Action Research in One's Own Science Classroom in Higher Education

Penny J. Gilmer, Ph.D., D. Sc.Ed.
Department of Chemistry and Biochemistry, Florida State University, Tallahassee, FL, USA 32306-4390;
also Curtin University of Technology, Science and Mathematics Education Centre, Perth, Western Australia

Abstract

Using the theoretical lenses of social constructivism, blended with cultural historical activity theory and Sewell's theory of structure/agency, I conduct action research in my own biochemistry classroom in higher education. I focus on use of technology and collaborative groups, while encouraging my students to learn biochemistry and increase their conceptual understanding and interest in biochemistry. Although I have three other lines of data, I present only my ethnographic data here, By focusing on the progression of my students learning biochemistry en route to their becoming professionals and how the various elements influence this flow, I understand better how to make my classroom system more productive in both a formative and summative fashion. This project is significant because it provides a model for how other college and university faculty might think about their own science classrooms and how they could study and improve the learning environments. Conducting the action research in my own classrooms gives me the power to teach in innovative ways.

Objectives of This Study

My main objective in this research is to improve my teaching, thereby enhancing my university students' conceptual understanding and interest in biochemistry. I hope to transform my teaching away from the positivist tradition. I want my students to see the connections between the various topics in biochemistry and to understand that all the sciences interconnect and link to each other. In my teaching, I hope to encourage students to tap into what they have learned already through their coursework (both in my course and in other courses) and real world experiences. I encourage my students to bring their previous knowledge and experiences into their learning of biochemistry and to have scientific discourse with other students. If future K-12 science teachers learn in this way, it will help them engage their future students with science content taught with reform-minded strategies in place.

My secondary objective is to develop a model to help other college science faculty improve teaching and learning in their own classrooms. Other faculty from universities and community colleges might become aware of the critical issues in the reform movement in the teaching and learning of science. I want faculty to become motivated to try new ideas in teaching, based from quality research, within their classrooms and become cognizant of the power of educational theory. I want them to see the power of conducting action research in their own classrooms.

Theoretical Background

My theoretical lenses include social constructivism (Solomon, 1987; Tobin & Tippins, 1993), cultural historical activity theory (Engeström, 1999), and Sewell's theory of structure/agency (Sewell, 1992, 1999).

In an attempt to improve my own teaching methods, I conducted action research (Collins & Spiegel, 1997) in my biochemistry classroom using fourth generation evaluation (Guba & Lincoln, 1989). This exploratory journey relied heavily upon my conceptualization and internalization of the constructivist paradigm, which was a drastic shift from my previous positivist perspective.

For most of my professional life, I have been a practicing scientist with my first doctorate in Biochemistry from the University of California, Berkeley in 1972. My scientific research for over 30 years had been in biochemistry. About 13 years ago I started to become involved in the science education community and its research agenda. I view science differently, i.e., how I view knowledge construction, and how I view teaching and learning. Since that time I have come to understand constructivism as a theory of knowing that utilizes *viability* rather than truth (Glasersfeld, 1989). By viability, I mean does the concept fit within one's experience? A constructivist realizes that in the light of new experiences, one's understandings and concepts may change with time. Each of us constructs our own knowledge due to our own unique set of experiences. For scientists, our experiences also include experiments, theories, and consensus building with other scientists. I subscribe to a subset of constructivism, called *social constructivism* (Solomon, 1987), which focuses more on the construction of ideas within a social setting rather than on an individual constructing ideas entirely on one's own.

A constructivist teacher encourages her students to bring their previous knowledge and experiences into their learning of the content and to start to connect what they have learned in the real world with what they are learning in the class (Tobin & Tippins, 1993). A social constructivist encourages her students to talk and debate ideas about science with each other, to construct meaning while writing about science, and to work together collaboratively or cooperatively on a group project (Solomon, 1987).

