RESEARCH REPORT

Understanding Chemistry Professors' Use of Educational Technologies: An activity theoretical approach

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The aim of this study is to understand the influences on chemistry professors' use of educational technology. For this, we use activity theory to focus on two university chemistry professors and the broader activity system in which they work. We analyse their beliefs and past experiences related to teaching, learning, and technology as well as other components of the activity system of teaching chemistry with understanding. We employ a qualitative methodology with phenomenological and symbolic interactionist perspectives. Our findings illustrate various contradictions within and between the components of the activity system. Those include the insufficient level of collaboration, reflection, and communication among faculty members, constraints for reform-based chemistry teaching, limitations of large class sizes, and "poor" design of technology-enhanced classrooms. We propose several possible resolutions to transform undergraduate chemistry education, including the effective utilization of technology-enhanced teaching strategies and building a more uniform culture of teaching within science content departments.

Introduction

Although the current reform efforts in science education in the USA typically target K–12 teaching (American Association for the Advancement of Science, 1989, 1993; National Research Council [NRC], 1996, 2000), there is a growing realization that, for science teaching in U.S. public schools to change, there must be a change in the way of approaching undergraduate education. Undergraduate education is where most future teachers refine and elaborate on their science knowledge. College students often find that conceptually fragmented content instruction can act as an impediment to the teaching and learning of reform-based science (Cheney, 1990; Meier, Cobbs, & Nicol, 1998; Gess-Newsome & Lederman, 1999; Taylor, Gilmer &
There are well-recognized constraints that shape much of the undergraduate science education—economic pressures force many institutions to offer large class sizes; faculties shape their teaching more by the demands of the content than the learning needs of the students; the patterns of instruction that science faculties experience as students shape their beliefs about teaching and learning (Southerland, Gess-Newsome & Johnston, 2003); and the reward system for faculty in doctoral/research universities extensively favours research over teaching (McCormick, 2001).

Despite these constraints, the NRC (1996, 2000) suggests that there are ways to overcome the limitations in patterns of undergraduate education. Although it acknowledges the complex demands of content, classroom size, and external expectations, the NRC (1996) introduces some general guidelines to enhance undergraduate learning. As described by these guidelines, teaching should engage students in active learning, allow students to make sense of observations and conceptions before the faculty member introduces the student to terms and facts, and foster a sense of a classroom learning community. Such elements of science education reform call for a pedagogical shift from a teacher-centred, textbook-based instructional paradigm to a student-centred, inquiry-based model (Von Secker, 2002).

Student-centred models based on constructivist principles emphasize active learning in “truly interactive” (Leonard, 2000, p. 385) lectures as well as making connections to students’ previous experiences. Teacher-centred teachers assume a dominant role in the classroom, as the principal conduit for dispensing knowledge, while student-centred teachers espouse beliefs and classroom practices more closely aligned with a negotiated understanding and inquiry (Simmons et al., 1999).

Fostering a “learning community”, engaging “active learning”, and requiring students to “make sense” of observations and concepts, all ideas suggested by the NRC (1996) and other national reform efforts geared towards a student-centred teaching, are tall orders if one is teaching a class of 50 or more students. Recognizing the need to move to such approaches within the institutional context of large classes, many institutions have embraced the use of educational technologies. Electronic mail, the Internet, and World Wide Web are seen as important tools in enhancing the learning experiences of the undergraduates in our science classrooms (Butler, 2001). Integrating technology and education can enhance teaching and learning activities in ways that can support student-centred teaching (Alexander, 1999; Beal, 2000; Cajas, 2001; Cope & Ward, 2002; Edelson, 2001; Jarvela, Bonk, Lehtinen, & Lehti, 1999; Jonassen, Hernandez-Serrano, & Choi, 2000; Lancashire, 2000).

Many argue that technologies are tools and mediation systems (or mediating artifacts) whose function is to support the formulation and exchange of ideas, reflection and meaning-making (Jonassen et al., 2000). In this sense, technologies have the potential of promoting the construction of knowledge, changing the usual passive form of traditional learning guided predominantly by the teacher (Amiri, 2000) to a more active form. Especially, in the discipline of chemistry, using computer animation tools and multimedia for helping students learn chemical phenomena at atomic
or molecular levels may be extremely important (Brooks, Nolan, & Gallagher, 2001), and central when it comes to reach out students with weaker chemistry backgrounds as well as being important for students who are women (Nakhleh, Donovan, & Parrill, 2000; Donovan & Nakhleh, 2001).

