainties into a journey or quest that remains always open-ended. Science does not appeal to any authority except experience open to public scrutiny—not to any person as an authority or tradition [18] . There cannot be a bank of truths getting larger everyday but there can be universes of discourse that expand through internet.

The misplaced feeling or wasted effort or sentiment for outdated processes comes from a general problem of learning for the wrong reasons. Learning is not for some future world that may or may not be there when we graduate. Learning is for now—for a process of problem resolution in which the outcome is important to us. In this Dewey antedates Constructivism and is united with it. If education is about reified facts then when they are not needed, the students feels cheated—its been wasted effort and time, but if education rests on a process of thinking within present experiences that are immediate then education is its own reward. However Dewey yet again enables us to go beyond Constructivism because in his philosophy he can explore the nature of experience and everyday life, its tragedies, uncertainties and unresolvable problems. His interests go beyond psychology. The purpose of chemistry too is not merely about solving problems or describing behaviors. Chemistry is a philosophy of the elements—a subject that embraces a gamut of interests from the quest for the ultimately real, the constitution and processes of life, a quest for a free and ethical mind and the present, past and future of technology in the service of human need and desires, (such as the automobile).

Dewey's philosophy pushes Chemistry out of its comfortable certainties and nice ivory tower theses. Dewey's championship of the sciences, chemistry included, was in part to get scientists to see themselves as a major player in the movement for freedom against all faces of insiduous authoritarianism. Chemistry, as noted above, has all too often de facto contradicted itself by confusing its theories with absolutes. It has reified knowledge into gobs of real data to be leaned. It has dismissed philosophy and morality as belonging to the arts—something tagged on to reality, not intrinsic to it. It has made experiments exemples of theory, not theory as tentative maps to problems posed by experiments, even though it may pay lip service to its relativistic status in introductory texts.

For Dewey, democracy is not about the institutions of govemment so much as a way of relating in all institutions of society—the classroom, school and academia included. It is a social way of thinking that is intrinsic to the community of science that needs to be universally generalized and most particularly to the relationship of teacher to student. Constructivisvn is agreed too but notice Dewey's broader philosophical context.

To understand Dewey's sense of freedom and open-endedness of knowledge requires more than this paper can do justice. However an analogy proposed by Boisvert, quoting Burbank, in his conclusion to "Dewey's Metaphysics", makes both an excellent summary to his theory of what the foundation of knowledge, and also illustrates how Dewey conscieves of scientific knowiedge as something changing, time bound, fulfilling, indexical of the real, instrumental, human, transformative and visionary [19] .

The Burbank citation concerns a contemporary of Dewey, a plant breeder, who described how some of his "most important and valuable work" was with plums. At that time, the plum, though consumed and enioyed, was prior to his breeding experiments, "small, usually acidic, generally unfit for shipping, often with a large stone."

> I wanted to get a plum that would ship. . .a plum that would be beautiful and delicious, a plum that would be large, a plum for canning, a plum with a small pit or none at all, and so on. My designs were pretty carefully worked out. For instance, as regards the shipping plum. The plum developed to be picked from the tree and eaten right there, or within a few hours in the house was quite a different thing from the plum that could be picked, packed, shipped, delivered may be thousands of miles away, unpacked, sold, carned home, and finally eaten fresh. . . .And this couldn't be acquired by accident or chance-it had to be studied and the specifications pretty carefully written [20] .

The experience of the plum was in the first place a matter of the senses greater and larger than the cognitive reflections. Actively reflecting within the experience, the mind started wondering about possibilities. A number of questions were posed by that experience. A future objective was posited that would ultimately provide a conclusion to a rational study. Thought was future oriented, visionary and a sociai enterprise. Truth and values were relative to the inquiry from the outset to the consununation of the experiment. Truth gained will not be about eternal forms but a creation of new forms within a certain context that, in turn, provided a new situation for the acquisition of future knowledge. "There is only one sure way of deciding whether a plum can travei a thousand miles, be stored on a grocery shelf, brougnt home, and remain not merely edible but tasteful: send some of the new varieties on just such a journey. The problematic situation arose within a context, and the success or failure in resolving it will be judged by a return to that context. . . . . .Success in inquiry is inextricably connected to interactions between humans and their environments. No theory which severs this connection can claim Dewev as one of its adherents.'' [21]