To analyze and understand the complexities of my classroom, I employ the cultural-historical activity theory (CHAT) (Engeström, 1999), which focuses on what inhibits and what enhances the ability of my *subjects* (my biochemistry students) to move to their *objects* (learning biochemistry) and on to their *outcomes* (becoming professionals). The domains that influence this flow-through are *tools* (including technology, the textbook, and the World Wide Web), the *communities* (the students' collaborative groups and the community of scientists who report their scientific understandings on the Web), the *division of labor* (i.e., having students work collaboratively within their group; enhancing my students' learning as their teacher), and the *rules or schemas* (the cultural emphases on science content, the norm of large lecture classes with traditional summative assessments of student learning). I use the same CHAT scheme to examine my own growth and what contradicts and what enhances my movement or flow towards my objects and outcomes.

I also abide by Sewell's (1992) notions and utilize his "theory of structure that restores human agency to social actors, builds the possibility of change into the concept of structure, and overcomes the divide between semiotic and materialist visions of structure" (p. 1). If we think of structure as permanent or stable, then we become afraid to change it. We need to think of structure as something more flexible, which can change with the goals and needs of human actors. Sewell's theoretical framework (1992, 1999) empowers me with the resolve to think "outside the box" of traditional science teaching and to learn from my students in a learning environment rich in technology and collaborative learning. I think of the culture of the classroom differently, and it helps me to analyze the results and learn from what my students say and write.

Action Research

To achieve my goals, I conducted action research in my own biochemistry classroom, focusing on collaboration (Bruffee, 1993; Linn & Burbules, 1993) and technology (Glaser & Poole, 1999; Jonassen, 2000; Tobin, 2002). I wanted to teach biochemistry with my college students actively engaged in the process of constructing their own understandings, using their prior experiences while learning the new information made available through our class. In the first semester of an undergraduate-level biochemistry course, students worked within collaborative groups to learn biochemistry by constructing group Web sites on specific topics (Gilmer, 1999). Each group of students presented three out of ten group-constructed Web sites to the rest of the class, sharing their understandings and responding to questions. Students needed to use the discourse of science in their conversations with group members, writing on the Web site, and oral presentations to the rest of the class.

Students within my classroom struggled to learn biochemistry, while using technology and collaborating to create and present Web sites on biochemistry topics. This study was in 1998 when the tools to create Web sites were much more primitive than now. I share my students' struggles in two ways: 1) presenting ethnographic, qualitative data of what students said in response to various surveys, in their e-mails, or in their electronic portfolios, and 2) writing a fictionalized story with four student archetypes in my class. As Britzman (1991) says, "[M]y dilemma as a researcher is to reconstruct and critically re-present the voices of others, and, in so doing, care for their integrity, humanity, and struggles" (p. 12). In this paper due to space restrictions I primarily discuss the first method of analysis.

My students were science majors or education majors who were planning on becoming practicing scientists, physicians, or science teachers. They earnestly wanted to understand biochemistry. I taught biochemistry with my students actively engaged in the process of constructing their own understandings, using their prior experiences while learning and applying the new information made available through our class. This was the first semester of a two-semester sequence. I encouraged students to use the discourse of science in their conversations with group members, writing on the Web site, and oral presentations to me and the rest of the class (Lemke, 1995).

My research questions were the following:

1. How does work in collaborative groups mediate learning?
2. What can I learn about my teaching through doing action research in my classroom?
3. How do the use of technology and the Internet mediate students' learning of and interest in biochemistry?
4. What are the sources of the transformation in the enacted curriculum?

I employed some of the methodology of fourth generation evaluation (Guba & Lincoln, 1989), using two types of quality criteria, using those that apply to:

1. conducting an ethnographic, interpretive action research study of my biochemistry classroom (Guba & Lincoln, 1989; Schaller & Tobin, 1998).
2. writing fiction (Goldberg, 1990; Stern, 1991; Burroway, 1996; Richardson, 1994).

I approached the answers to my research questions by careful data analysis and reflection in light of the results of other researchers.

Data Sources and Methods of Analysis

My data sources included students' electronic portfolios, e-mails, group-generated Web sites, and responses on the Collaborative Learning Forms, collected on each day that a Web site was due. I distributed a Learning Environment Questionnaire (LEQ) during the last week of class, which produced both quantitative and qualitative data. I also interviewed two students from the class shortly after the semester was over, and one of those students, Suzanne, gave me feedback on her electronic portfolio about one year after the course ended, and, five years later, she read and critiqued the data chapters of my doctoral thesis.

