9-28-2009

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Larry Kolopajlo
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Many people have nightmares about their undergraduate chemistry experiences. I suspect, though, that if Larry Kolopajlo had been our teacher, this would not be the case. Larry's work in this chapter is motivated by his desire to see students achieve mastery in this challenging subject. Larry has developed an impressive collection of computerized animations that, for example, show students the movement of atoms in chemical reactions. By being able to observe what previously had been hidden aspects of the subject, students should be able to gain a deeper understanding of what is going on. This should help the students to perform better in this class. As with all the chapters in this volume, Larry does not just assert claims, but gathers data to assess their accuracy.

By examining the way students learn, Larry is able to attempt some (preliminary) statements about the types of learners who find these animations helpful and the types of users who do not. It is too simple to say that a method "works" or "does not work" when realistically, most methods work well for some students and less well for others. By means of administering a simple, short survey to students, Larry has opened wide a door that promises to bear fruit in the study of student learning in his class.

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Framing the Question

Since my position on the Chemistry Faculty at Eastern Michigan University revolves around secondary teacher education, I am naturally interested in the scholarship of teaching and learning. However, for the teachers of future secondary teachers, such as myself, there are larger questions to consider. Scholarship in the teaching and learning of chemistry is important because there is a need to allay the critical shortage of U.S. citizens who major in science related fields. Bill Gates (2005) of Microsoft Corporation alluded to this problem when he noted: "When I compare our high schools to what I see when I'm traveling abroad, I am terrified for our workforce of tomorrow." Indeed, the National Science Board (2004) has reported that in both China and France, about 50% of undergraduates receive degrees in the sciences whereas the corresponding statistic for the U.S. is only 15%. It is hoped that work by a number of faculty in this basic area of teaching and learning chemistry will ultimately increase the number of U.S. chemistry graduates and will draw upon the reservoir of under-represented groups, while maintaining the high standards for which the chemistry profession is known. By producing more and better trained chemistry teachers and graduates, the U.S. economy would be strengthened, helping to protect it from the multifaceted threat of globalization.

Another major reason for my participation in SOTL work stems from my classroom experiences in teaching general chemistry. In a sense, I was searching for the chemical formula that would spell student success. However, that success depends on student mastery of both verbal and logical thinking skills. On one hand, students must become proficient in the language of chemistry, whose vocabulary is rich in symbols and whose interpretation depends on chemical context. On the other hand, students are required to apply logical thinking skills utilizing reasoning, algebra and physics in problem solving. The gap between required skills and course standards is often difficult to overcome without some type of intervention strategy.

Although many students succeed in general chemistry, cognitive difficulties exhibited by the unsuccessful population cause affective difficulties as well. My desire to provide a richer learning experi-

ence within both the cognitive and affective domains of knowledge was another impetus. One constraint was that my SOTL project had to maintain the high standards of the chemistry profession. Lowering standards would be an artificial means of improving student success and would not help the U.S. become more competitive on the global level.

I decided to use guided inquiry learning as a vehicle to increase student performance in general chemistry. One prominent inquiry-oriented chemistry teaching strategy is Process Oriented Guided Inquiry Learning or POGIL (Hanson 2006). This best practice teaching methodology organizes students into teams who learn chemistry together through the exploration of a chemical model. Although POGIL has enjoyed widespread success, its teaching models suffer from the disadvantage of being static, whereas real chemical and physical processes are dynamic. Dynamic models represent particles in the form of atoms, ions or molecules that are in motion, interact with each other and change with time. Models of static systems generally show only initial and final system states and do not show how those states are connected. Another disadvantage of POGIL is that not all students benefit from group work. For example, according to learning styles research, some reflective learners may enjoy group work less than active learners. In addition, the best students may not profit from group work because they can move at a fast pace and don't need group interactivity to learn.

My goal of promoting student achievement in general chemistry while maintaining high standards led me to contemplate what I had studied in POGIL workshops. I greatly enjoyed analyzing concept models but I felt that static models could be made more interesting if, instead, they were dynamic. I sensed that the powerful tool of computer animations would bridge the gap between the initial and final states of a static model, transforming it into a dynamic mode. Moreover, since the field of nanotechnology and its instruments, such as the atomic force microscope, have allowed the filming of actual atomic and molecular processes, I believed that the dynamic "microscopic" realm of chemistry could be more accurately taught through virtual techniques. I also decided to use animations as part of a case study on a practical chemical application, the fuel cell.

