Learning Through Action Research While Teaching Undergraduate Science

Penny J. Gilmer[1]

Department of Chemistry and Biochemistry

Florida State University

95 Chieftan Way

Tallahassee, FL 32306-4390

Office: (850) 644-4026

FAX: (850) 644-8281

gilmer@chem.fsu.edu

Course Title: *Biochemistry I*

May 15, 2012

[1] This paper was given as part of the National Study of Education in Undergraduate Science (NSEUS) Conference, held in Tuscaloosa, AL on May 21-22, 2012.

Abstract

Using cultural historical activity theory as the theoretical framework, I conducted action research in an upper division undergraduate biochemistry class, focused on improved student interest and learning using collaborative groups and technology. Each collaborative team developed ten web sites on major themes taught in first semester biochemistry and presented three of these sites in class. The factors that enhanced the students' interest and learning of biochemistry included communities, tools, and division of labor, while the rules within the university tended to diminish interest and learning. Using ethnographic, autobiographical, fictional, and metalogic lenses, I learned from the action research to improve my teaching. I contacted students I could find ten years after the course and found ways the experimental course influenced them.

Learning Through Action Research While Teaching Undergraduate Science

This paper focuses on my action research to improve my teaching and the students' learning, both short-term and long-term, in an undergraduate, upper-division biochemistry course. Sunal, Wright and Day (2004) highlight various reform efforts in teaching science to undergraduates. Also Taylor, Gilmer and Tobin (2002) provide examples of undergraduate science education reform on identifying barriers to reform, pushing the envelope, providing potentialities, and being realized. However, most reform efforts involve lower division, introductory science courses.

In a review of biochemistry education in North America, Bratton and Gilmer (2009) state that most undergraduate biochemistry teaching is teacher-centered, with predominately fact-based lectures for delivering the content and traditional hour examinations for assessing the students. However, Bratton and Gilmer (2009) highlight two reform efforts in biochemistry courses: 1) problem-based learning (White, 2001, 2002) with instructional goals focused on students, and 2) teaching using social constructivism and cultural-historical activity theory (Gilmer, 2006a, 2010) to focus on student learners.

Research from sociocultural areas of education suggest the importance of encouraging students to use the language of science, to talk science rather than just hear some professor speak about science (Lemke, 1995, 2001). In collaborative group projects, in addition to talking science, students have to listen critically to each other as they work on their team project to get the tasks accomplished. One way to encourage talking and listening critically is to have collaborative learning integral to the course with students working together to do their collaborative group assignments. In this way, students must construct meaning and express their thoughts and understandings in words, annotations, and diagrams as students work on their group projects while working with their collaborative team.

Jonassen (2000) and Jonassen, Hernandez-Serrano and Choi (2000) point to "the potentialities of technologies to promote meaningful learning" (Jonassen et al., 2000 p. 103). Jonassen (2000) further states, "it is necessary to adopt a transformative view of technologies as resources for transforming existing practice by providing new ways of thinking, knowing, and acting in education (p. 23). Both Jonassen (2000) and Jonassen et al. (2000) utilize theoretical perspectives of social constructivism and cultural-historical activity theory while transforming student learning as students use technology.

Methodology and Theoretical Perspectives

Hunter (2007) provides an overall description of action research. He describes Kemmis and McTaggart's (1988, 1990) classic work in action research as "an informal, qualitative, formative, subjective, interpretive, reflective and experiential model of inquiry in which all individuals involved in a situation are knowing and contributing participants to the research study" (p. 153). Wright and Sunal (2004) suggest action research as a way for higher education faculty to design, conduct, and analyze data from studies done in the faculty members' classrooms.

In the early 1990s I was one of the principal investigators of an NSF grant entitled, Science FEAT, in which K-12 teachers mainly from middle schools could earn a master's or a specialist degree program in science education. One critical component of this program was that each teacher conducted a yearlong action research project in his/her classroom. I could see the powerful effect of the action research on the teachers' thinking and teaching (Spiegel, Collins, & Lappert, 1995; McDonald & Gilmer, 1997). This experience led me to choose action research methodology for my own research study of teaching biochemistry. I felt action research had the potential to influence my teaching and the students' learning.

Action research has six key principles, as originally described by Winter (1989) and summarized by Hunter (2007): 1) reflexive critique, 2) dialectical critique, 3) collaborative resources, 4) risk, 5) plural structure, and 6) theory, practice, transformation. These are the features that I wanted in my research methodology I saw them as powerful components in the transformation of Science FEAT teachers. Therefore, I challenged myself to engage in action research in my biochemistry classroom using a reflexive and dialectical critique in which I asked the students to be co-participants during the class and asked a biochemistry colleague to engage in a metalogue with me on the problematic issues of bringing reform to higher education science classes.

I also engaged in writing a short story about my classroom by taking a class in fiction writing. In this way, I could address the interactions of the students with each other as they engaged in collaborative groups while building web sites on biochemistry for their assignments.

As part of my doctoral dissertation in Science Education through Curtin University, I wrote my doctoral thesis on this action research study, focusing mainly on the students and their experiences and less so on my changes as the teacher. This thesis is now in book form (Gilmer, 2010).