Using the QSR software program to sort large amounts of qualitative data into categories and subcategories (Denzin & Lincoln, 2000) allowed me to see the patterns across data from many sources for all the data chapters (Janesick, 2000). These categorized data were central for analysis of the ethnographic data.

Using CHAT, instead of focusing only on the coherences to the flow, I have learned to attend to the contradictions associated with the flow of my *subjects* moving towards their *objects* and their *outcomes*. I am looking for what inhibits my students from reaching their *objects*. As I address these contradictions, I learn to work with the system to increase the coherence. I find that it is powerful because it gets at the crux of effectively mediating the learning of college biochemistry.

Results

Using Ethnographic Evidence on Collaboration

Glasersfeld (1989) points out that "the most frequent source of perturbations for the developing cognitive subject is the interaction with others" (p. 136). One primary perturbation is the interaction of students with others in collaborative groups. In this section I utilize the comments of my students to understand and evaluate the environment to learn biochemistry.

When coding the students' comments from the LEQ, 18% of the comments fell into this category of Collaboration. There were six subcategories: Group Presentations; Co-Learners; Accomplishments; Real World; Conflicts; and Cooperation. I chose two subcategories to present here: Group presentations and Co-learners. Suzanne, a student in my classroom, provided portfolio data, which I sorted into contradictions and coherences in the learning environment for collaboration.

Group Presentations

In the course of the semester each collaborative group had to present three of their Web sites to their peers and me. As a team, my students needed to determine what topic they would research, prepare for the Web site, upload onto the Web, and present in class. Typically, the co-learner teams found relevance for their topic and could make it seem worth knowing.

There were three ways that students wrote that taught me how each person contributed to the Web site. The first way was what each student wrote about his/her own contribution to the group Web site in the individual's electronic portfolio. This was a method to track each person's accountability for group projects. I would read each student's portfolio on three occasions during the semester and comment individually via the Web.

The second way of assessing accountability of their Web site involved use of the CLS. One crucial question I asked the group members was whether the credit should be given equally or unequally within their group. Near the beginning of the semester there was one group that gave unequal credit to one group member—it never happened again with that group because the affected student attended to her share of the work. One other group of two students fell apart midway during the semester; the one student who continued her assignments indicated unequal credit each subsequent week after the dissolution. Word got around that each group member had to do his or her share of the work. I am not saying that it was always equal for every Web site. Sometimes group members worked it out with each other that if one did more in one Web site, then another would do more for the next one. They worked around each other's schedules and examinations in other courses.

The third written method of keeping track of how students contributed within their group was a form that I distributed at the end of the semester. I asked the students how each member of their group was as a learner, as a teacher, and as "being there." Each student responded using a number code; students could write comments about what happened in the group. I could get a sense of how the group interacted from using this self and group assessment of group activity form. It gave me a sense of how the individuals worked (or not) as a collaborative group.

I also had each group self- and peer-assess every group presentation. I provided the students with copies of the groups' comments pooled together so students could not tell which group had written what comment. Students learned from this feedback that they received to improve their next presentation. I think that they also became more aware how to present their Web sites more effectively while listening and providing feedback for other group's presentations.

There were some problems with the presentations of group Web sites. One reason was that many students were nervous. Through their writings I learned that the students were not only concerned with their grade for the presentation but also with their responsibilities to each other and with learning how to teach. Many of them had never taught previously. Sometimes the presentations were rushed, partly because they did not know how to pace themselves so others could learn. However, if getting the Web site up and running in class took longer than expected, we could not do the two or three presentations planned for a single 50-minute class. One student commented about this in the LEQ:

> I feel like the group presentations were always rushed and there wasn't enough time to get the actual point across. I don't think I learn as well from my peers as I do from a teacher that has studied this for 20+ years.

One student thought that I should have given individual grades for the group presentations rather than the group grades. The student said in the LEQ, "Grades for projects should be individual (This will make everyone involved more comfortable)." Another student said something similar in the LEQ: "I don't think [group work] should be totally based on your collaboration..."

Giving individual grades for a group project is something that I have not resolved, because a group project when done well involves collaboration, and then it's hard to give individual grades because it has been a joint activity. One thing I could do in the future is to give students a joint grade on the Web site and individual grades on the oral presentation to the other students in the class.