Literature Search

Burke, Greenbowe and Windschitl (1998) discussed optimum design requirements for chemical concept animations and advised that they be 20 to 60 seconds long, utilize forward and reverse buttons, be interactive, and be tested by both faculty and students. They also recommended that design teams be utilized in making animations. One important precept in their paper was that animations should address a single concept. Sanger, Phelps and Fienhold (2000) investigated students' conceptual understanding of a can-crushing demonstration. They found that students who witnessed the demonstration prior to viewing an animation had attained better conceptual understanding than students who viewed the demonstration without animation. Students who viewed the animations were also better able to explain the demonstration based on the kinetic molecular theory of matter.

Yezierski and Birk (2006) used animations to investigate student misconceptions of the particulate theory of matter and employed them as an intervention strategy at the middle and high school level. They used published computer simulations and found that animations provided significant improvements in student understanding. They recommended that their methods be taught to pre- and in-service teachers. Gil and Paiva (2006) employed computer animations to enhance student understanding of the equilibria of partially insoluble salts and then relate their understanding of solubility to entropy changes. These authors use animations before introducing students to calculations. Sinex and Gage (2003) reviewed the wide range of available computer and calculator tools that are available to enhance student understanding of conceptual chemistry. They also discussed widely available Internet applications that allow visualization of chemical phenomena.

How My Question Changed through Group Discussions

Faculty in the scholarship of teaching and learning seminar were organized into small groups and met at various times throughout the year to discuss our projects, to support each other and to freely exchange suggestions and ideas. One advantage of working in

our SOTL group was that we were exposed to pedagogical work representing the diverse fields of biology, business, education, engineering, health administration, history and political science. I feel that our multidisciplinary team, composed of experts, allowed for expedient changes in project direction and finding new insights. For example, our discussions led us to the insight that many university courses are of a "weeding-out" variety and fail to take into account the emotional needs of students. Several of us, led by Sarah Ginsberg, consequently pursued this direction to better understand the affective domain of learning. Our discussions also showed that we were encountering similar problems (poor performance, disengagement, a need to raise skill levels) and that fact alone promoted a feeling of group rapport. It was very obvious that each participant was a team player, enjoyed teaching, and was dedicated to scholarship.

Since we worked independently between group meetings, there were substantial intervals during which we did not interact at all. Therefore, when we gathered, we seized the opportunity to provide constructive suggestions reflecting the range of our backgrounds. When, as a result of periodic group discussions, we stepped back and viewed the big picture together, we found that we shared these student-centered commonalities: effectuating performance, imbuing a sense of professionalism, appreciating the concept and importance of scholarship, and eliminating roadblocks that effaced student self confidence. This synergy expanded projects to the meta-cognitive realm and our realization of this unique situation demonstrated that, although our training, methods and fields of scholarship were markedly different, we were all working toward the same goal of promoting positive student change by bridging the gap between teaching and learning, and between the cognitive and affective domains.

Project change took place (1) through group discussion or (2) through the independent generation of new ideas during research. Our group process effectuated changing the direction of my overly ambitious investigation, which began with the intent to create and show computer animations, to devise and implement case studies in the classroom, and to adapt Greenbowe's (Iowa State University) Heuristic Writing Technique to my chemical laboratory course. To be specific,

our team leader and group members properly advised me, more than once, to limit the scope of my expansive project to just a few animations, and to defer sub-projects, such as case studies and heuristic writing, to another study. Such suggestions were very helpful and transformed my project, in effect, from a treatise to an essay.

What's more, project leader Jeffrey Bernstein provided an incisive comment that fundamentally changed my research question when he asked if animation data could be correlated with learning styles. As I performed my study, I also independently devised new ideas with regard to learning style maps, two-dimensional multiple choice questions and the use of an animation within a case study.

Central Questions

Enlightened through group discussions, my central research theme was then reduced to the more manageable question of determining if computer animations of chemistry concepts would enhance student understanding, test performance and satisfaction in General Chemistry I and II. It also extended to seeking to explain the variation in the effectiveness of this technique - would visual learners, for example, perform better than verbal learners?

The Context: General Chemistry for Science Majors

General Chemistry I and II are three credit lecture courses, designed for science majors, that meet three hours per week. Their curriculum follows the topics and standards set forth by the American Chemical Society. Well over 90% of the course grade comes from examinations, all of which, except the final exam, follow a non-multiple choice format. The emphasis of exams is on problem solving. Students generally need a C grade to meet program requirements. One advantage that EMU students have is the small class sizes that are set at 55 students or below. However, challenges plaguing EMU students are that many students are nontraditional, are commuters and have time-consuming jobs. Many students have transferred from community colleges having already taken one semester of general chemistry while

others have not had a chemistry course in several years. The average EMU student ACT and SAT scores are 21 and 1,014 respectively. Many students are first generation university students.