My aim for this presentation at Research Based Undergraduate Science Teaching Conference II, sponsored by the National Study of Education in Undergraduate Science (NSEUS), held in Tuscaloosa, Alabama in May 2012, is to focus more on the changes in the curriculum and the transformations in myself as the teacher. I use the framework of cultural-historical activity theory to examine the sources of transformation in the enacted curriculum. I look for the factors that enhanced or inhibited the transformation.

Cultural-historical activity theory (CHAT), first developed by Engeström (1999), stemming from Vygotsky's work, is powerful framework to use in action research. One of the tenets of CHAT is that various aspects to life can add coherence or contradict the flow of the subject (in this case, me, the teacher) moving to her object (conducting action research) and her outcomes (enhanced student learning and transformed teaching) (Figure 1).

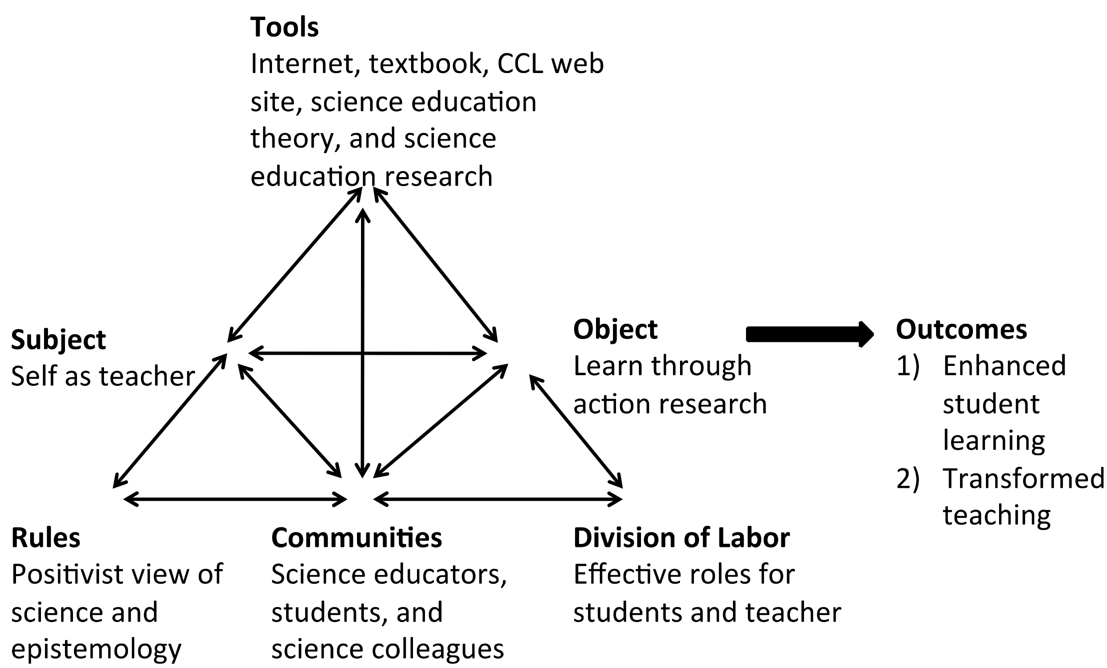

Figure 1: CHAT diagram with Rules, Communities, Division of Labor, and Tools influencing the subject's object and outcomes (adapted from Engeström, 1991)

The tools, rules, communities, and division of labor interact with and influence each other and can enhance or inhibit the flow of the subject to her object and to her outcomes. This CHAT diagram of the teacher interacts with similar CHAT diagrams of the students and other stakeholders in the study. The culture and history of the lifeworlds of these individuals influence the interactions among the different parties. I indicate various aspects to the tools, rules, communities and division of labor here, but I explain them with data in the results. Here I try to provide you some context for the study, and we examine the diagram again in the discussion section of this paper.

Experimental Design

At Florida State University in 1998, I taught an undergraduate-level course, *Biochemistry I,* a capstone course for majors in chemistry, biochemistry, biological science, and engineering, and for science education majors. A biochemistry colleague, Timothy Logan, offered to take some of the enrolled students in his lecture section so I could have a more manageable number of students for the action research study. The class had three 50-minute periods each week for a 15-week semester. The School of Business let me use their technology-enhanced classroom for two of the three days per week, so students could work together on computers one day per week and make presentations using the computers on another day. The third day we met in a regular classroom where I gave an overview of the chapter, to help the students identify themes and key points. Many of the students from my section would merge with students in the other section for *Biochemistry II*, so I felt compelled to keep the same pace and include the same chapters as Logan's section.

I chose the process of fourth generation evaluation because the hermeneutic dialectic process, which was integral to this evaluation, allowed each stakeholder and the evaluator to hear "different constructions, and different claims, concerns and issues," so issues could be "understood, critiqued, and taken into account" (Guba & Lincoln, 1989, p. 72). Stakeholders included 34 students (four of whom were graduate students in the sciences), eight biochemistry colleagues, and one professor from the medical school.