Some students felt that I should have given the students more time for group work to be completed. I realized during the course and especially afterwards that it was hard for students to have time to work together on group projects. Students had other obligations—other courses, family, part-time jobs, so that they could not always find a time in which they could all get together, plan their project, put their Web site together, and plan their presentation. One student in the LEQ said:

> Cut down on the amount of homework problems and chapters that need to be covered. Focus more on chapters and allow groups more time for group work to be completed. I know this is college, however, it's difficult to read the chapter, do the homework, research and post information and get a presentation ready every week.

I did expect a lot of my students, as there were three presentations and ten Web sites within 15 weeks. However, the technology at that time in 1998 did not support as conducive a place on the Web for students in each group to post information and files to each other, as I have now for students working in collaborative groups. Now on Blackboard, when I put the students into collaborative groups, there is not only a discussion board just for the members of that group, there is an E-mail exchange and a file exchange, so students can post information and intermediate files while a group works on a final project.

Since doing this study, when I teach a similar but less rigorous course, I have students only conduct one group project, and students can select to use PowerPoint or Web site presentation. I have also made a Web site on how to work collaboratively to create a group project. This course is an integrated laboratory-lecture, so the students give their presentations in smaller sections during the laboratory portion of the class.

Co-Learners

I must agree with Solomon (1987) on the importance of social influences in learning. I have seen some of my students in many classes thrive with social interactions as they learn from each other. Sometimes a fellow

student can explain, in a few words, what the teacher could not explain in an entire lecture. In part, it is because the fellow student has just learned it, so understands what it takes to learn it. Also, the students utilize similar styles of speaking, so they can pick up the meanings more easily from each other than from their teacher. I want my students to be able to learn from each other and to be able to teach each other.

However, it was difficult for students to learn to work together in collaborative groups. Because many of my students' traditional science classes were competitive, it was hard for them to learn to work collaboratively. Also some students may have had fears that they were inadequate, so they may have projected those fears onto each other (Brown, 2002). Retrospectively, this sort of fear and projection may have been happening in the interactions with two particular students. One time when I met with their group, the two of them were yelling at each other. The two other group members and I convinced them not to yell at each other. It was the most forceful I have seen students interacting with each other.

Many students wrote at length about having to work with and learn from others. They were passionate about whether or not they enjoyed the group work. Basically, I divided the comments into three subcategories: those by students who highlighted the strong points; those by students who wrote about the "headaches" of working with peers; and general comments about working in collaborative groups.

Students commented in the LEQ: working in a collaborative group "helped [me] to develop skills necessary to work with other people, e.g., understanding, respect for the other's opinions, learning how others learn." In other words they "pull from each other's experiences." Similarly, another student said, "Working in groups is wonderful—not only does it help to prepare you for the real world, but if you are willing to listen to others, it can help you understand and confront your weaknesses." This last comment fit nicely within my action research. By listening to my own students I could better understand what happened in the classroom. This knowledge helped me to confront my own weaknesses and how I could improve.

On the CLS, one group member said the following about what she learned from her group member:

> Working independently on loading [the Web] site made me realize how nice it was to work side by side with [my group member]. I think that after splitting the Web sites we came together more effectively. We met each other on a more equal level of expectation and performance!!!

This student suggested that in the beginning, they just split the work, so they did not work collaboratively. With time they learned to work together collaboratively and to expect approximately equal quality of work from the other.

Other students focused more on what did not work in the collaborative groups. I entitled this subcategory as "Headaches," in part due to this student's comment from the LEQ:

> Group work made this class a headache. Cooperation and effort will always lack in groups of Western cultures. The diffusion of responsibility [in group work] perpetuates many members' laziness, while hurting those who give a damn.

For me it is sad that this student has yet to experience working well with others in my class or any other. There were some who indicated on the LEQ that while they have had good experiences working in groups, they had negative experiences in our class.

> If you get someone in your group who is just determined to be unconstructive and negative, then it seems to lower the morale and definitely the whole purpose of the cooperative learning experience.

In the LEQ one student had a valid comment to increase the probability that groups would work better:

> Since we were going to work in groups for the whole semester, in the first two weeks we should have been given the chance to get to meet our group members and see if we could work effectively as a group by seeing our own interests and schedules, so that in the case the group did not fit, we could have the opportunity to change to another group.