The Chemistry Department at Eastern Michigan University is known across campus for its commitment to high standards. Because the student audience is non-homogenous with respect to chemistry background, both the depth and pace of the course are too much for many students, and they withdraw or fail. Although faculty such as myself strongly encourage students to avail themselves of the Chemistry Department's tutoring center, supplemental instructors and review sessions (often run in the evenings), many student deficiencies cannot be corrected because most students do not take advantage of remediation opportunities. Thus, classroom intervention strategies, such as computer animations and case studies, are needed.

My general chemistry course utilizes a coursepack consisting mostly of class notes, homework problems and worksheets. Students are able to read class notes before coming to lecture. Since students already have most of the notes, I can focus in the classroom on teaching important concepts and problem solving. I occasionally supplement lectures with demonstrations and group work.

Gathering the Evidence

The classroom intervention strategy that I selected was computer animations, performed using three software programs:

1. Odyssey (Wavefunction Corporation) contains pre-built ready-to-use animations
2. Flash 8 (Macromedia Corporation) professional animation software
3. PowerPoint (Microsoft Corporation)

All of the animations written either in PowerPoint or in Flash 8 represent my original work. I wanted to know, for example, if students could translate an animated model of a chemical reaction into a chemical equation. For the sake of presenting an example, let's review one

guided inquiry animation written in Flash with the aim of helping students understand how to interpret and predict the entropy change for the reaction of nitrogen and hydrogen to form ammonia in the gas phase:

$$N_2(g) + 3 H_2(g) \rightleftharpoons 2 NH_3(g)$$
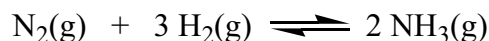
The animation begins by asking the student to predict whether the entropy change for the above reaction is greater than, equal to, or less than zero. After the student writes her answer on a worksheet, the animation depicting the reaction on the molecular scale is shown. Figure 1-1 shows the initial and final snapshots taken from the animation. The above reaction equation is shown along with the equation translated into molecular structures.

Figure 1-1: Initial and Final Snapshots Showing Reactants in the Entropy Animation

(a) Initial Snapshot   **(b) Final Snapshot**
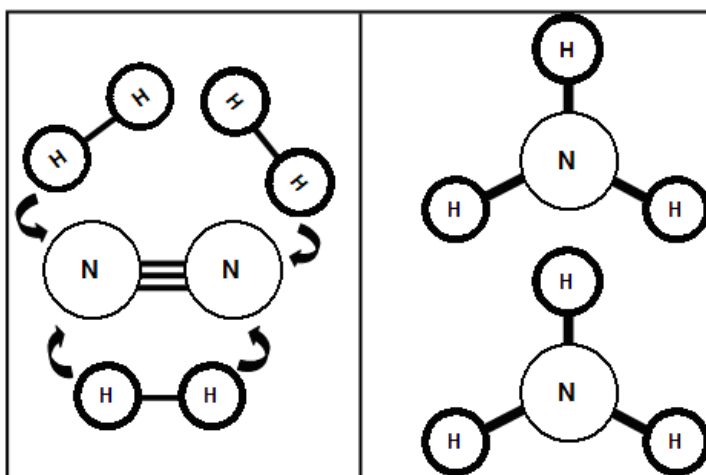
After giving the student time to connect the picture image to the equation, the screen switches to showing three hydrogen molecules and one nitrogen molecule. A hydrogen molecule approaches the triply-bonded nitrogen molecule and one of the three N_2 bonds

and an H-H bond breaks. Two H atoms attach to the nitrogen molecule. A similar sequence takes place showing a second hydrogen molecule approaching nitrogen, bonds breaking, and new bonds forming. Finally, two ammonia molecules are produced. Students can watch the animation repeatedly. They then use a thermodynamic table to compute the entropy change and compare their predicted and calculated results. They then must reason why their answers are correct or

Table 1-1: Animations Used in General Chemistry I
(Chemistry 121)

Title	Program	Description	Learning Objective
Dimensional analysis	PowerPoint	Dimensional analysis	Perform multi-step unit conversions
Behavior of Positive/Negative Ions	Flash 8	Models Coulomb's Law	Discover Coulomb's Law by viewing ionic processes
Formulas of Ionic Compounds	Flash 8	Models criss-cross rule	Write the formula of an ionic compound
Ionization	Flash 8	Models chemical equations	Conceptualize ionization through models and equations
Ionization of NaCl in Water	Flash 8	Models role of solvent in dissociation	Explain the role of solvent in the ionization of NaCl in water
Ionization of $CaCl_2$	Flash 8	Guided inquiry animation with worksheets	Compute mol of reactants and products; balance a chemical equation
Mass-Mass of $KClO_3$ Decomposition	Flash 8	Lab experiment simulation, calculation & worksheet	Set up and perform mass-mass calculations

incorrect. Finally, student success is evaluated by having students predict the entropy changes of several reactions, whose results they turn in to me so that I can judge their progress.

