James S. Kopchains Action Research Paper

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Chemistry in Art: Learning to Understand

My Question

I was stuck this year between a rock and a hard place. I wanted to find a way to follow up last year's project, "Art and Chemistry: Crossing the Curriculum," but I didn't know what to follow. I did not want to write a second-year addition to the report because it would seem like a tweaking of the same conclusions as last year.

Background and Context

Students in New York State have to pass a course and a Regents examination in one of three courses: Earth Science, Chemistry, or Physics along with introductory Living Environment (Biology) Regents, as part of the NY State science requirements.. To receive Honors Regents credit and, presumably thereby have a better chance for acceptance to college, students must pass one of these three examinations.

I began teaching at Flushing High School in 2001. The school resembles many large, urban high schools that serve a racially and ethnically diverse student body. Flushing records a wide range of average and above average scores on the annual New York State Regents Examinations.

Unfortunately, scores on the science regents have been below average. We received a large influx of chemistry students between 2001 and 2004 accompanied by a precipitous drop in passing rates (see Table 1) which led the school administration to decide in 2004-2005 to limit the number of Chemistry classes

offered each year. Even so, the scores failed to rise. Something had to be done to raise these passing rates.

Table 1: Passing rates on Chemistry Regents between 2001 and 2006

Regents Examination Year	*Passing Percentage*
June 2001	40 percent (n=174)
June 2002	17 percent (n=356)
June 2003	20 percent (n=523)
June 2004	25 percent (n=343)
June 2005	23 percent (n=167)
June 2006	27 percent (n=159)

Last year I decided to introduce an alternative curriculum to my Chemistry class. Titled "Chemistry in Art: Crossing the Curriculum" the curriculum tied in chemical concepts with art materials and art theory. The curriculum fused lessons in chemical concepts and art to produce pieces of art that explained the chemistry. The students claimed to like the connections made between art materials and chemical concepts. They said they were more motivated to stick with the chemistry curriculum. Best of all, the students also passed the Regents at 35 percent rate (as opposed to school wide 27 percent passing, but these results could have been prompted by other factors such as student ability or classroom chemistry or an easier Regents examination.

To determine whether my curriculum did indeed improve my students' achievements I would have to find a way to assess how much of chemistry they had understood. A possibility presented itself in a book by Grant Wiggins and Jay McTighe titled "Understanding by Design" that I had ready during my research for last year's report, The authors proposed that teachers should aim toward better

“understanding“ of their material with the students by doing more than designing lessons that simply satisfy the teacher’s designs. Wiggins & McTighe favored a “backward design” concept that goes after an ultimate objective (a big idea) so that rather than composing lessons in a sequential order from the beginning, a unit is organized with a focus on the ultimate objective.

Last year, my plan was to use art instruction and material science to introduce chemical concepts to the students and have them understand physical and chemical properties. Each project included the necessary lesson topics for the Regents. This year, I decided to run the program again and then assess how much each student really understood the chemistry The students would still focus on producing artwork based on chemical and physical properties, but my goal for each student was to look beyond the production of artwork to a true understanding of the chemical concepts.

I designed last year’s project to get the students involved and produce better grades. This year I wanted the students to go beyond motivation to develop an understanding of chemical topics. I wanted to teach the lessons and direct homework and examinations toward what they brought out of the lessons. I also wanted to provide more support for the students on the Regents examination. Focusing on the overall student understanding would allow me to monitor how the students would prepare for the test. I would change the focus of my chemistry lessons and use the action research project to make the Regents easier to pass.

If my units worked, I reasoned that the students would know more of what is necessary to pass the Regents. Last year, I completed only half of the curriculum I planned. Because the time was short, I rushed through a group of missing topics within the last two weeks of the school. I squeezed in much new information without

review time, then, I asked the students to learn a lot of information without supporting facts. This year, I decided to clearly define my objectives and determine exactly how much time I would take to cover the topics. To avoid the risk of running out of time, I decided that I would set a specific deadline for the project and include only a limited number of topics. I also decided to start the project's time frame from the point after which I had covered the early basic concepts of the course and, to be safe, finish it several months before the Regents examinations.