By having fewer group projects, it would be possible to give groups more time to see how it works. What I do now is give active learning exercises in class, and they can talk with their peer during the exercise, figuring out how well they work together before it is a project with a group grade.

One student suggested in the LEQ that I provide "guidelines to promote studying with others would be helpful in the future." I looked through my students' comments and collated this list on lessons learned on how to work collaboratively on a project such as they did in our classroom. I make this list available to students since then:

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 are 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.

Suzanne's portfolio on collaboration

I utilized one student's electronic portfolio, that of Suzanne, in order to demonstrate the historical aspects within the time frame of the course—how one student felt throughout the course, on the environment for collaboration. I focus on the contradictions and the coherences that she experienced and on which she reflected in her writing in the electronic portfolio.

Suzanne had done a member check of her entire portfolio after the end of the course. By looking at her goals and her contributions to her group's 10 Web sites, it provided a historical look at how Suzanne felt about her participation in this Web-enhanced class. I read her contributions to her Web sites carefully, examining her text for contradictions and coherences in her learning biochemistry. I collated and tabulated her words for each Web site, focusing on collaboration.

Suzanne wrote that in the beginning, their group selected too many research topics to be able to focus and go into depth. Her group had a hard time arranging times to meet to work on their projects. She found that everything took a lot of time, especially in the beginning while she learned the technology. On the fifth Web site, she wished that she could have learned more from her group members on the topic of mutated plasma membranes. With time her contradictions that were apparent in the early Web sites were no longer apparent after the fifth Web site. Meanwhile, the coherences increased over the 10 Web sites. She liked being able to learn from others in her group.

Analyzing a Classroom by Writing a Story About It

With the modernist movement, writers generally portray science as a set of absolute truths. With the postmodernism movement, we are learning to break away from such representations. We are learning how to share with others what is happening within science (Capra, 1996, Shepherd, 1993) and in science classrooms (Taylor, 1998, 2002; Taylor et al, 2002). Lincoln (1997) states:

> As we absolve ourselves of the modernist fancy that texts can stand as memorials to the truth about the world, we let go of the last measure of certainty to which we might have clung… But the postmodernist textual analysis suggests that all texts are created from partial perspectives, and that furthermore, that is the best we can hope for. (p. 37)

The goal is to experiment with various representations, to push the envelope for science education reform beyond the K-12 level to the university level, to get beyond the more traditional, modernist ways of reporting science education research to a postmodern context.

As the researcher-teacher, I wonder how will different genres of writing enhance or inhibit what scholars in education and in science learn from this education research. Bruner (1986) points out the differences between narrative and the paradigmatic mode of writing, comparing the "human or human-like intention and action and the vicissitudes and consequences that mark their course" with narrative and the "heartlessness to logic: one goes where ones premises and conclusions and observations take one…" with the paradigmatic (p. 13).

Fiction serves a purpose in that it allows the feelings and dynamics of interactions to be more visible than traditional modernist accounts of university classrooms (Tierney, 1997). Stern (1991) says, "The shapes of fiction inspire by presenting ways to embody your experiences, memories, and imaginings" (p. 3). Burroway (1996) highlights this:

> Whereas the hierarchical or "vertical" nature of narrative, the power struggle, has long been acknowledged, there also appears in all narrative a "horizontal" pattern of connection and disconnection between characters[,] which is the main source of its emotional effect. (p. 35)

How I Chose to Study Learning

To demonstrate some struggles that my students experienced within collaborative groups within my biochemistry classroom, I describe how I came to write a fictionalized account from their perspectives. All the words that my students wrote about our classroom in the LEQ are available (Gilmer, 2004), but I think it may be interesting to get an impressionistic look (Taylor, 2002) by reading a fictionalized story about my classroom. I have written what I think is consistent with those data. I asked the students from my biochemistry classroom to read for the verisimilitude of the fictional story, and I ask myself whether it elicited "pedagogical thoughtfulness" (Van Manen, 1991). There is not room in this short paper for the fictionalized story, but I have included some quotes from one student after she read the fictionalized story.