Table 1-2: Animations Used in General Chemistry II (Chemistry 123)

Title	Program	Description	Learning Objective
States of Matter	Odyssey	Animate phases	Explain phase changes
Molecular Motion	Odyssey	Real & ideal gases	Kinetic molecular theory
Intermolecular Forces	Odyssey	Animate intermolecular forces	Given a molecule(s), predict all intermolecular forces
Molecular Motion	Flash 8	Shows translation, rotation & vibration	Explain how a molecule stores energy in various modes
Miscibility	PowerPoint	Experimental simulation	Relate solute & solvent structures to miscibility
Henry's Law	PowerPoint	Animated tutorial	Construct knowledge related to gas solubility in a liquid
Entropy	Flash 8	Guided inquiry with worksheet	Students predict and compute entropy changes
The Fuel Cell	PowerPoint	Case study	Group work

Tables 1-1 and 1-2 summarize the animations used according to the software employed to design them, their description and the anima-

tion learning objective. The fourteen animations in the study spanned mathematical problem setup, modeling chemical processes like physical or chemical changes, simulating experiments, and a case study on a practical chemical application involving the fuel cell. The study was carried out during winter semester 2007 in both Chemistry 121 and Chemistry 123. Animations were used only in the first half of the semester. It should also be noted that the Chemistry 121/123 classes were run concurrently and so each data point identifies a unique student. After each animation, a questionnaire (Likert Scale) was distributed to allow students to rate the animation's effectiveness.

Learning Styles

The Felder-Soloman Learning Style Inventory (Felder and Soloman 1993; see also Felder and Silverman 1988) was used to establish a database of learning styles for both the Chem 121 and Chem 123 student audiences. It was used to determine if computer animations impacted visual learners more than other learning types. Felder and Soloman resolved learning styles into four dimensions with each dimension consisting of two diametric components. Table 1-3 summarizes the learning styles dimensions, by name and by characteristics of learners who exhibit that learning style. As Felder and Soloman note, learning styles can be interpreted as being on a continuum; relatively few people are at one end or the other of the scale for a particular learning style dimension. There are several reasons for gathering learning styles data. For example, one would want to learn what learning styles predominate in science courses, especially in chemistry and biology, in order to determine:

- Will students who favor particular learning styles be more effective than others?
- Which learning styles are favored by most professors in general chemistry courses?
- Will the use of computer animations favor visual learners over verbal learners?

- How can an instructor adapt his/her teaching style to benefit each student?
- Should all learning styles be accommodated in classroom presentations?

Table 1-3: Felder-Soloman Learning Styles

Learning Style Class	Characteristic of Learners
Active	Learn by doing, like group work
Reflective	Thoughtful, like to work alone
Sensing	Like facts, memorizing, hands-on
Intuitive	Like discovering relationships
Visual	Like pictures, diagrams, charts
Verbal	Like writing and spoken explanations
Sequential	Logical, linear steps
Global	Need the big picture

Emergent Findings and Broader Significance

Grade Comparison

Table 1-4 provides a summary of the 49 students' pooled course grades calculated as GPA's (on a scale where A=4.0) for both Chem 121 and Chem 123 students. In this table, the project grade line represents the grade earned at the conclusion of the animations; this grade summarizes student performance through the first two exams, in which course material was supplemented by animations. The second line represents the average grade the student received on the final two exams (on which material was not supplemented by animations) while the line for final course grade denotes the average grade on all four in-semester exams and the final exam. The table clearly reveals

that student performance was strong during the part of the semester in which the animations were used and *much* weaker during the last two exams, when there were no animations. While assertions of a causal relationship cannot be made firmly, these results are at least cause for speculation about the efficacy of this approach. Note that because the sample size (49 students) was small, no attempt was made to analyze data by gender or race.