Conclusion:-from philosophy to practice

Particularly in science, Dewey became the patron saint of high school teachers. His philosophy, however, proved much more difficult to put into practice than, perhaps, even Dewey himself could have realised. The more rigorously scientific approach taken by Piaget's followers as evidenced in Constructivist writings, has brought Dewey back into the class room through the back door. In the following lesson plans, Deweyan philosophy is implemented in and through gains made bv Constructivist research. Teaching the Water Cycle according to the lesson plans described for the Yale New Haven Teacher Institutes 1994 Units, turned out to be more difficult than expected too. The lesson plans of 1994 were fundamentally good but they were not practically grounded enough for my kind of students, and more importantly, I had ignored essenfal aspects of Dewey and Constructivism that would have made all the difference. Rather than start from scratch, just as a painter reworks a canvas, so the following lesson plans are a reworking of the 1994 units—with the added dimensions of Professor Lasaga's inspired Geological expertise and the Internet.

Lessor. Plan 1: From Oceans to Clouds.

The idea of the lesson is to develop a Socratic dialectic between teacher and student about evaporating water and clouds. The dialectic is not to reveal a priori knowledge but critical and analytical reflections on their daily experience of the water cycle. In tne process, students would come up with some answers to problems posed that could then be tested by devising a simple experiment. From the results of this simuiation, students would have an immediate experience from which to understand some of the dynamics of what happens when vast quantities of water rise up from the oceans tc the clouds. It is far more intellectually stimulating event than reading about it in a book.

Why would such a lesson plan not work? There is nothing wrong in principle but to realise its objective it needed much more than one or even two 50 minute classes. Cutting it down to one class meant that it became too teacher centered and students did not have time to learn from their own mistakes or achievements.

Creative lesson plans of the sort envioned by Dewey, it seems to me, may well take a week to achieve. Monday, can as it were, be the initiation and introduction, perhaps including a video. Tuesday and Wednesday can be used for briefing and getting ready for the exploration. Thursday is the day for the formal exploration or experiment. Friday then becomes the time for debriefing, integrating of ideas, evaluation and closure.

The problem with the initial lesson plan is that it did not anticipate or take into account the amount of orientation, planning, clarification of background ideas and prior experience needed by students to successfully 'make the journey'. Furthermore, my most common problem was failure to have enough time to 'debrief', i.e. to critically reflect on what the results meant, which of course is the most important, and for my self, the most fun part of the whole enterprise. Had I done so, I would still have robbed myself of real satisfaction since students, (mine certainly), needed time to develop technique and time to reflect on the best way to set up an experiment. Their lack of technique severely diminished the likelihood of having good results. Pre-lab is then much more than just about intellectual discussion and anticipation of lab safety procedures.

The unportance of adding preparatory days helps give the student background from which to maximise their ability to learn from the lab experience. Building up that background does not mean that one merely passes on information but that one makes sure prior experiences and understandings of them are in place. It is recommended for this lesson plan that many simple problems and hypotheses be tested and experiments carried out so as to build up an understanding of transpiration, evaporation and so forth as described in the '94 unit.

Lesson Plan 2: Clouds to Soil.

The 1944 lesson plan is tried tested and true for its workability and teaching value. From a Deweyan perspective, the value of the exercise increases in proportion to which it involves all ones senses, the earthiness and realness of the experience and the degree to which it matches the actual environment in which one lives. Dewey insisted that the mind works best when used for the purposes for which it evolved—an interactive problem solver in a compiex environment full of interesung possibilities.

From the perspective of the 1995 seminar, the experiment can take on real drama and challenge by setting it in the actllal context the students live in—the geology of Connecticut, its soils, rocks and so forth. Experiments can be carried out at temperature levels and conditions found in differing seasons and sites in the state. Local soils and water collected from different locales can be used. Further explorations can involve the Water Board and State DOE.

Lesson Plan 3: Entering rocks and out again

Experience teaches and the more profoundly moved we are by the experience, the more we are likely to be stimulated to think and learn. Going out to the field is one way to achieve this. Dewey was sceptical of extrinsic rewards in education. Pleasure is not the point of field trips but a means to invite the thinking mind mto the complexities and wonders of the phenomenal world around us. In the case of the hydrological cycle, ie effects of water on ie landscape are dramatic but often require an educated eye to see them. For example, at the Connecticut state park of Hammonasset, there are boulders of all different kinds of rock on the shore line. The variety is striking when it is pointed out. Without thinking one would imagine they had been tipped there by trucks until one thinks again—they are far too big for that. With the aid of geological maps one can realize that the rocks took a ride on a glacier from the last ice age. At the entrance to the park there are gneiss rocks that show the markings and shaping of the glacier through polishing and scraping as it passed over the rock. The stack of rocks found by the waters edge are the remains of rocks that rode the glacier as on a conveyor belt from as far off as Canada. There are many kinds of minerals to be found here, including iron ores.