I also decided this year to focus on only one class of 28 students. The class is one of the school ESL classes, which means that it is completely filled with students designated as English Language Learners. There were 17 Chinese students, five Korean, three Arabic, one Indonesian, one Filipino, and one African student in the class. There were 17 girls and 11 boys in the class. To take Chemistry as a course, the students had to have a good facility with both reading and writing English, and they had to have passed the first year Regents examination in mathematics.

My New Study

I relied upon the Understanding by Design (UBD) system developed by Wiggins and McTighe. I designed units that I hoped would maximize the students' understanding of a subject area, and in this pursuit, I tried to adhere to Wiggins and McTighe's conceptualization of "understanding." In the UBD system, "understanding," or the students' grasp of subject material, can be broken into six different facets--each facet explores a different way that a student can realize the subject material. Each facet is a separate aspect of understanding that the teacher helps the students to connect (see Table 2).

Table 2: Wiggins and McTighe's Definitions of Facets of Understanding

Facet	*Definition*
1. Explanation	A student can provide thorough, supported and justifiable accounts of phenomena, fact, and data.
2. Interpretation	Students can provide a revealing historical or personal dimension to ideas and events.
3. Application	Students can effectively use and apply what they know in diverse contexts.
4. Perspective	Students can see and hear points of view through critical eyes and ears.
5. Empathy	Students can perceive sensitively on the basis of prior direct experience.
6. Self-Knowledge	Students are aware of what they don't understand and know why understanding is so hard.

Wiggins and McTighe consider the facets to be different, yet related. They caution about using hard and fast criteria to grade a student's efforts. Instead, they believe assessing a student's understanding involves the teacher's skill in determining how developed all six kinds of understanding are within the student. Further, Wiggins and McTighe propose that teachers first identify the results they want to see (objectives of the unit), then determine what evidence would be required to demonstrate understanding (assessment),finally, plan learning experiences and instruction based on the expected outcomes.

I chose two lesson units that I knew well, "Color" and "Pigments and Binders." The material of the units was not simple, but it could be assessed easily, and it fit within a 3-month timeframe.

For "Color" the following "big" questions guided my unit design:

Color Objectives
1. How does the size, structure, and electrical arrangement of an atom permit material to have a perceive color? 2. How are the different properties of elements used to classify elements on the Periodic Table? 3. What are chemical and physical properties used to classify matter?

For Pigments and Binders, the following questions were pursued:

Pigments and Binders Objectives
1. What is the importance of concentration with solution properties? 2. How can we write balanced equations to represent chemical reactions?

To determine the effectiveness of my units and the depth of student understanding in a number of ways: I planned an activity that would feature oral presentations and interviews with each student. I also planned to speak to each student about his project. I proposed that the students to build a piece of art that could be displayed in an imaginary museum and then explain it. In addition, I planned many small quizzes and oral feedback to determine who grasped the material and understood the concepts.

For the unit on Color, the lessons that I chose to focus on were:

Lesson Title	*Topics Covered*	*Major Activities*
1. Color vs. Black/White	Electromagnetic Spectrum	Spectrum Poster
2. Color and Energy	Wavelength and Amplitude	
3. Creating Atoms	Atomic Theory and Light	Models of Atoms
4. Excited Atoms	Energy Transformations in Atoms	Mathematical Models
5. Mixing Light and Colors	Color Theory and Visible Light	Creating Fireworks in Test Tubes
6. Color Wheels and the Periodic Table of Elements	Classification of Elements	Creating a Color Wheel
7. Color Value and Solution Concentration	Saturated and Unsaturated Solutions	Hue and Intensity Comparisons

For Pigments and Binders, the lessons included:

Lesson Title	*Topics Covered*	*Major Activities*
1. Mixing Primary Pigments	Chemical reactions and precipitates	Mixing Primary and Secondary Color Pigments
2. The Composition of Paint	Solubility	Solution Preparations
3. Preparation of Colored Pigments	Soluble and Insoluble Compounds	Pigment Preparations
4. Binders	Colloids and Suspensions	Binder Comparison Project
5. Preparation of Binders	Physical Properties of Mixtures	Binder Preparation in Test Tubes
6. Preparation of Paint from Pigments and Binders	Concentration of Colloids and Suspensions	Preparation of Different Paints

I began the projected units in early December with the goal of finishing the project before President's Week vacation in February. This gave me approximately eight weeks to run the project over an 11-week span of time [There were two breaks in school: December 23 – January 2 for Holiday Week and January 20 – February 1 for Winter Regents examinations.]