Table 1-4: Summary of Combined Course Grades for Students in Chemistry 121 and 123 *(n=49)*

Segment of Term	Avg.	A	A-	B+	B	B-	C+	C	C-	D+	D	D-	E
		4.0	3.7	3.3	3.0	2.7	2.3	2.0	1.7	1.3	1.0	.7	0
Project Grade (First 2 Exams)	**2.7 (B-)**	11	3	1	8	5	2	6	2	1	4	4	2
Last 3 Exams	**1.3 (D+)**	1	1	0	8	3	3	6	0	0	3	5	19
Final Course Grade	**1 (D)**	6	3	2	5	4	3	8	3	5	0	5	4

Animations were given before Exams one and two. The percentage of grades from A to B- was 57%. The last three Exams were given without students being exposed to animations. The percentage of grades from A to B- decreased to 26%.

Student Evaluations of Animations

Upon completion of animation assignments, students were given an evaluation form; they responded to a number of questions asking if the animation was "effective" using a scale from 1 to 4 where 4 = "strong agreement," 3 = "agreement," 2 = "disagreement," and 1 = "strong disagreement." The results are summarized in Figure 1-2 for Chemistry 121 (top panel) and Chemistry 123 (bottom panel), where the data from all course animations are pooled together.

Figure 1-2: Survey Evaluation of Chemistry 121 and 123 Animations Responses to Questions Asking if Animations Were "Effective" in Teaching Course Material

Chemistry 121

n=24 students, 312 responses to 13 questions

Chemistry 123

n=25 students, 225 responses to 9 questions
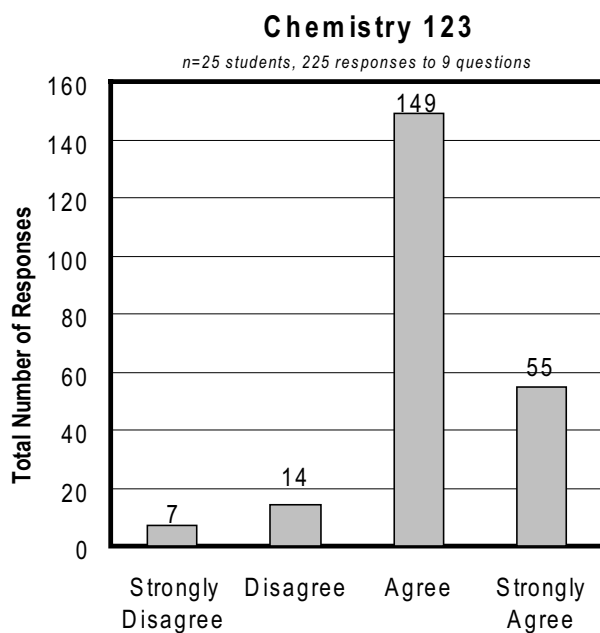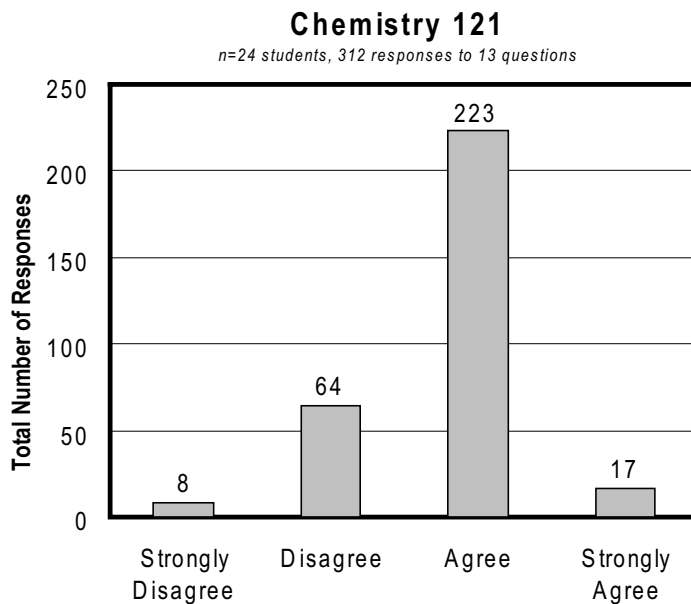
Students overwhelmingly agreed that the animations were effective – the agree column consistently recorded the highest number of responses. The animations appeared particularly effective in Chemistry 123, although even in Chemistry 121 the vast majority of students either agreed or strongly agreed that the animations had been effective. Clearly, from the standpoint of student opinion, this pedagogical innovation is worth continuing.