Despite this promise, there is an ongoing debate among scholars regarding the effectiveness of technology for educational purposes. Lancashire (2000) describes advances in the areas of computer hardware and software, Internet, and the World Wide Web over the past 20 years, noting “the Internet has made a huge impact on the way chemists work, but as yet far less on the way they teach” (p. 239). Cuban (2001, p. 179) echoes this, suggesting that “computers have been oversold [to schools] and underused, at least for now”. Indeed, technology has not had the expected impact on enhancing teaching and learning, as lecturing has remained a central approach to undergraduate education in the USA, a trend he attributes to the structural and cultural inhibitions to change (Cuban, 2001).

Cope and Ward’s (2002) work furthers Cuban’s structural focus to suggest that teachers’ beliefs about technology are vital factors to its successful integration into teaching and learning activities. These beliefs include teachers’ beliefs about students and the learning process, about teachers and teaching, and about epistemology or the nature of knowledge (Levitt, 2001). Like their K–12 counterparts, numerous researchers argue that scientists’ beliefs play a critical role in their enactment of science curriculum (Gess-Newsome, Southerland, Johnston & Woodbury, 2003; Southerland et al., 2003), and others argue that scientists’ beliefs influence their practice more than other factors such as the specific setting (context) or subject content (Blake, 2002).

Clearly, universities expend vast amounts of resources to equip “technology-enhanced” classrooms in the hope that such expenditures will translate to improve undergraduate learning (Squires, Canole, & Jacobs, 2000). However, despite Lancashire’s (2000) and Cuban’s (2001) cautionary words, and Cope and Ward’s (2002) conclusion about beliefs and technology utilization, scant information exists on how scientists interpret and negotiate such environments. Therefore, in this research we investigate the ways in which two chemists employ technology while teaching undergraduate chemistry and the contradictions that arise.

One approach to understanding the use of technology in undergraduate chemistry teaching would be to focus on the role of beliefs of teachers (in this case, scientists as teachers) in shaping classroom uses of technology for teaching. However, even while we find the teacher belief literature useful in helping understand the enactment of reform, and have conducted such research ourselves (Southerland et al., 2003), we recognize that there is a limitation to such approaches. While fundamentally important, a sole emphasis on teacher beliefs leaves the reader to focus only on the teacher as the unit of change—thus placing responsibility for change on the individual or individual(s) as it removes responsibility from the greater structural and cultural features of schooling to support, permit, and foster change.

In an attempt to acknowledge and include such explanations, we have employed cultural–historical activity theory (Engeström & Miettinen, 1999) to understand the
use of a technology-enhanced classroom in teaching undergraduate chemistry. We selected activity theory as the frame in which to search for meaning in this research, as this frame not only requires the researcher to describe teacher beliefs and knowledge, but also embodies a serious consideration of the other aspects of the activity system, including the structural, cultural, and historical features that shape the activity of teaching chemistry. Also, an important aspect of activity theory is the analysis of imbalances or contradictions in the overall system (Engeström, 1987; Roth, Tobin, Zimmermann, Bryant, & Davis, 2002), a search for features of the system that are at odds with one another. In other words, in this analysis it is essential to illuminate areas of conflict. Thus, like Issroff and Scanlon (2002), we find activity theory to hold promise for generating a better understanding of the tensions, or contradictions, when faculty do or do not employ technology in undergraduate education, in this specific case, in undergraduate chemistry education.

Cultural-Historical Activity Theory

Activity theory represents a unit of analysis in the framework of "object-oriented, collective, and culturally mediated human activity, or activity system" (Engeström & Miettinen, 1999, p. 9). By contrasting the societal, historical, and collaborative nature of actions, Engeström proposes the collective activity system (Figure 1).