Integral to the study was the having the students use technology, both for their group projects and for the reflective aspects for their assessment. The group projects involved searching on the web for sites of interest that focused on an aspect of biochemistry related to each chapter, which they could use for their group-generated web sites that they created. Students learned to make and post web sites. Each student had some aspect of each project that s/he developed. Students interacted while making these sites, so each site would be cohesive in the content and focused on an aspect that the students chose. Web tools were relatively primitive in 1998 to those now available, so learning to use the technology posed problems. Still, generally one or two students in each team became more technologically literate and did the posting for the group. During the semester each of ten teams posted ten web sites, so we had 100 in all at the end of the semester. During class time, each team presented three of the 10 web sites it created, and I provided written feedback for ways to improve their presentation. A teaching assistant graded and provided written feedback for the other seven web sites for each team.

Students also needed to post weekly reflections on their learning, including two questions that they had in their minds for each chapter, with answers to their own questions plus answers to the questions posted by one randomly assigned student in the class. We did these postings on a Connecting Communities of Learners (CCL) web site, developed by Tobin (2002). This exercise helped the students formulate their questions and answers but also informed me of where the students were formatively in their thinking during the semester.

Although I did not have formal traditional tests in the syllabus (because there were so many other alternative methods to assess students), I did add a bonus traditional mid-term and an optional final question at the end of the semester for students to answer. The optional final question (Figure 2) asked the students to select and write about a biochemical theme that they saw in the web sites.

Type two pages of text that demonstrates that you see connections on a topic that has come up repeatedly in the course. For instance, you can select a topic like one of the following:

- energetics, or
- coenzymes, or
- oxidation-reduction, or
- hydrophobic/hydrophilic interactions, or
- catalysts, or
- thermodynamics, or
- another topic of your own choosing

Go to our table of web sites, and follow your theme, checking out some of the 100 web sites that both your group and the other groups have developed in our course. Then clearly identify your topic, and write a text that is coherent that links at least three of your group's web sites and up to seven other class web sites. Use active hyperlinks, so your ideas can be easily followed.

Figure 2. Optional final examination question posed to students in biochemistry class.

Later in the results I provide an example of part of one student's response to this optional final examination.

All names of students are pseudonyms.

Genres for Writing the Action Research

I chose four genres for writing the qualitative results of the action research study. In my book (Gilmer, 2010) I fully developed three of the genres: ethnographic, fictional, and metalogic. The fourth genre was autobiographical (Gilmer, 2006b). All four genres interacted in my mind and helped me to answer my four research questions.

Being a chemist, I represent the four genres as apices of a tetrahedron (Figure 3). These apices also signify the four bonding positions of carbon, the atom central to life. I gather information using the four genres to help me evaluate the changes in the teaching and curriculum in the action research study and to provide feedback on ideas for the next iteration of an action research study.

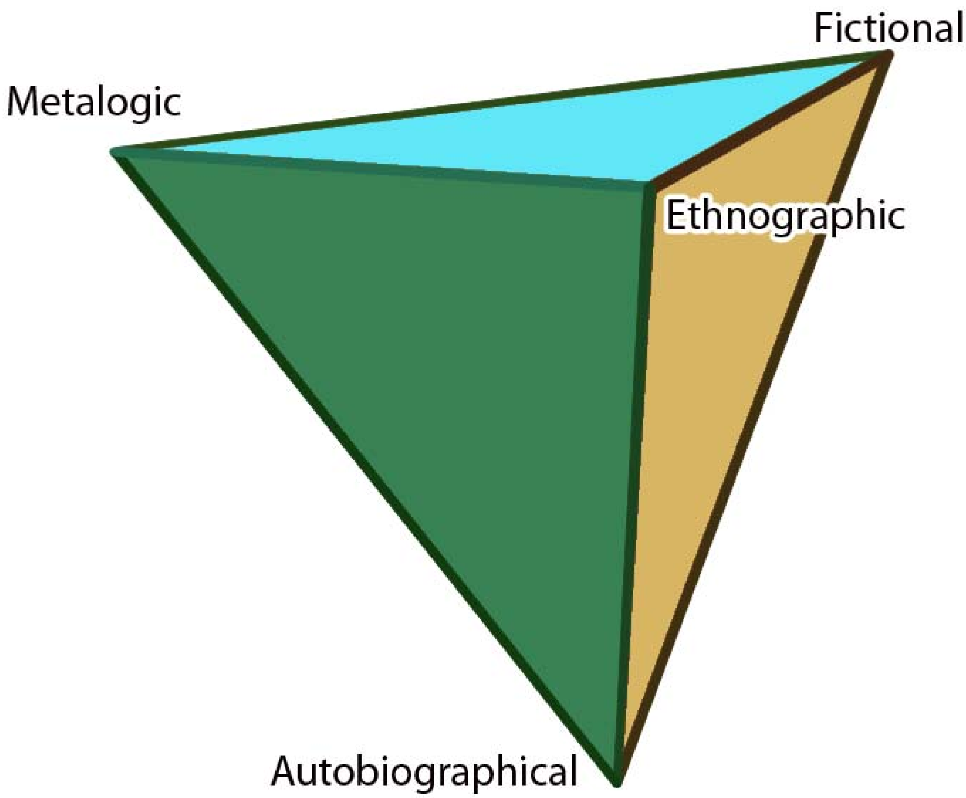

Figure 3. Representation of the four lenses, ethnographic, metalogic, autobiographical, and fictional, used in this action research study.

