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 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 already learned 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.

My secondary objective is to develop a model to help other college science faculties become aware of the critical issues in the reform movement in the teaching and learning of science, and thus improve teaching and learning in their own classrooms. I want faculty to become motivated to try new ideas in teaching, based on 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 conceptualisation and internalisation of the constructivist paradigm, which was a drastic shift from my previous positivist perspective.

For most of my professional life, I have been a practising 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. Since that time, I have come to understand constructivism as a theory of knowing that utilises viability rather than truth (Glasersfeld, 1989/1998).
constructivist realises that in the light of new experiences, one's understandings and concepts may change with time. Each of us constructs our own knowledge from our own unique set of experiences. For scientists, these include experiments, modelling, 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. I wish my teaching to reflect these beliefs about learning.

To analyse and understand the complexities of my classroom, I employ cultural-historical activity theory (or CHAT, Engeström, 1999), which focuses on what inhibits and what enhances the ability of my students (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 labour (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 use Sewell's notions and 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 (1992, p. 1). Thinking of structure as something more flexible, changing 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 an environment rich in technology and collaborative learning. I think of the culture of the classroom differently, and it helps me to analyse the results and learn from what my students say and write.

**ACTION RESEARCH**

To achieve my goals, I focused on using collaboration (Bruffee, 1993; Linn & Burbules, 1993) and technology (Glaser & Poole, 1999; Jonassen, 2000; Tobin, 2002). In the first semester of an undergraduate biochemistry course, students worked within collaborative groups to learn biochemistry by constructing group Web sites on specific topics (Gilmer, 1999). Each group of students orally presented 3 out of 10 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, to write reflectively on the class Web site, and deliver oral presentations to the rest of the class. My students were science majors or education majors who were planning on becoming practising scientists, physicians, or K–12 science teachers.

Students within my classroom struggled to learn biochemistry, while using technology and collaborating to create and present Web sites on biochemistry topics. I did this study in 1998 when the tools to create Web sites were much more primitive than now. I shared my students' struggles in two ways: (a) presenting ethnographic, qualitative data of what students said in response to various surveys, in their e-mails, or in their electronic portfolios; and (b) writing a fictionalised story with four student archetypes in my class.

My research questions included:
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 does 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 that applied to:
1. conducting an ethnographic, interpretive action research study of my biochemistry classroom (Guba & Lincoln, 1989; Schaller & Tobin, 1998); and
2. writing fiction (Burroway, 1996; Goldberg, 1990; Stern, 1991; Richardson, 1994).

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

**RESULTS**

*Using Ethnographic Evidence on Collaboration*

Glaser (1989/1998) pointed 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 utilise the comments of my students to understand and evaluate the environment for learning biochemistry.

**Group presentations.** For each Web site due, my students needed to determine what topic they would research, prepare for the Web site, upload it onto the Web, and present it in class. Typically, the teams found relevance for their topic and could make it seem worth knowing.

There were three ways that the students taught me through what they wrote how each person contributed to the Web site. The first way was what each student wrote about his or her own contribution to the group Web site in the individual's electronic portfolio. The second way of assessing accountability involved the use of a Collaborative Learning Survey (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 on 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 Learning Environment Questionnaire (LEQ) that I distributed at the end of the semester. In it, I asked the students how each member of their group was as a learner, as a teacher, and as "being there".

There were some problems with the group presentations. 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 before. 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 group grades. This student said in the LEQ, "Grades for projects should be individual (this will make everyone involved more comfortable)." Another student wrote something similar in the LEQ: "I don't think [group work] should be totally based on your collaboration..."

Students commented in the LEQ that 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."

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 worked 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 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 have been possible to give groups more
time to see how they worked together.

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

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 about her contributions to her Web sites carefully,
examining her text for contradictions and coherence in her learning of
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 in 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 was learning to use the technology. For
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, the contradictions
that were apparent in the early Web sites were no longer apparent after the fifth
Web site. Meanwhile, the coherence increased over the 10 Web sites. She liked
being able to learn from others in her group.

Analysing 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

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.

Fiction serves this purpose in that it allows the feelings and dynamics of
interactions to be more visible than traditional modernist accounts of university
presenting ways to embody your experiences, memories, and imaginings" (p. 3).

How I chose to study learning. To demonstrate some struggles that my students
experienced within collaborative groups in my biochemistry classroom, I describe
how I came to write a fictionalised 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 fictionalised story about my classroom. I have written what I
thought is consistent with the data. I asked the students from my biochemistry class
to read for the verisimilitude of the fictional story, and I asked myself whether it
elicited "pedagogical thoughtfulness" (Van Manen, 1991). There is not room here
for the fictionalised story, but I have included some quotes from one student after
she read it.

Sheila Ortiz-Taylor and the students in a fiction workshop class with me (who
were creative writing majors) gave 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
thought they would have said as they worked (or not) together in collaborative
groups. But I remind you, as Mulholland and Wallace (2000) stated, "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 the fictionalised story, please see my
doctoral thesis posted on my Web site (Gilmer, 2004).
Receiving feedback on story from my students. I include only one of the students’ responses here, 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.

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 and asked her for feedback on the story. That was when she found the transcript of her interview I had given her earlier. She commented by e-mail on both the story and the interview. In addition, she commented on how the course had impacted how she thinks about teaching and learning. I include here a few of Mary’s sentences about the story:

The [story] depicted any group of students that worked together for the duration of the course. There is commonly a level headed 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.

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, suggesting Sewell’s ideas on structure and agency being in dialectic tension. It is interesting that reading the story got Mary thinking about which persons in our class took which roles in the story.

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 non-foundational views of knowledge and the kinds of negotiation that occur in a non-foundational social construction of knowledge. Having been trained in 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.

Reading my students’ comments on the fictionalised story confirmed that I had 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.

REFERENCES