Learning Styles

Table 1-5 summarizes the learning style data. Each dimension of the Learning Styles Inventory test (i.e., active versus reflective) is summarized in terms of the number of students in each category, together with average and median GPA's on the first two exams (when animations were used) of those students in the combined Chem 121/123 class sample. There were eleven questions dealing with each learning style dimension; thus, if the student answered seven in a way that revealed a preference for active learning and four that revealed a preference for reflective learning, their index score would be a 3, in the direction of active learning. Each learning style index was plotted on a number line; however, one dimensional plots suffer from the disadvantage of ignoring learning style interactions. In order to quickly visualize the data while showing interactions, *learning style maps* can be generated by plotting the Felder-Solomon indices against each other as discussed below.

The sample of 49 students were predominantly visual, sensing and sequential learners at approximately a 3/2 ratio over verbal, intuitive and global learners. Active/reflective learners were balanced. The average grade of all learners was 2.49 and visual learners had an ever-so-slightly higher average grade than verbal learners. Predominantly sensing learners had a significantly higher GPA compared to intuitive learners: 2.56 vs. 2.37. Global learners had a higher GPA than sequential learners: 2.61 vs. 2.44.

Although there are six possible two-dimensional learning style plots, for convenience only three plots are shown. Figures 1-3 through 1-5 (below) emphasize visual learning in order to show correlations with computer animations data. Such surface plots resolve

learning styles data into quadrants. For example, the upper left quadrant in Figure 1-3 describes a sensing/verbal learning style, the right side of Figure 1-3 shows all visual learners and the bottom half displays all intuitive learners. There are 34 visual learners and only 15 verbal learners. In contrast, there are 31 sensing learners versus 18 intuitive learners. Grades can be superimposed upon the data points, effectively yielding 3D plots. Choosing a single point on the x or y axes allows a quick determination of a learning style frequency and all of the grades associated with them.

Table 1-5: Summary of Learning Style and Project Grade Data for the Pooled Sample

Learning Style Dimension	Symbol	No. of Students	Average GPA *scale=4.0-0.0*	Median GPA *scale=4.0-0.0*
Active	A	25	2.51	3.00
Reflective	R	24	2.48	2.85
Sensing	**S**	**31**	**2.56**	**3.00**
Intuitive	I	18	2.37	2.65
Visual	**V**	**34**	**2.51**	**2.85**
Verbal	Vr	15	2.45	3.00
Sequential	**Sq**	**32**	**2.44**	**2.70**
Global	G	17	2.61	3.00

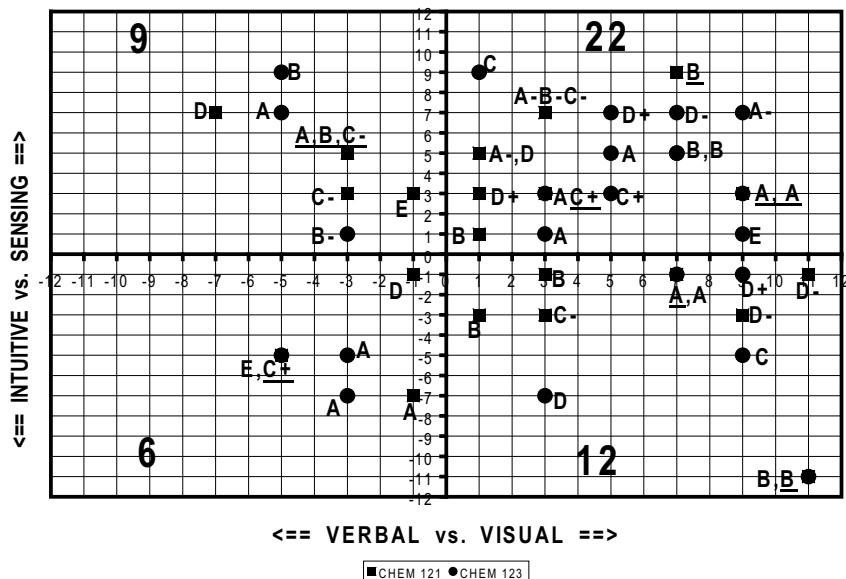**Figure 1-3: Sensing-Intuitive versus Visual-Verbal Learning Style Map** *(Chem 121, n=24; Chem 123, n=25)*

<== VERBAL vs. VISUAL ==>

CHEM 121 ● CHEM 123

Figure 1-4: Sequential-Global versus Visual-Verbal Learning Style Map *(Chem 121, n=24; Chem 123, n=25)*