December:

At first, the students first appeared quite pleased with the changes in my lessons and curriculum. They seemed to appreciate the work in the laboratory and collaboration with their classmates to create art. They attended classes regularly. My attendance figures spiked to a higher percentage than in the months previously. I averaged about 83 percent during December compared to 72 percent during October and November. In conducting one-on-one interviews with the students they told me that the projects made the class more interesting and that they felt motivated to continue coming to class.

However, the same students intensely disliked oral presentations and oral examinations even when I conducted them in relative privacy and with ample time. The students felt the oral presentations made it more difficult to phrase chemical concepts because of their limited knowledge of English. Different students explained that the oral examinations were too much of a handicap to overcome. "No other teacher makes me do this," said one. Another said, "I can't keep all the facts straight in my head." The students also claimed that the oral examinations undermined their confidence about understanding the material.

If the evidence was clear that the oral examinations and presentations that vexed the students were the source of their difficulty, I would have been happy to change direction and assess only in written form. However, I saw that written examinations and quizzes also showed a disturbing trend: the scores showed almost no gain over the weeks after I implemented the change in units. In some cases, students' scores actually dropped slightly.

I had changed the kinds of questions that I used for these various assessments from rote response questions to more thought-provoking critical questioning, but the questions were designed to test for simple understanding, but I had not spent much time teaching test-taking strategies to accommodate the changes in questions. I felt the directness of the questions would lead the students to understanding. However, the students remained confused in their answering. Often, their answers would be short with little explanations.

January:

Over time, the students seemed to become upset about the classes and the examinations. In January, they became dispirited about their lower grades. They still enjoyed the projects, but they didn't seem to understand what the lessons were about other than producing art. In interviews, several students explained that the work didn't "feel" like chemistry and that the class seemed different from their other subjects. They felt the class was different; they didn't trust the science they were being taught and did not have the confidence needed to understand the subject fully. They did not quit studying, but their efforts did not help them to completely understand the concepts being presented.

I tried to analyze what was happening with the class and how it was affecting their understanding of chemical concepts. I also reviewed my notes and lesson plans to see if I had neglected items needed to teach this unit. What I came to realize is that students, just like anyone else, have a "comfort zone" where they operate within guidelines that can be naïve. When I innovated and changed the manner in which they had been taught chemistry I changed the rules of procedure in which they had

been used to learning. It did not matter to them whether the traditional methods of teaching and learning were not good enough, the students had accepted them by now and they did not feel comfortable with changes. Even though I had introduced the new curriculum slowly over weeks, I had not adequately prepared my students for the change so the change appeared abrupt and disturbing to those students. And with their anxiety high over language difficulties, the new format added to a general state of confusion and then resistance by the pupils.

The students continued to be polite throughout the units, but I recognized the difficulties in developing a clearer understanding of chemical concepts with the entire class. At the end of January I needed to change the units so that the students could become comfortable.

I decided to drop the painting project and oral presentation during the Pigments and Binders unit. Instead, I added two additional written quizzes and additional instructional material from their textbooks to their lessons. Additionally, I combined several planned activities into one and spent the additional time verbally explaining the connections I wanted them to take from the material. I feared that student-driven activities had proven difficult for the students to follow. I worried that the material would be lost to the students.

As I compromised the direction of the units, the students' comprehension began to rise. Test scores also showed that more of the class began understanding the material. Because the proper outlines were maintained, I felt that the rise was because the students felt more comfortable.