For this action research study, I had four research questions:

1. How does work in collaborative groups influence learning?

2. How do the uses of technology and the Internet influence students' learning of and interest in biochemistry?

3. What can I learn about my teaching through doing action research in my classroom?

4. What are the sources of the transformation in the enacted curriculum?

In this paper, I focus on the third and fourth questions. My book (Gilmer, 2010) focuses more on the first and second questions, although I address all questions.

Results

For this paper, I provide examples of the qualitative data from each of the four genres that helped me to evaluate this classroom-based action research study. The uses of the genres overlap to a certain extent. For example, I use qualitative ethnographic data to help me write the fictional story.

Learning from Writing the Fictional Story While Using Ethnographic Data

One of the powerful ways for me to learn about my classroom was to write a fictional story about interactions of four fictional group members working in a collaborative group while using the Internet to learn the biochemical topic of their choice, to generate, post, and deliver a presentation for the class. I had to put myself in student's shoes, listen to their voices (through qualitative data I gathered through the semester) and give a voice to each of the four students in my story.

I used the data that the students had written when they responded to a Higher Education Learning Environment survey (Gilmer, 2010) that I gave them on the last day of the course. I typed their comments, sorted the qualitative data into categories, and utilized those comments in writing the fictional story.

I had never written a short story beforehand, so I enrolled in a semester-long, undergraduate class entitled, *Writing Workshop*, at my university. In that workshop we worked in collaborative groups, much as I had my biochemistry students work. Interestingly, some of my fiction workshop group members happened to have been friends with some students who had been in my experimental biochemistry class. As my fiction workshop group members read the initial drafts of my story, they would ask me questions not only about writing but also about the context for the class, and these questions made me think more deeply about the class. Also the professor for that writing workshop made me realize aspects that make a good story.

After the class ended I interviewed one of my biochemistry students, Magnolia, in depth, transcribed her words, and learned her way of speaking, using that for one of the characters in my story. Another student, Suzanne, worked with me on rewriting more clearly her electronic portfolio. Using Suzanne's data, I could identify coherences and contradictions in her learning. These became elements in my story. Again these were ethnographic sources that I used to construct the fictional story.

Learning More from Other Ethnographic Data from the Classroom

I learned through other types of qualitative data, including 1) member checking from the stakeholders on the fictional story, 2) the Collaborative Learning Survey, and 3) the optional final examination question.

Member checking on fictional story.

With fourth generation evaluation, member checking is a critical component to the project. Therefore, after I finished writing the fictional story, I shared it electronically with as many of my biochemistry students as I could contact a year after the biochemistry course ended. A number of students responded, and they could see that I learned from writing the story but then they felt they could tell me more about the classroom, perhaps in part because they were already graduated and/or with time they reflected more on the learning environment. Here were Suzanne's responses to four questions on the learning environment that I sent to the students with the story:

1. How did you respond to the type of learning environment we had in our biochemistry class? *I was excited about the opportunity to learn science in a new way, involving group work and the use of the World Wide Web; I thought that it would be more enjoyable than traditional learning. However, I was also skeptical that all group members would have the same enthusiasm and standards in their academics and did not want my grade to suffer as a result. The integration of other disciplines, such as computer technology and public speaking, intrigued me because it would add variety to my science education and provide me with valuable skills outside of science.*

2. What happened as you tried to work together in your collaborative group? *Our group got along well. It was nice always to have someone to discuss and sort out problems with. However, we didn't find much time to meet and discuss our individual findings and common themes. If we had, the education would have been much richer.*

3. How did the use of technology influence your learning? *It facilitated my learning. As opposed to a traditional course, many perspectives were offered, making it easier to reach a clear understanding.*

4. How did having an open and critical discourse influence your learning? *It is always easier to reason and comprehend concepts when the topics are verbally discussed. This, and the accompanying criticism, allows for an accurate understanding that is clear, certain, and permanent in the mind.*

In addition, I asked the students to respond to the fictional story. Here are Suzanne's responses to these additional questions:

1. How do you feel that the fictionalized story represents or does not represent what might have happened in our web-enhanced biochemistry classroom? *Overall, the*

characters and scenarios of the fictional story are realistic. Bristol, Magnolia, Heather, and Charles are typical students that encounter [each other] in group assignments. Such dialogue and actions probably did take place between group members in the actual class.

2. What sort of feelings does reading the fictionalized story bring back to you from our classroom? *As I read the story, I analyzed each of our group members and compared our group to the fictional group. We were lucky because [in my group] there wasn't much conflict or need for confrontation that I can remember. I just remember and smile upon the funny times and the different personalities. The only negative feeling that I recalled as I read the story was the frustration from not being able to get our group together to discuss and organize our web site and presentations.*

3. How can you help me get in touch with how to improve my teaching and my students' learning in university science classrooms? *You have already gotten in touch with this by trying a new type of course and assessing the course's effectiveness by writing realistically about it and talking with your students about it.*

Suzanne's responses provided me feedback that I was on the right track. Her comment about her remembering "funny times and different personalities" of those group members led me to modify the fictional story slightly. Other students' comments also influenced me similarly (Gilmer, 2010).