Engeström (1998) and Issroff and Scanlon (2002) understand an activity as a form of doing, directed toward an object. The subject in the activity system refers to the individual or subgroups whose agency the researcher chooses as the point of view in the analysis. The community comprises multiple individuals and/or subgroups who

![Figure 1. Engeström's activity theory model](image-url)
share the same general object and who construct themselves as distinct from other communities. The object refers to the "raw material" or "problem space" at which the subject directs the activity, and the object connects the individual actions in a system into a collective activity. One distinguishes an activity system from another on the basis of the objects.

For example, in the activity system at hand, the object is the teaching and learning of chemistry with understanding. Scientists, educators, and the university administration, to name a few, accomplish this object through complex interactions. In an activity system of reforming education, their object would be to establish standards toward which science education would be geared. In this case again, there are various other communities interacting with one another with this object in the background.

Subjects feel motivated by the need to transform an object into an outcome, which "consists of societally important new, objectified meanings and relatively lasting new patterns of interactions" (Engeström, 1999, p. 31). In an activity system of chemistry education, the outcome might be forming new learning communities and producing new intellectual tools, compared with solely teaching the principles of the science of chemistry.

The transformation is the process when the object leads productively to the outcome. In other words, while the object and the outcome represent the milestones of the activity system, there is a gap between the two that needs to be bridged by transforming the system. Division of labour is the implicit and explicit organization of a community as related to the transformation of the object into the outcome. Thus, this includes both the horizontal division of tasks between the members of the community and to the vertical division of power and status. The rules component includes the explicit and implicit regulations, norms, and conventions that focus and constrain actions and interactions within the activity system.

When the subjects change the elements of the activity system, internal contradictions, or areas of conflict, either within or between different elements of this system, may be introduced. Although it seems negative, contradictions and their resolution are the driving force of change and development within an activity system. Activity systems are almost always in flux as the system works through contradictions.

Our research focus is to understand the ways in which the subjects utilize technology in teaching undergraduate chemistry. For this analysis represent graphically the activity system for this analysis of the teaching and learning of chemistry (Figure 2).

The subjects of the activity system we describe are two chemistry professors who teach within a technology-enhanced classroom at a research university in the western USA. The object of this activity system is the teaching of chemistry via means of textbooks, supplies, physical environment, learning technologies, teaching methods, and the like (mediating artefacts). The communities that share the same general object include science and science education faculty members, the computing services at the institution, and the upper administration. Optimally, these subjects and the communities work together towards teaching science, and, more specifically in our study, chemistry. Each member in each of the communities has his or
her role in the activity system (division of labour) and, overall, they have a "collective responsibility" (Roth et al., 2002) towards reaching the object. The mediating artefacts that the professors use and the ways that they use them are historically developed by the structure of the institution (Sewell, 1992) and the culture of teaching and learning of which they are a part (rules). The eventual outcome of this activity is the development of new learning communities and new intellectual tools. Via chemistry education, there is the potential outcome that the students will create new learning communities of various fields, such as in science, medicine, engineering, and science education. The students would not only understand and comprehend the chemical concepts and principles, but also develop intellectually and become able to solve more complicated problems that they encounter in life.

From an activity theoretical perspective, one of our primary concerns is the investigation of the two chemistry professors' uses of technology in their teaching of chemistry, in tandem with an analysis of their beliefs about utilizing technology in their teaching. Thus, one important aspect of the analysis of this activity system is looking into the subjects, their beliefs about teaching, learning and technology, and their past experiences with teaching and learning chemistry and using technology. We complement this analysis by describing other components of the system as we search for possible tensions and contradictions existing within or between system components, contradictions that may be hindering the object of teaching chemistry.
with understanding and the outcome of the emergence of new learning communities and new intellectual tools.

**Methodology**

**Study Design**

We employed a qualitative methodology with phenomenological and symbolic interactionist perspectives (Bogdan & Biklen, 1998). Within these theoretical frames, individuals are understood to revisit and adjust their behavior patterns depending on the interactions they have in the society. In other words, people generally share meanings and grow through interactions (Jacob, 1987).

This study focuses on the teaching of introductory chemistry by two chemistry university professors, Ryan and Matthew, as we seek to understand the forces that influence their uses of technology in teaching. The participants and the contexts in which they work will be described in more detail in the results section.