Rather than supply students with elements out of a bottle or can, they can collect their own minerals so as to test for ionization in water. They can heat them to see if the water will come out of the crystal, and find out its changed physical properties. Students can mechanically test rocks to find out rates of dissolution in water under different mechanical, physical and chemical conditions. Crystals can be made to remind students how water enters into rocks and can stay locked up for eons of time.

Lesson 4: In the bath and kitchin

The activity described for this lesson plan is fun and successfully demonstrates hydrogen bonding by showing how different oils repel water and then can become miscible in water using a variety of soaps or detergents. To really bring out the full value of this activity it is worthwhile converting it into a formal experiment that exemplifies all aspects of a classical experiment. Students can make creative adaptations and write them up in a Science Fair format or as a practice for open ended types of science testing as is found in the State mandated CAP test. It is easy for students to come up with a defineable problem and a hypothesis as a hypothetical answer to the problem. The procedure is simple to describe and the materials are few and safe. As mentioned in the '94 plan, the setting up of the data table is critical for success and the experiment lends itself to all manner of kinds of statistical manipulation. Since technique is also critical in this experiment, there is plenty of opportunity to criticaily reflect upon why testing may not work out as expected. The experiment also lends itself to being accompanied by a short theoretical essay, using textbooks as guide, to explain results. Students can take the experiment a step further by applying the experiment to actual situations in the kitchen or household where their results have relevance and discuss environmental consequences or applications of the same. One can test brands of soaps and differences between effectiveness of dish washer detergents.

What began as a fun activity has now turned into a serious exercise in scientific method, mathematics, interpretation, creativity, application and use in commerce, home, environment, and an exercise in challenging chemical theory. It is critical thinkig at its best.

From a learning theory point of view, tne exercise demonstrates how the scientific method is learned by doing it and not by recital in a rote manner during an introductory class in Chemistry. What has questionable abstract curiosity value as presented by dogmatic teachers adlvocating for the superiority of scientific chemistry over alchemy, now in this manner of presentation, turns the scientific method into a useful logical tool linking theory with the everyday world.

Lesson 5: Bubbling through Rocks

The experiment described for testing hardness of water for last year's unit is similar to the above epxeriment in that it is easy to become subjective despite apparent objectivity because of the importance of good technique. It involves soaps, detergents end water and so is always safe for student creativity. Putting the experiment into the Connecticut context and testing for differences of results depending upon temperature and acidity is a variation to enrich the experience. What I would envision this experiment lending itself for, especially from a Deweyan point ot view, is to use it to demonstrate the importance of argument in science. John Dewey was committed to science as the best way to solve any kind of problem, presuming that we do not take a wooden approach to scientific method. In essence, science is about testing experiernce using reason that unites inputs with outcomes, using literal or analogical models. In a way, it is no different from a trial in a court of law. The event precipitating a trial is the scientist's problem. The accusation is the hypothesis. The evidence in the court is the experimenter's evidence. Lawyers for the prosecution and the defense must come up with scenarios linking evidence with the hyothesis. The plot carried out by the villain corresponds to the procedure that the scientist claims unites evidence to justify theory. A jury of peers has to be persuaded by the court heanngs and in science the jury consists of his peers in science and the judges are the editors of scientific journals.

In this experiment, one group of students can present their results and act as a prosecution team. It presents evidence to justify a hypothesis as true. Another group can act as the 'defense' to weaken or negate the truth of the hypothesis. Another group of students can act as jury. The teacher or suitable student can act as judge or guide to the procedings . The 'trial' can be repeated using another three groups of students and change in judge.

Lesson 6: Over Roads

In a modified form, this experiment was given as the science experiment for Connecticut's mandatory test for all sophomores. The task was to compare the effectiveness of table salt relative to rock salt in defreezing roads or sidewalks. Students could devise experiments to test their hypotheses by either using thermometers, weighing scales or stop watches as ways of measuring rates of melting ice. Students were not told that the colligative properties of both should in theory be the same. In proctoring the examination I was struck by how conflicting students results were. The more finely ground table salt, because of its greater surface area, presumably would have increased the initial rate of melting, but it depended in part how the experiment was conducted as to whether this was a significant factor. Possibly there were impurities in the rock salt that led to unexpected results.

By setting this experiment on colligative properties into the problem raised by the State introduces debate and a more interesting context. It also gives the students the opportunity to wholly design their experiments for themselves and to defend their results where there might be a variety of good answers. As an extension, students could demonstrate how ice causes weathering of roads and how hot summers can accelerate the process.