Goldberg's (1990) advice on writing every day helped me gain momentum in my writing and to stay in touch with all of my being,

> …wild mind surrounds us. Western psychology calls wild mind *the unconscious,* but I think *the unconscious* is a limiting term. If it is true that we are all interpenetrated and interconnected, then wild mind includes mountains, rivers, Cadillacs, humidity, plains, emeralds, poverty, old streets in London, snow, and moon. A river and tree are not unconscious. They are part of wild mind. I do not consider even a dream unconscious. A dream is a being that travels from wild mind into the dot/monkey mind/conscious self to wake us up… So our job as writers is not to diddle around our whole lives in the dot but to take one big step out of it and sink into the big sky and write from there. Let everything run through us and grab as much as we can of it with pen and paper. Let yourself live in something that is already rightfully yours—your own wild mind. (pp. 32-33)

Sheila Ortiz-Taylor and the students in a *Fiction Workshop* class with me (who were creative writing majors) provided me considerable feedback, to improve my writing and to reflect on what happened in my classroom. We learned the culture of writers by attending the local establishment called the *Warehouse* to hear various authors read their fiction.

The audiences for this research vary from scholars in educational research to scientists who may have interests both in teaching and research. To reach such a wide audience and to paint differing perspectives on what occurred in my classroom, I have employed different genres of writing.

The Fictional Characters

The characters in my story were not actual students from my classroom, but those who might have been there. I tried to write what I think they would have said as they worked (or not) together in collaborative groups. But I remind you as Mulholland and Wallace (2000) state, "it has been argued that all stories are restories, the teller selecting from among many possibilities in lived experience to create a story in which a self is invented and other stories are repressed or forgotten." For my fictionalized story, please see Chapter 4 in my doctoral thesis (Gilmer, 2004), posted on my Web site.

Receiving Feedback on Story from My Students

I was able to contact a number of the students from my biochemistry class and asked them to read my story and provide me feedback. I only include one of student's responses from Mary, although there are more students' comments in my doctoral thesis (Gilmer, 2004). Mary was an African American student from Florida who had plans to become a high school biology and chemistry teacher. I was particularly interested in future teachers of science because at the time I was just becoming one of three co-principal investigators of a grant, called the Florida Collaborative for Excellence in Teacher Preparation, funded by the National Science Foundation.

Mary was in one of the three collaborative groups that needed attention at the beginning of the semester to help make it functional. I met with Mary and her group members for over an hour, helping the students learn to listen to each other and to work together. Mary was the student whom I interviewed in depth at the end of the semester. I transcribed her tapes myself, and my doing that opened a doorway into Mary's point of view.

About a year later Mary came to see me in my office, and I gave her a copy of the transcript from the interview. I asked her to look at the transcript and do a "member check" for me. I did not hear back from her until I sent her the fictional story and asked her for feedback on the story. That is when she found the transcript of her interview I had given her earlier. She commented on both the story and the interview. In addition, she commented on how the course has impacted how she thinks about teaching and learning. I include here a few of Mary's sentences about the story:

> This short story about the technology-based biochemistry course was excellent. The scenario depicted any group of students that worked together for the duration of the course. There is commonly a

> levelheaded member who guides the group with confidence. One or two members of the group show strength in the course content and/or the technology of computers and the Internet. Then, there is the student who is always "so busy" and lacks cooperation and commitment. As I read this short story, I tried to figure out who held these characteristics in my group and [other] members of my class.
>
> Details of the student's lifestyles and daily events give the reader(s) some insight into the student's environment. I liked the illustration of the atmosphere at Barnes and Noble. I know that I studied there from time to time when the Library got full during final exams week. Inserting the events of the tropical storm and its connection to hurricane Andrew were great. That particular part brought back memories of my own experience with Hurricane Andrew. Last, but most important, were the details of what the students planned to do over the weekend. The science majors at Mabel Clark University are very diverse in background and interests. Our university town provides an hour's access to the Gulf Coast, and a variety of activities around town. (E-mail, 27 June 2001)

It was satisfying to me that Mary felt that I portrayed the course in a way that reflected what happened. I was particularly interested that she could see the structure of the groups and how individuals in the group seem to assume certain roles. This relates to Sewell's ideas on structure and agency being in dialectic tension. It is interesting that reading the story got Mary thinking which persons in our class took which roles in the story. I know that some students did meet in Barnes & Noble Booksellers, and it seemed to have connected for Mary.