<== VERBAL vs. VISUAL ==>
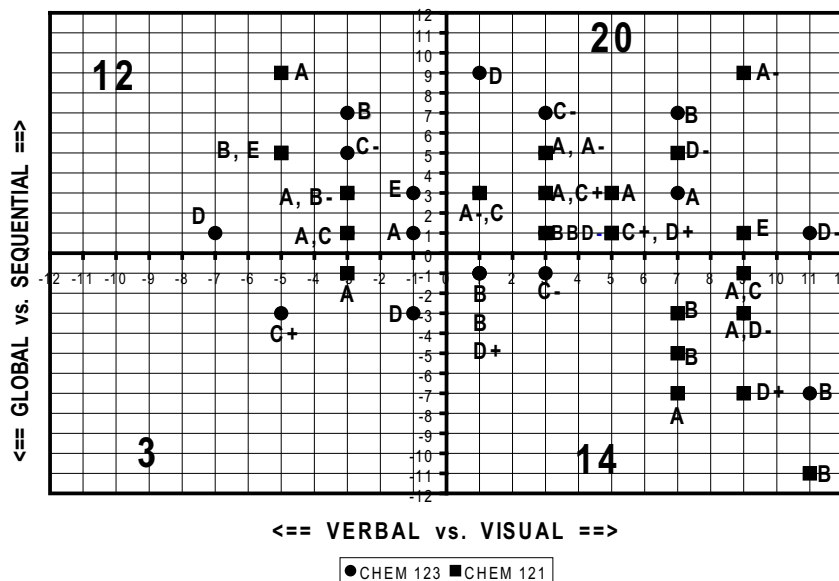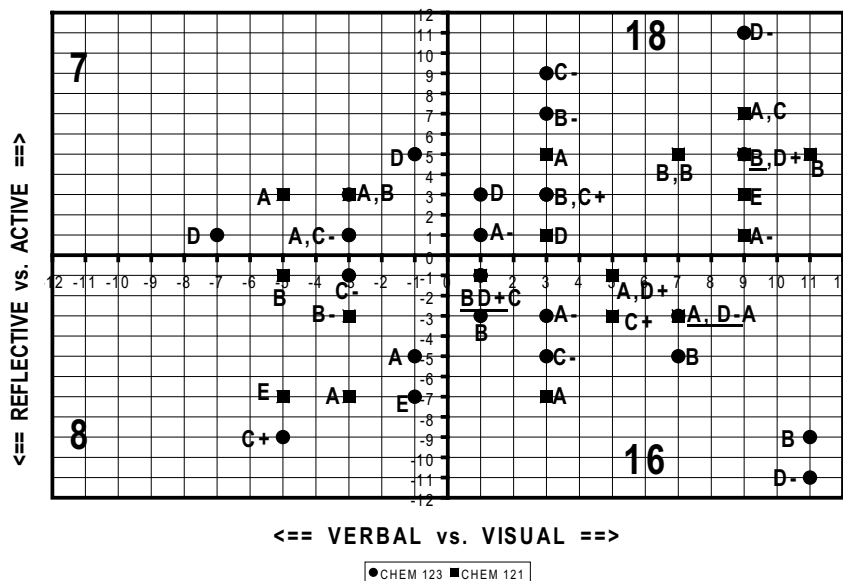
● CHEM 123 ■ CHEM 121

**Figure 1-5: Active-Reflective versus Visual-Verbal Learning Style
Map** *(Chem 121, n=24; Chem 123, n=25)*

The learning styles maps of Figures 1-3, 1-4 and 1-5 show that my students possessed every combination of learning styles, with the visual style being dominant. For example, these Figures show that visual learners predominate over verbal learners by over a 2 to 1 ratio, and these results therefore support using visual learning tools such as animations in the classroom. The Figures allows us to speculate, however tentatively, about which combinations of learning styles do better than others.

As shown in Figure 1-4, sequential learning styles predominated over global learners by a 1.9 to 1.0 ratio. This fact favors using the chalk board to work through problems in a step-by-step routine during lectures, since about two-thirds of students naturally learn through this mechanism. Sequential learning in chemistry is also important as a "tool of the trade", because students must show the sequential process used in solving problems on exams.

Figure 1-5 indicates that my classes were almost perfectly balanced between active and reflective learners. This result indicates that almost half of the classes of science majors may prefer active learning strategies such as case studies, which are not available in abundance.

However, since the computer animations utilized in this study require students to complete surveys, and to fill in worksheets, animations may qualify as an active learning tool. The above results may show that although instructors feel that reading the chemistry textbook is an important duty of all students, it is not the way in which most students learn.