We used three qualitative research methods for data collection: participant observation, in-depth interviewing, and artefact analysis (Bogdan & Biklen, 1998). We observed Ryan in his class for a semester at various times, in total for about nine class periods (50 min each time). Observations for Matthew lasted about five class periods, ranging from 35 to 55 min. We took field notes (Bogdan & Biklen, 1998) in the following frame: (1) description of the physical environment, (2) events in the classroom with the teacher and the students as “actors”, and (3) observer’s comments (Bogdan & Biklen, 1998). These field notes later served as a background information while interviewing the faculty members.

We used a semistructured format of interviewing (Kvale, 1996) in which there was a sequence of themes and suggested questions, as well as an openness to change the questions depending on the answers of the interviewees (see Appendix for the interview protocol). We videotaped the interviews and transcribed the dialogues verbatim. We provided a brief description of the study prior to each professor’s first interview and confirmed that we would keep their identities and the location of the study confidential.

We conducted a number of interviews with each of the professors, some interviews being in follow-up nature and in electronic format. The face-to-face interviews ranged from 13 to 35 min in length. We tried to understand the chemistry professors’ beliefs of teaching chemistry, the meaning of technology, and teaching with technology. We utilized course handouts, syllabi, examinations, quizzes, Ryan’s BlackBoard site, Ryan’s “one-minute takes” distributed occasionally to the students for their opinions about the various components of the course, and the web sites developed by Ryan’s students as projects for extra credit. Our purpose was to deepen our understanding about the teaching and learning of the professors and their approach to use of technology. We examined other sources such as the university and departmental bulletins to better understand the context of our study. These artefacts complemented our making sense of the observation and interview data. We
qualitatively analysed our data and made in-depth elaborations by looking through the lens of activity theory.

**Analysis of Data**

We performed the data analysis in five phases. First, by analysing the artefacts and the field notes from the observations, we determined potential interview questions. Second, we transcribed the videotaped interviews verbatim and coded the transcriptions. We performed the “member checking” process to verify the constructions with the interviewees, and to prevent incorrect and unintended interpretations of data (Guba & Lincoln, 1989). Third, we categorized the emerging patterns of the three themes, beliefs of chemistry teaching, technology perceptions, and learning experiences, in symbolic trees. We made interpretations about the similarities and differences in light of the three emerging themes and their interrelations.

As we began data analysis, Matthew deviated significantly from Ryan in his comments, beliefs and teaching approaches. Ryan’s views about the role of technology in teaching college-level chemistry were more reform minded, compared with Matthew. Thus, Matthew’s case disconfirmed our original assumptions that championed the use of technology in teaching. His “negative case” forced us to make new connections among the components of our activity system (Ryan & Bernard, 2000) and to look for explanatory contradictions. So in the fifth phase, with the activity theoretic lens, we looked for possible contradictions among the elements of the chemistry education system. We triangulated the multiple data sources, such as observations, interviews, and artefacts, ensuring that we investigated teaching college-level chemistry with a technology-enhanced approach, from different aspects, using multiple processes to clarify meaning (Creswell, 1994; Stake, 2000).

**Findings**

**Context of the Study**

A teaching and research university in the western USA was the site and context of our study. The university encompasses the subjects, rules, and communities, and the interactions among these and the other components in the activity system. As stated in the university’s bulletin, the university’s philosophy of undergraduate education goes beyond the “acquisition of skills” needed for employment. The university’s history and philosophy centre on students learning both the arts and the sciences in order to understand the current technological world.

The technological emphasis goes beyond the undergraduate teaching philosophy. Indeed, the university is one of the highest ranked with respect to its technological infrastructure and scientific research. As indicated in the university bulletin, according to the *Yahoo!* magazine, the university is the most wired university in the state, and it ranks in the top tier of technologically advanced universities in the country. On campus, students have free Internet access to virtually every online
research database in the world, including one developed, tested, and first used at this university.

Naturally, the emphasis given to technology in the university leads to form strong infrastructure and communities related with computing. In other words, as Sewell (1992) points out, the technological resources become the products of the cultural schemas within the university structure. As advertised through the university bulletin, faculties often implement web-based or web-supported teaching, and it is common for students to contact their professors online for academic assistance. The bulletin implies that there is a strong interaction between the subjects and the learning technologies (mediating artefacts) with the object of teaching and learning chemistry. The faculties’ use of technology in their teaching perpetuates the role of the computing communities with respect to education, and it also allows for potentially enhanced student learning.