Reflecting on the fictional story

Just before starting to teach the biochemistry course, I had finished reading a book on a postmodern perspective on collaborative learning (Bruffee, 1993). I remember this was the first time I had confronted nonfoundational views of knowledge and the kinds of negotiation that occur in a nonfoundational social construction of knowledge. Having been trained within science with a foundational view of knowledge, it was a tough transition for me. Even so, I was trying to bring many of these ideas into my classroom, but in hindsight, I think I tried to do too much, too quickly, at least for the structure that was present at my university.

Reading my students' comments on the fictional story confirmed that I hit upon several of the threads of what happened in the class, but they also told me more. Therefore, my fictional story became a research tool, as I learned more about my classroom as the students felt that they could share more with me.

Conclusions and Implications

I realize now that I survived in science because I could learn by listening to lectures and by constructing my own knowledge. However, when we teach students *only* by lecture, we tend to encourage only those who learn like we do. Therefore, to break the mold, I took a radical step and incorporated all I could from what I thought would improve teaching and learning. It was as if in my action research, I did everything to the hilt, with each group preparing 10 Web sites and presenting three of them, thereby increasing the dynamics within collaborative groups. I "pushed the envelope," to find what worked and what did not. From the multitudes of interactions, I learned how to improve my teaching and my students' learning.

In hindsight, I realize that it was too radical a change. It was hard for my students suddenly to be learning in collaborative groups, trying to learn to use the Web, and writing reflectively in an electronic portfolio. Still a good number of the students grew "exponentially" in their learning of biochemistry and in their realization of the power of learning through the Internet and collaborative group work and became critical thinkers. In terms of activity theory, such students experienced externalization within a process of transformation.

I was able to contact about half of my biochemistry students, more than a year after the course ended, and shared my fictional story with them. I found that my former students' reading of my fictionalized story provided me an avenue to tap into the emotions of what happened in my classroom, to explore the feelings and incidents that were not fully visible to me at the time. Writing the fictional story became a powerful research tool, both in allowing me to put myself in my students' shoes and to think from their perspectives, but also in giving me a way to get their feedback a year later. Once the students saw that I captured some of what happened in the classroom, they told me more. Writing the fictional story and collecting my students' feedback helped me to reflect on my own autobiography and on how I could improve the teaching and learning.

In the years that it took me to analyze the data and to reflect on what happened, I have had opportunities to test the ideas that I learned through my action research while teaching other courses. I now have a Web site (and have had it for the previous two years) where I scaffold science undergraduate majors as they are learning to work collaboratively while using technology [URL: http://garnet.acns.fsu.edu/~pgilmer/glp_website/index.html; look under "Information" and under "Projects"]. This Web site has been very helpful to students who have not

yet experienced learning like this in science classrooms. It has provided a flexible structure that still allows students to select topics that interest them, but they have a procedure to follow to help them on their journey.

Now I am working on my second objective to expand this learning to other college science faculty. In the past year while still writing the dissertation, I helped a colleague in my department improve her scores on student evaluations by enhancing active learning in her classroom. To help with my second objective, I now have a book contract from Springer to publish my dissertation as a book.

Significance of the Study

I challenge higher education faculty by "inviting [them] to dance at the ongoing reform party (*a pas de deux*, rather than a solo)" (E-mail, Peter Taylor, 2 February 2004). There is much to be done to improve the teaching and learning of science in higher education. This study is significant because it is a step in that direction, and action research is something that college science faculty *can* do to improve their teaching and their students' learning.

This study is unique because of its use of CHAT, combined with social constructivism in the context of college science teaching. As more faculty become involved in the reform, a critical mass will develop, and students will become accustomed to learn in new ways. Students need to learn to use technology and to collaborate with peers in powerful ways as they move into their professions. We need to teach science as less of "just the facts, ma'am," and more as a process of our understanding of the systems under study. Currently, we tend to discourage people from learning science by how we teach it (Seymour, 1992; Tobias, 1990). This not only hurts our students and their growth as educated people, but it hurts the scientific enterprise as well. Therefore, I invite scientists to become involved in education, learn what we know about learning and how to bring that to our students.

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