Although I could not complete a full analysis of the students' understandings, the experience of working through the units gave me a good idea of how the students

actually respond to my lessons. I knew the units did not provide enough understanding among the students. But I also knew changing the lessons would also change the results. I reasoned that this would not be wrong as long as I could account for this change in the final result. I determined that simply abandoning the project would not be right because the units had had some success – students did attend class and become involved in the activities. Finally, I could not simply follow the original plan to the end without modification just to analyze results because it might mean shortchanging the students in curriculum areas necessary for the Regents. I considered continuing along and hoping that the students would eventually comprehend the format and begin understanding the material, but I rejected this as unrealistic.

<u>February:</u>

In February, I chose to make modifications, but to try to keep them simple so that I could analyze exactly what had changed. I decided that in putting together my conclusion, I could make room for the change in the original plan, yet keep the integrity of the information intact. I decided to change my definition of "understanding. " For the last four weeks of the investigation I zeroed in on the facets of explanation, interpretation, and application I reasoned that if the students could score highly in these areas, they would probably have achieved the same results in the other areas.

The change in my assessment focus meant I only assessed that they knew the concepts and could draw on them for further application. Much of chemical knowledge demands that a student apply previously learned facts and concepts to

solve a more complicated problem. With more material coming during the spring months to be covered on the Regents, there would be a strong need for the students to understand this material for the test.

The results did not change dramatically. The students generally scored about the same at the end of the investigation. However, the students' attitudes was much more improved. Since the students worked inside their comfort zone, they felt better. I understood that this would mean a different result but I did see their feelings of confusion leave and their self-confidence return. This wasn't a long enough time to track the changes in the students' pattern of attendance but the numbers of absent did not seem to change very much.

In reviewing the entire unit, I believe I made the best choices regarding how I taught the students chemistry. However, I feel the results could not gain a good reading on whether the students gained in understanding the concepts. There was some improvement in attitude and motivations towards the new material and the majority of students did seem to grasp the general concepts pretty well. I believe that the overall performance of the students was improved and this should make them better prepared to take the Regents examination and pass.

<u>What I Learned about Backward Planning</u>

What I did not prepare for in this investigation is how strong a student's "comfort zone" is in regards to their studies. The need of students to remain confident as they approach new material is as strong as their curiosity about learning new facts. In designing any new units for learning the student's previous way of grasping material must be taken into account.

I believe one of the reasons the students resisted the changes in material is that I had not prepared them properly for the changes in how I processed material. In putting together new material, I learned that I needed to proceed more slowly and prepare the students' for the changes first and then introduce a change. Without such preparation, student resistance to the new could sabotage a teacher's best intentions to innovate.

I also learned that the objectives that a teacher sets on at the beginning of a unit of study may not always fit neatly into what you end with. The unit of study is a matter of time and there is never enough time nor materials nor availability of people to meet all the needs that your goals may require. However, remaining flexible allows a teacher to change goals and expectations to meet the unexpected changes that occur over the course of your study unit.

<u>What I Learned about Action Research</u>

I feel that the action research has a great deal to offer, but not necessarily about the students. This action research unit had as much to do with me as it had to do with the students. Since I set up the parameters of the investigation and determined what to look for, I observed my teaching as much as the class. I cannot conduct action research is not meant to be exactly like a controlled experiment. The students are not lab mice, so the rules for objective research do not apply in action research. And since I allowed the variables to change, I could only examine any change in this light. I could only report generally on the unit's success. This means that no analysis I make can be considered without criticism.

Action research does a better job chronicling the progress of a lesson unit or a school year rather than produce definitive answers or conclusions. I started out my unit with high-minded objectives to do better for my students. Part of the way through I had to change course and work in a different manner because I needed to be sure they would have to know for the Regents.

What I Will Do Differently

I feel that the experience of running this unit has given me a greater insight into how I teach and what conscious decisions I make as I move through a unit. I am confident that the conclusions I reached represent the best I could do under the circumstances. I am certain that I have caught the mood of the students correctly and changed the unit in the most positive way.

If I go back to this study unit I would plan out a longer period of time to focus attention. This would allow the students to gradually understand what is expected of them by the end of the unit.

I also would spend time early in the semester to review the listening, reading, and problem-solving skills necessary to understand the concepts better. I also will review the material over a greater amount of time than I did this year. Finally, I would arrange the objectives of the units to be simpler so that the students can handle what they need to learn.

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