Lesson 7: Down to Sewers

The focus of the lesson for '94 on sewers was narrowly chemical. Water in its journey to a sewer picks up debris and living organisms in addition to suspensions, particulates and chemicals in true solution. Water could be collected from a variety of sewers. Students could guess its contents using maps that indicated where the water came from and devise mechanical (physical), biological and chemical means to separate and identify the contents of water. 'ChemTech' kits can be ordered that are designed for the purpose of testing water purity. The experiments could then be developed to teach aspects of analytical chemistry.

The experiment encourages the critical art of sleuthing for answers. It naturally uses an interdisciplinary approach. Science is then experienced not as a set of narrow disciplines in self-contained boxes but as a way of going about solvingproblems and presenting evidence to justify ideas.

Lesson 8: Down to Dumps

As discussed above, Dewey was driven from beginning to end of his career by a concern to overcome the dualism in our culture between mind and matter, body and soul. No where was this more disconcertingly true than in the separation of science from morality, yet he thought that the way one arrived at ethical and scientific judgment were essentially the same. The problem posed by water going in and out of a dump provides a setting in, which problem definition and solution clearly and inseparably involve science and ethics.

Indeed economics, politics, philosophy and religion find their place too. It provides a classic example of how Dewey conceived problems should be solved. Neither absolutes nor simple rational abstractions are of much value. One has to begin with a sense of vision of what kind of future one wants and from there, work backwards to finding necessary facts and construct working models of how one gets from present realities to proposed destiny. Science, economics, politics, philosophy, ethics and religion are inseparably bound because one is dealing with the fate of the earth and decisions have to be made now.

One way of clarifying the process is to role play the current debate of New Haven and the State of Connecticut over what to do with garbage. Garbage is dumped outside of the state. One could imagine a proposed site and have students play roles of people involved in a planning hearing. The dump will bring in money and help the local economy. There will be a school nearby. Greenpeace activists have got involved including a New Age witch, a local church, farmers, the DOE and a university geologist etc. Data is collected from existing Connecticut dumps and students build a model of a dump using probable waste that will be tipped into it. Water is seeped though it and residues are collected at the base lining of the dump. Samples are analyzed. Simple chromatographic analysis may be useful as part of a general investigation as to what happens inside of dumps in terms of decomposition (or lack of it) and in terms of leaching and chemical reactions between materials and water etc.

How safe is the dump and over what time scales are we dealing with. What are the consequences and so forth and so forth. In this way the reasoning becomes necessarily interdisciplinary; and the reasoning skills essentially a single piece as the fate of the dump is decided upon.

Lesson 9: To rivers lakes and back to the Ocean.

There could be many experiments used, but the one chosen on the solubility of gases in water is important because of the requirements of a High School Chemistry syllabus. In terms of developing last year's unit along the lines of Dewey's pedagogy, the most serious omission was evaluation. It is proposed here that the final lesson be primarily used as means to measure skills and learning achieved in the unit.

It was Dewey's contention that using extrinsic rewards in education demoralized true educational performance. In current reforms, it is proposed that the method of evaluation correspond to that used by professional scientists, research laboratories and job performance. Dewey held that the school was an intimate and inseparable part of the wider community and what happened in a school should parallel what occurs in other institutions, hence democracy belonged to school as logically as it did elsewhere. What exactly does that mean for this unit?

One important criterion of ability is presenting research for publication. As is normal in contemporary science, this would be a group project. The four main parts of the evaluation would be the definition of the problem and hypothesis to be tested, the description of the experiment as a repeatable process, the presentation of results so that they are clearly understandable and the self-criticism in the validity of the results, implications and so forth. There are differing techniques of giving individual grades—the one I like is to assign specific responsibilities to individuals (roles chosen by the group) and hold them responsible for that aspect of the project. Projects could be published on an Internet page for the High School.

The preferred mode of giving an overall grade is for students to compile a portfolio and choose the best work to present for grading. My preference is for students to keep a log book of all work carried out, rather like a personal diary and to use it along with work carried out in the unit to write a monograph on the subject of the unit. Again, these can be published on a Web page in the Internet.

In terms of keeping jobs, attendence and cooperative slcills are irnportant factors in assessment. Looking after equipment, initiative and individual responsibility towards the enterprise are criteria in general assessment used in professional labsratones. Learning accountability in this way, I think, begins in school and so should enter into the overall assessment.