Collaborative learning survey.

Another way that I learned information from my students was through using the qualitative data in the Collaborative Learning Survey (CLS) (Gilmer, 2010) that each team submitted on the ten days that their group web sites were due. In one of the questions, I had asked teams for suggestions of ways that they improve their work in collaborative groups, in an effort to get them to reflect in the heat of the moment when their projects were due on ways that they could work more productively. I organized these qualitative data into a timeline that collaborative groups could use in the future to work more effectively. I shared this list of 11 items with students in later semesters:

1. Coordinate and communicate within the group.
2. Try to be punctual to all meetings.
3. Listen to each other's thoughts and feelings.
4. Get more organized and start making meetings more efficient.
5. Assign in advance the tasks needed to complete on time.
6. Communicate and share (Web) sites/info that is helpful to each particular aspect.
7. Talk one on one.
8. Do (biochemistry) chapter problems together.
9. Meet outside of class more.
10. Keep in mind all of the information we have learned for future collaborative work.
11. Continue working closely and accept ideas from one another (Gilmer, 2010, p.127).

Optional final examination question.

Whenever a teacher makes a change in the learning environment, "some students may benefit and others may be harmed" (Hunter, 2007, p. 156). All students are not affected equally as individuals have different prior experiences and different optimal ways of learning. Therefore, when a teacher decides to make a change in the classroom, risks are inherent.

I chose not to have traditional hour examinations or a final examination. My students had initially expected this form of assessment. At the start of the semester they learned of this change and had a chance to switch to the other section, taught at the same time as my section, and a few students did leave my class and transferred to the other. However, there were more students in the regular section that wanted to take my course taught in the alternative way. I ended up with more students than I originally planned in the experimental section because of this, but I was glad that I did accept them (although it was more work, and I had to revise the schedule with more students).

One student, Michael, came to me a few days after classes started, saying he was a "farm boy from Georgia" who wanted to learn biochemistry using technology and thought he would learn well in this way. I did add Mark to my section, and he profited in terms of his learning by being taught in this more open-ended way, using the Internet and collaborative learning groups. Michael was a shy student but he contributed well within his group. He really would shine when he came individually to my office to ask me questions. We would have long discussions as he explained to me his understanding of biochemistry. Michael also evidenced his learning in his written response to the optional final examination. He chose the theme of hydrophobic-hydrophilic interactions. Here is a short part of his response:

> Just for a brief review, hydrophobic is the molecular property of being unable to engage in attractive interactions with water molecules. Hydrophobic substances are nonionic and nonpolar. They are nonwettable and don't readily dissolve in water. Hydrophilic refers to the ability of an atom or a molecule to engage in attractive interactions with water molecules. Substances that are ionic or can engage in hydrogen bonding are hydrophilic. Hydrophilic substances are either soluble in water or, at least wettable. These rather elementary concepts govern so many reactions, structures, and functions of biochemistry… Let's look at my link, "Globular Proteins' Nature and Structures" [he provided the link to his group's web site]. Here we see this kind of hydrophobic and

> hydrophilic structure in a globular protein. The tertiary structure of globular proteins reflects their interaction with their aqueous solvent. At a simple level, a globular protein may be considered to consist of a hydrophobic core surrounded by a hydrophilic external surface, which interacts with water. The tertiary fold of the polypeptide is such that those residues with apolar side chains are buried in the center, while the polar residues remain exposed. This principle is held by many to be the dominant driving force behind the folding of the polypeptide chain into the compact globular form: the aggregation and burial of the hydrophobic surface reduces the number of unfavorable interactions of these groups with water; thus the hydrophobic effect.

This description was just for one of the ten web sites that Michael cited. He also referred to his and other groups' web sites on lipid metabolism, metabolic pathways, cell-surface carbohydrates, G-protein linked receptors, and membranes. Michael posted his final reflection with the optional final examination:

> I am actually sad this class is over. It has made studying for other classes seem very boring. On the up side I can leave this class knowing I have a solid biochemical background, and I am no longer afraid of computers. They are now truly my friend and not the feared enemy.

His participation in the class made him become more confident in himself, and he definitely was no longer afraid of technology and became much more proficient in both biochemistry and technology. Michael went on to medical school and became a practicing radiologist.

Learning from the Metalogue with a Biochemistry Colleague

The purpose of the metalogue (Bateson, 1972) is "provide a chance for formal reflection on some experience, such as the action research in which I was engaged" (Gilmer, 2010, p. 156). A metalogue is a conversation with a stakeholder in the research study about the problematic issues of the study; in this case, the problematic issues are of bringing reform to higher education. Not only do I reflect but my biochemistry colleague, Robley L. Light, does too. We had the metalogue in two parts, as I had a break in my writing due to my mother's death. We addressed such topics as the fictional story, the value of collaborative learning, the grading issue, depth of learning, science as "truth", constructivism, different levels and aspects of a subject, and positive aspects.