Table 1-6: Student Comments Taken From Fuel Cell Case Study

Student	Sample Student Comments
1	"Yes, apart from spending time only on mathematical course based material, it gave a chance to students and teacher to converse and relate up – to – date issues with the subject of chemistry." "I as an individual feel more informed in the current events where the subject of chemistry is significant."
2	"I think it would be worthwhile because of the fact that it kind of sums up a lot of the concepts that we learned in the semester."
3	"No, if it were a class on fuel cell theory it would be worthwhile, but it only relates to a few lectures of Chem 123 - the time would be better used going over problems."
4	"Yes, I think that the activity was very interesting." "I think that the use of H+ in the fuel cells would save a ton of money compared to combustion engines."
5	"Yes, it would be an awesome way to spend a class period." "I would suggest maybe some more animations on how this works."
6	"Yes. Interesting real world issues such as the current oil situation in the Middle East, our own over-consumption of oil, and possible solutions to the current (or future) problems is great in any class." "More large group discussion might be helpful."
7	"Yes, because doing the case study on Fuel Cells would give a better understanding of chemicals and our environment." "To make the group activity more interesting, there could be more information on the technique of how to use fuel cells and what kind of repercussions there is involved."
8	"No, I think that there is a lot of information to cover in this class already, and devoting a day to something that won't be on the final will only hurt students."

Case Study with Animation

The purpose of the case study animation was to address "beyond the classroom" issues that pertain to chemistry and society,

to global warming, and to invite students to brainstorm solutions to the gasoline crisis in the United States. The exercise also includes a review of electrochemistry, the topic under study. Moreover, at the end of the case study, there were numerous questions, both of a cognitive and affective nature. The fuel cell case study with animation was successful from an affective standpoint. It received 13 positive responses, one neutral and 4 negative responses. Sample responses are shown in Table 1-6 - they respond to the question of whether the case study was "effective."

As I reflect on student comments, I conclude that students are generally interested in a varied set of teaching methods, some that deviate from the traditional lecture format. However, the pressure of grades may have induced some students to respond in a negative way while others perceived the case study as taking away from the main course goal. I feel that this case study and others like it can be an effective teaching tool when integrated with the subject matter. In the future, I will try to explain why it is important to consider real world applications of chemistry. It would be also interesting to relate student comments to learning style data.

Conclusion

There was an unexpected drop in student examination grades after the animation projects ceased but the reasons for this are ambiguous. The data shows that 26.5% of students did not attain a C grade in the animation part of the course but that figure rose to 40.8% by course end. Perhaps this is confirmation that animations had a positive effect on student exam performance.

I discovered that my learning style is highly intuitive, reflective and visual, but somewhat balanced between global and sequential styles while my students were predominantly visual, sequential and sensing, but balanced between active, and reflective modes. My learning style only matches that of my students with respect to visual learning, but markedly differs from theirs in intuitive thinking. This latter discovery appears to support my class observation that students preferred being given information in concrete increments and conversely

asked for help in discovering relationships when performing problem solving.

Based on the evidence, although student subjective evaluations rated animations in an unequivocally positive way, it is not clear that animations had a greater impact on visual learners versus other learning types. Because the language of chemistry and required mathematical skills represent a formidable obstacle to student success, one might predict that student success could be better correlated with verbal learning styles, but again, no clear evidence supports this conclusion. I have not yet analyzed the data to such an extent so as to answer all questions posed about learning styles but hope to address this more in the future.

Conditions for Doing the Scholarship of Teaching and Learning

I believe that both Chem 121 and Chem 123 classes benefited from viewing the animations. I feel that the experience helped me better interact with my students, for example by giving them a voice in the classroom. The original computer animations were successfully devised and used as an intervention strategy in both general chemistry I and II. New ideas with regard to learning style maps, two-dimensional multiple choice questions and the use of an animation within a case study were successfully employed in this SOTL project.

I invested a lot of time learning and constructing animations before I could begin my study. I experienced problems making the animations available online as some would not run properly, even with technical support. In addition, my classroom computer would not support Flash 8 and so I had to provide and set up my own computer and LCD projector. Complicated Flash animations were burdened with long loading times. Having been a hands-on manager of analytical laboratory work in industry, I am accustomed to multi-tasking but my colleagues taught me to be realistic with respect to the amount of work attempted. I, therefore, greatly reduced the amount of heuristic writing and case study work that I originally planned.

The data collected in this study provides me with a wealth of information to change my teaching to fit student needs. The director of the Faculty Development Center, Karen Busch, Jeff Bernstein and my

colleagues in this SOTL group have been especially helpful and supportive. One reason for participating in this project was because I felt that I needed to go beyond the scholarship and teaching and learning opportunities available in my department. I have gained much from this project; it has even extended to collaboratively giving a seminar on affective learning with my SOTL colleague Sarah Ginsberg.

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