Assessment is rarely carried out in the business or the scientific community by one person. The 'viva' is an example of an interview with teacher and external examiner (usually another teacher, but in this case it could be a volunteer parent or local business man etc.) who could participate in assigning grades. Students could be present to answer questions. It is particularly good for assessing the work of borderline or outstanding students, but for all students it quickly reveals how much is known and understood about the subject matter. Alternatively the viva or oral could be carried out by the class as a whole, rather as in peer trials, and guided by the teacher in the background.

Bibliography

Alexander, Thomas. John Dewey's Theory of Art, Experience and Nature. New York, SUNY 1987.

Boisvert, Raymond. Dewey's Metaphysics. New York, Fordham Univ. 1988.

Dewey, John. Interest and Effort in Education. Boston, Houghton Press 1913.

Dewey, John. Experience and Nature. New York, Dover Pub. 1958.

Dewey, John : Ed. R. Archambault. John Dewey on Education. Random House New York, 1964.

Dewey, John : Ed. R. Bersnstein. On Experience, Nature and Freedom. N.Y. Liberal Arts Press, 1960.

Feldman, William. The philosophy of John Dewey. Baltimore, Johns Hopkins 1932.

Hook, Sidney, a symposium. John Dewy: Philospher of Science and Freedom. New York, Dial Press. 1950.

Kannegiesser, HJ. Knowledge and Science. Australia, McMillans 1977.

Webb, Rodman. The presence of the past. University of Florida, 1976.

Zeltner, P. John Dewey's Aesthetic Philosophy. Amsterdam, Gruner 1975.

Journal Articles

Yelich, Glenn. Constuctivist Interpretation of ADH disorder. Journal of

McWilliams, Spencer. Construct no Idols. International Journal of Personal

Stewart, James. Students' ideas on Conservation of Matter Science and Education.

Pope, Maureen. The art and science of Constructivist Research in Teacher Thinking Teaching and Teacher Education. 9:5/6 529-544, 1993

Prawat, Richard. Philosphy and Constructivism. Educational Psychologist, 29:1/ Winter 1994 37-48

Lebow, David. Designing Instruction. Educational Technology 41:3 4-16 1989

Roth, Wolf Physics and Constructivism. Journal of Research in Science Teaching 31:2/Feb 1994 197-223

Annotated Bibliography

Dewey, John. Experience and Education. NY, McMillan 1963 Americans seem to have wiped form their collective memory their own greatest of all philosophers of education, John Dewey. The ideas succinctly expressed in this short book on experience-based education are nt quite the same as those worked out in this unit, but they are consistent with them.

Horne, RA. Chemistry of the Environment. NY, Wiley 1978 In most texts, the hydrological cycle is included as one datum among others. In this major text, the hydrological cycle is the datum upon which the rest of life hangs.

Manahan, Stanley. Fundamentals of Environmental Chemistry. Michigan, Lewis Pub. Though currently a standard text on environmental chemistry, nearly half of ffie book is given over tQ a turgid summary of general chemistry. He does this because he knows his students have poorly mastered inkoductory concepts. Prom the perspective here, he would more effectivelv have retaught these concepts by using the environment as a context to bring these abstractions to life, as per this teaching unit.

Wilbraham, Antony. Chemistry. California, Addison Wesley 1993 I chose this book as the student text because it beautifully represents the best of contemporary texts on the market. What is wrong with it is what is typical, i.e. theory not context centered. The key concepts found in this unit were taken from chapters 15 and 16 on Water and aqueous systems and Properties of solutions. Ideas for the experiment on electrolytes were taken from the accompanying small scale laboratory manual for this text.

STUDENT TEXT

Wilbraham, Antony. Chemistry. California, Addison Wesley 1993

A good reference text book for when the basic ideas of the chemistry of the hydrological cycle are understood.

Materials

The most basic requirements. per group:

Household items—Pennies, variety of coins, spoons, tape, lollipop sticks, sterile pads, scissors, thin and wide straws (one fits in the other, to be used as substitue for glass tubing), Christmas tree light bulb, socket,wire, clips or solder, battery, paper cups, paper towel, liquid soap, three medium sized beakers and a measunng cylinder, thermometer; clock with second hand, accurate plasic micropipets, filter paper, chalk, cooking dyes, can of soda and bottle of vinegar.

Chemicals—Copper sulphate, magnesium sulphate, dilute nitric acid, dilute hydrochloric acid, soluble compounds of chloride, phosphate, mercury, lead and carbonate ions, silver nitrate, ammonium hydroxide, tin(II)chloride, and acetate and chromate solution, and if possible, the dye p-nitrobenzene azoresorcino.