The Chemistry Department’s approach to undergraduate education also reflects the technological emphasis in the cultural schemas (Sewell, 1992) of the university. Initially funded through a federal grant to improve undergraduate teaching, there is an undergraduate chemistry computer laboratory available to students enrolled in courses through the department. The students can use various software programs and computer simulations of chemistry experiments, allowing them to explore issues in more depth. The undergraduates offer their synthesized products for nuclear magnetic resonance analysis and get their results through the computing system.

Just as it is in the laboratory approach, lectures, too, are to have a strong technological component in the chemistry department. To encourage using technology in lectures, the department has provided faculty with a cultural “tool kit” or repertoire (p. 277) as mediating artefacts. For example, the department touts a large chemistry lecture hall recently renovated with modern technological equipments as “the state-of-the-art lecture facility” in its departmental bulletin to “bring technology and an improved learning situation to students”. The lecture hall includes computer and projection systems with two big screens for projection on the front wall. There are two large, lit periodic tables on both sides of the screens. This is a major investment for the university, indicating in part the value the university places on the use of technology in teaching.

The hall can hold about 230 students; clearly the purpose of the hall is to conduct large, economically efficient classes such as General Chemistry. The prominence of technology in the hall signals that the intentions are to balance the “low” effectiveness of teaching and learning in the context of large classes with the “high” technology embedded in the design. The students’ chairs, mounted to the ground, can swivel. The downstairs main section has the seats arranged in rows, like in a theatre. There is a pathway down the middle of the hall allowing the teacher to come closer to the students and to move between the rows.

There is also a balcony, which represents the “upstairs”. The balcony includes about the same number of rows as “downstairs” and has a similar structure. Students sitting in the balcony can easily see the big screens, but they cannot see the teacher if he or she moves closer to the students downstairs.
Given the acoustics, the instructor must use the microphone to be heard throughout the lecture hall, so most instructors stay close to the teacher's desk. This desk provides a long and wide space for demonstration materials and course documents. On one side of the teacher's desk is a computer connected to the projection system and to the big screens. On the other side of the desk there is a laboratory desk, suitable for chemistry demonstrations. There is a camera attached to the demonstration side of the desk, so that the students can see the demonstrations projected onto the screens. Using the computer the teacher can project one image onto one screen and a different image onto the second. In the middle of the desk there is an overhead projector allowing the teacher to write notes and project these onto the screens.

As described by Tobias (1990) in *Stalking the Second Tier*, the students in the lecture hall demonstrate two different cultures depending on the place in which they sit; indeed, as explained by Sewell (1999), the student culture expresses contradictions. The students downstairs are usually more attentive, and ask or answer questions when encouraged. On the other hand, the students preferring to sit in the balcony, which is somewhat isolated from the rest of hall, are silent compared with their peers downstairs. It is difficult for the professor to even see the students in the balcony. Some take notes from the big screens, some just listen to the teacher and watch the screens, some talk with each other, others read newspapers, eat potato chips, or sleep. Clearly, they have no chance of participating in the chemical demonstrations that occur downstairs. A safety barrier at the base of the balcony distances the students from the teacher, their peers downstairs, and the centre of teaching and learning even more.

According to the university bulletin, the university hires faculty members for their commitment to excellence in teaching, research, and public service. The university and individual departments support the use of technology in teaching by providing the infrastructure described above, as well as offering a host of professional development experiences for faculty to become familiar with online teaching tools. Echoing the broader campus, the Chair of the Department of Chemistry indicates that “many chemistry faculty members utilize technology in the classroom and make their courses available through the Internet”*. Based on the philosophy of the university, the infrastructural investment of the department, and the comments of the Chair, the overall picture of undergraduate education reflects that the university is one in which the university and department provide the resources and encouragement to teach with technology. In other words, transformation is the goal of these administrators and the resources provided are expected to have influence on faculty schemas of teaching (Sewell, 1992). Faculty members are to provide the intellectual capital to use the technology well to teach chemistry.