From my perspective (Gilmer, 2010, p.3),

> Traditional teaching of undergraduate science typically presents science as a set of absolute truths (i.e., a set of objectified facts to be learned) rather than as a progressing area of inquiry, in which the "facts" may change with more scientific research.

Robley Light, on the other hand, responded to a sentence of mine about "truth" in science as follows (Gilmer, 2010, p. 170):

> In your Preface to the original doctoral thesis, you said: 'Traditional teaching of science presents science as the 'truth,' a set of objectified facts to be learned, rather than as an interesting area of inquiry.'
>
> I disagree. Some science courses are taught that way, but need not be. The perception comes in part from the need to develop the vocabulary of the subject (which often consists of learning 'facts') before one can introduce the subtleties and uncertainties. When Conant et al. (1948a, b) sought to develop a course for non-science majors, they resorted to focusing on early experiments in science (e.g., Boyle, Lavoisier, etc.) because there the students did not need so much background to be able to appreciate the way

> models rose from experimental findings, in turn suggesting further experiments. In biochemistry, one cannot begin to discuss the subtleties of the way structures affect function (or different ideas of what a structural effect might be), for example, if the student does not have a fundamental grasp of the structures one is talking about. Often one gets bogged down in presenting the 'vocabulary' which makes it appear that one is only presenting 'Truths.'

Robley Light is right that biochemists typically do not get around to teaching the evolving epistemology (i.e., nature of knowledge) of science. It is easier to teach biochemistry as facts with the professor as the authority of the knowledge. This is just one example from the complete metalogue in the book (Gilmer, 2010).

The metalogue was most informative as it allowed me to see the culture of science from the outside, even though I was immersed in it, because my views had changed through the research yet the culture within science was more resistant to change. One of the external examiners for my action research study said that she found the metalogue to be the most interesting part, as she could understand the culture in which I worked.

I do think that the culture of doing research in biochemistry is evolving to take into account subtleties in the interactions and dynamics of molecules binding to macromolecules, rather than just determining the structure of the macromolecule. As scientists start to think this way with respect to their research, I think it is starting to influence the science culture.

Learning Through Writing Autobiographical Reflections

In developing my ideas on "truth" in science, I wrote in my autobiography that reading Bruffee's (1993) book on collaborative learning, just before teaching the biochemistry course in which I did the action research, was revolutionary for me. I had come to science education with a doctorate in Biochemistry from University of California in 1972, with my research study on quantitative nature of pH dependence of the kinetics of the binding of a vitamin to an enzyme (Gilmer, 1977a, b). With these data I could predict the pK_a values of the critical ionizable groups in the binding reaction. However, reading Bruffee's book at that time greatly influenced how I taught the experimental class. I stated (Gilmer, 2006, p. 133):

> My life as a scientist had the authority of knowledge as its mantra, yet Bruffee's book challenged my beliefs. It made me realize that knowledge is tentative. 'Knowledge is what is said—or perhaps what can be said—in some language, by members of some community, to other members of that community' (Bruffee, 1993, p. 142). I realize we construct our knowledge and come to agree as a community of scientists that a certain construction is our best understanding at a certain point in time. However, what I needed to accept is that these understandings are only constructions, not the absolute truth, or Truth.

By using the autobiographical writing, I became aware of my changing ideas, when they changed and how they changed.

The two of other topics I addressed in the autobiographical writing included collaborating as both a scientist and a science educator and using technology as a tool. I realized the reasons that I chose to focus on collaboration while using technology in my teaching. I became more certain of these ideas by writing autobiographically.

Coherences and Contradictions in CHAT Diagram Influencing the Flow

In Figure 1, the CHAT diagram shows the components that can influence the flow of the *subject* to her *object* and *outcomes*. I, the teacher, am the subject of this CHAT diagram. The components that influence the flow and influence each other are the *tools, rules, communities*, and *division of labor*.

Tools.

Not only were the Internet and the CCL web site facilitating my research but also educational theory and science education research were critical to my study. The textbook as a tool was good but it was static. The students noticed that at times the textbook was wrong, in that new ideas had developed since their book was written.

Communities.

The communities were powerful influences, in some ways as coherences when the collaborative groups really worked well together and when groups helped each other, but not all groups worked well. I would meet with some groups that had trouble interacting to try to help them interact more productively.

Other communities included my biochemistry colleagues, who were both reluctant and supportive, to various degrees. Tim Logan helped me by taking more than half of the students in his section of the same course so I could keep my research section smaller. Robley Light was important to my study in participating in the metalogue. Some biochemistry colleagues visited my class once. The science educator community encouraged me to conduct the action research study and supported me through my research presentations.

Division of labor.

The teacher and the students fairly divided the labor. There was much to do for all parties involved. In retrospect, I asked my students to do too many web sites—however, I did it that way so that the students would work and learn biochemistry found in all the chapters for the first semester.

However, division of labor within collaborative groups was not always evenly divided, but group members tended to work it out among themselves. I saw evidence of problems in the some of the group's CLS reports for each web site. Having the students to reflect on their learning was important for the student to have an outlet in which to write and for me, the teacher, to understand the dynamics of the students within their groups and in the class.

Rules.

Often the rules in human activities contradict the flow of the subject to the object and the outcomes. At the time of the study in 1998, teachers in chemistry and biochemistry in my department taught almost totally by lecture with three hour examinations and a final exam for assessing students. Therefore, my biochemistry faculty colleagues were skeptical of my research design without traditional testing, and of my understanding of the epistemology in science. These forces constrained me some, but I was persistent and worked through the issues.

Flow of subject to object and outcomes.

I was the *subject* in this CHAT diagram (Figure 1) with my *object* of conducting the action research in my biochemistry classroom. This was part of my doctoral study in Science Education at Curtin University of Technology (in Western Australia), which I finished in 2004. I had read deeply on undergraduate reform and had co-edited a book on transforming undergraduate teaching with my co-major professors (Taylor, Gilmer, & Tobin, 2002) during my doctoral study. I was determined to conduct the action research study but the coherences and contradictions influenced my path.

I achieved two *outcomes,* enhanced student learning and transformed teaching, shown in Figure 1, to various degrees, depending on the student and the aspects of my teaching that are considered. Because of the cyclic nature of action research, my learning from the study here influenced my teaching of the next classes.

Implications for Action Research

Doing action research in one's classroom enables the teacher to address problematic issues that students are having in learning the curriculum. The power of action research is in the catalytic authenticity (Guba & Lincoln, 1989)—that "I, the researcher, became stimulated into action" (Gilmer, 2010, p. 60). Action research is cyclic in nature, so the learning from one round of action research influences the next round.

Bringing My Learning from Action Research in My Next Class

These four genres of writing helped me to think through ways that I could support students as they worked in collaborative groups when teaching in later semesters. When I taught a similar biochemistry course for a different type of students, mainly those majoring in nutrition, I developed a web site (Gilmer, 2005) that would help support my students as they worked in collaborative groups using technology to learn biochemistry and present a Group Learning Project (GLP) to their classmates and me. I constructed a two-part process, with subprocesses within:

1. Submitting the proposal for the GLP
    a. Choose your topic and question
    b. Find resources
    c. Prepare your project proposal

2. Submitting the GLP and the critiques
    a. After approval, work on the project
    b. Prepare a reference section
    c. Critique your own project
    d. Post your project on the group Web page on Blackboard
    e. Critique one other group's project

I prepared links to other pages that explained each step with supporting ideas and examples to help the student work in collaborative groups while using technology. I used this site for four years as I taught this same class and improved on the process each time I taught. Group projects became a component of later courses but not the central focus as it had been in my original action research study.

Power of Educational Theory

Although I used more than one educational theory, I cite only one in this paper, due to the shortness of the paper. I discussed the three educational theories in the book (Gilmer, 2010). The CHAT diagram (Figure 2) was a powerful theory for looking at the coherences and contradictions in the flow of humans engaged in social activities, such as in teaching my class. I provided a summary of these factors in tools, rules, communities and division of labor as I, the subject, moved toward my object, conducting action research, en route to my outcomes, improved student learning and transformed teaching.

As mentioned in action research, some people profit from the change in teaching and others do not, so the results in the one experimental class were not all positive. However, still I learned from the study and applied that knowledge to the next classes I taught.

Using the four genres of writing helped me learn more deeply because I could see the data from various perspectives. The ethnographic data certainly informed the writing of the fictional story, and gave Robley Light and me some data to discuss. My autobiographic genre informed me on the reasons I did things in certain ways, such as my choice of emphasizing collaborative learning while using technology. The metalogic lens allowed me to see more clearly the culture of science in which I was immersed. Therefore, I recommend that others conduct action research in their classrooms and not be afraid to try various genres in their writing.

Students Ten Years After the Action Research Study

I was able to contact a number of my former students from the action research study in 1998. For my book (Gilmer, 2010, p. 53), in 2009, I conducted the follow-up on my students, and I found that many had gone on to medical school or graduate school:

> In searching on the Web, I found that both Manny and Rebeka, two of the graduate students in the class I studied, now have doctorates in Exercise Science, and Manny is an assistant professor in Kinesiology at a major university. Michael, one of the undergraduates from my classroom that I highlight in this study, is now a Radiology Fellow. I continue to keep abreast of the effect that the students' experience in the biochemistry classroom played later in their lives. For instance, the one student, Mary, whom I interviewed in depth, was extremely weak in technology at the beginning of the biochemistry course, but now she is a high school biology teacher and working towards her doctorate in education. The second student, Suzanne, I interviewed in depth is finishing her doctorate in science at a prestigious US university.

Many of the students did well in their careers, and technology became a source of strength for them.

Acknowledgments

I thank Dr. Ajda Kahveci for working with me on the development of the web site for the Group Learning Projects. I appreciated Robley Light taking the time to read my action research and to comment with me in the metalogue.

References

Bateson, G. (1972). *Steps to an ecology of mind: Collected essays in anthropology, psychiatry, evolution, and epistemology*. San Francisco, CA: Chandler.

Bratton, D. III, & Gilmer, P. J. (2009). Undergraduate biochemistry education in North America. In W. M. Roth & K. Tobin (Eds.), *World of science education: North America* (pp. 207-220). Rotterdam: Sense Publishers.

Bruffee, K. A. (1993). *Collaborative learning: Higher education, interdependence, and the authority of knowledge.* Baltimore, MD: The Johns Hopkins University Press.

Engeström, Y. (1999). Activity theory and individual and social transformation. In Y. Engeström, R. Miettinen, & L. Punamäki (Eds.), *Perspectives on activity theory* (pp. 29-38). Cambridge, UK: Cambridge University Press.

Gilmer, P. J., McIntire, W. S., & Kirsch, J. F. (1977). Pyridoxamine-pyruvate transaminase: I. Determination of the active site stoichiometry and the pH dependence of the dissociation constant for 5-deoxypyridoxal, *Biochemistry, 16(24),* 5241-5246.

Gilmer, P. J., & Kirsch, J. F. (1977). Pyridoxamine-pyruvate transaminase: II. A temperature-jump and stopped-flow kinetic investigation of the rates and mechanism of the reaction of 5-deoxypyridoxal with the enzyme, *Biochemistry, 16*(24), 5246-5253.

Gilmer, P. J. (2005). Introduction to Biochemistry. Retrieved from http://mailer.fsu.edu/~pgilmer/glp_website/info.html

Gilmer, P. J. (2006a). Action research in one's own science classroom in higher education. In W. D. Bokhorst-Heng, M. D. Osborne, & K. Lee (Eds.), *Redesigning pedagogy: Reflections on theory and praxis* (pp. 145-155). Rotterdam: Sense Publishers.

Gilmer, P. J. (2006b). As a woman becoming a chemist, a biochemist, and a science educator. In K. Tobin & W. -M. Roth (Eds.), *The culture of science education: Historical and biographical perspectives* (pp. 133-145). Rotterdam: Sense Publishers.

Gilmer, P. J. (2010). *Transforming university biochemistry teaching using collaborative learning and technology: Ready, set, action research!* New York: Springer.

Guba, E. G., & Lincoln, Y. S. (1989). *Fourth generation evaluation*. Newbury Park, CA: Sage.

Hunter, W. J. F. (2007). Action research as a framework for science education research. In G. M. Bodner & M. Orgill (Eds.), *Theoretical frameworks for research in chemistry/science education.* Upper Saddle River, NJ: Prentice Hall.

Jonassen, D. H. (2000). Transforming learning with technology: Beyond modernism and post-modernism or whoever controls the technology creates the reality. *Educational Technology 40*, 21-25.

Jonassen, D. H., Hernadez-Serrano, J., & Choi, I. (2000). Integrating constructivism and learning technologies. In J. M. Spector & T. M. Anderson (Eds.), *Integrated and holistic perspectives on learning, instruction, and technology*. Dordrecht, Netherlands: Kluwer Publishers.

Kemmis, S., & McTaggart, R. (1988). *The action research planner* (3rd ed.). Geelong, Victoria, Australia: Deakin University Press.

Kemmis, S., & McTaggert (1990). *The action research reader.* Geelong, Victoria, Australia: Deakin University Press.

Lemke, J. L. (1995). *Textual politics: Discourse and social dynamics.* Bristol, PA: Taylor & Francis.

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching, 38*, 296-316.

McDonald, J. B., & Gilmer, P. J. (Eds.) (1997). *Science in the elementary school classroom: Portraits of action research.* Tallahassee, FL: SERVE.

Spiegel, S. A., Collins, A., & Gilmer, P. J. (1995). Science for early adolescence teachers (Science FEAT): A program for research and learning. *Journal of Science Teacher Education, 6*(4), 165-174.

Sunal, D. W., Wright, E. L., & Day, J. B. (Eds.) (2004). *Reform in undergraduate science teaching for the 21st century*. Greenwich, CT: IAP Information Age.

Taylor, P. C., Gilmer, P. J., & Tobin, K. (Eds.) (2002). *Transforming undergraduate science teaching: Social constructivist perspectives.* New York: Peter Lang Publishing, Inc.

Tobin, K. (2002). Learning to teach science using the Internet to connect communities of learners. In P. C. Taylor, P. J Gilmer, & K. Tobin (Eds.), *Transforming undergraduate science teaching: Social constructivist perspectives* (pp. 323-348). New York: Peter Lang Publishing, Inc.

White, H. B. III (2001). A PBL course that uses research articles as problems. In B. J. Duch, S. Ed. Groh, & D. E. Allen (Eds.), *The power of problem-based learning* (pp. 131-139). Sterling, VA: Stylus Publishing.

White, H. B. (2002). Confronting undergraduate dualism with problem-based learning. In P. C. Taylor, P. J. Gilmer, & K. Tobin (Eds.), *Transforming undergraduate science teaching: Social constructivist perspectives* (pp. 231-243). New York: Peter Lang Publishing, Inc.

Winter, R. (1989). *Learning from experiences: Principles and practice in action research.* London: Falmer Press.

Wright, E. L., & Sunal, D. W. (2004) Reform in undergraduate science classrooms. In D. W. Sunal, E. L. Wright, & J. B. Day (Eds.), *Reform in undergraduate science teaching for the 21st century* (pp. 31-51). Greenwich, CT: Information Age.