*Understanding the Participants*

In contrast to many other research institutions, the department has entrusted the introductory chemistry courses to only senior faculty in an effort to ensure that the
undergraduates receive the best teaching available. Indeed, the participants in this study were two senior faculty teaching introductory chemistry courses. Our intentions were to investigate the activity system of their teaching, a system that includes teachers' beliefs about teaching with technology, to understand the schemas that influence the ways in which the faculty enact their beliefs in practice, and to look for possible tensions in their teaching with technology-enhanced approach.

Both of the chemistry professors involved in this study had college-level teaching experience of 33 and 40 years. Both were men and full professors. Both had outstanding educational accomplishments. The university named Matthew as the university's distinguished professor, and the Chemistry Department selected him to receive a newly named professorship for his excellence in teaching. He is also a recipient of many other university teaching awards. Also notable, in a different manner, Ryan has been involved in science educational research projects at various times throughout his career, and he often works collaboratively with graduate students from the College of Education at the institution. Also, Ryan has been a principal investigator on a number of National Science Foundation-funded teacher preparation and teacher enhancement programs and has been involved in research in science education.

Each of the professors had about 100 students in their introductory chemistry course. Most of the students in these courses were freshmen, or first-year students in the university. At the time of this study, Ryan taught in the spring semester and Matthew taught in the fall semester.

We examine the faculty members' cultural schemas (Sewell, 1992) in depth and look at the interaction between their schemas and the available resources (mediating artefacts) at the university, and specifically available in the chemistry classroom, as well as at interactions among the other components in our activity system. We present our findings with supportive data across the themes that emerged from our analysis. The themes are: teaching beliefs, learning experiences, and technology perceptions.

Teaching beliefs identify how the faculty members set the teaching and learning environment along the continuum of a constructivist or traditional teacher-centred approach (Taylor, Fraser, & Fisher, 1997), and how they implement the college chemistry curriculum. As discussed previously, these can be central in shaping what happens in the classroom. Learning experiences are the professors' reflections on their own experiences of learning chemistry and on the methods that their teachers used to teach them chemistry. Technology perceptions are their beliefs about teaching chemistry with technology.

**Teaching Beliefs**

*Matthew: Textbook, lecturing, and interactions.* Matthew was older than Ryan and very close to retirement. The students in his classes appeared respectful, listening to his lectures quietly and carefully. Nearly all of the students seemed to be busy with writing lecture notes, or performing calculations for the problems Matthew posed...
from time to time. Those not actively recording notes simply sat and watched the whiteboard.

One of the most common practices in Matthew’s teaching was for the students to read the textbook and solve chemical problems, usually geared towards the types of the questions that would appear on the examinations. He linked the problems that he solved in class to the problems on the mid-term or final examinations.

Matthew attributed “good” teaching to the teacher’s own personality. He commented, “I think teaching is a manifestation of one’s personality whether you are good at it or not good at it, more than a methodology” (interview, September 7 2002). He strongly believed that “good” teaching was strongly dependent on how well the teacher explains things and how well he communicates. He recognized that his teaching centred on lecturing, which he defined as standing up in front of the students and explaining things in own words. Matthew’s enthusiasm to lecture was evident in our observations, too, as he usually stepped up in the lecture hall and walked among their desks while talking rapidly, offering descriptions at a fast clip. Such an approach to teaching highlights the interactions between the subject and the object in the activity system of chemistry education constraining the interactions with and among the rest of the components. In his schema of teaching chemistry, Matthew understands the teacher as the most important component of a school setting, leaving other interactions in the activity system in the background.

Matthew used his proximity to students to enhance communication and to try to ensure that students “understood” the topic. He commonly walked toward students, and asked questions during his fast-paced lectures. These questions seemed to be genuine attempts to solicit student’ reactions; however, the wait time for responses was very short. Given that Matthew’s average wait time was around 5 s, combined with the structure of the classroom, it seemed that students barely had time to think about the questions before the lecture would move on. Given his quick pace of speech, his rapid progression through the material and limited wait time, Matthew always appeared to be in a “rush”. This rapid, lecture-based approach to teaching seems to be partly related with the loaded curriculum, or the “university rules and organization” in the activity triangle. This creates a contradiction between the subject and the rules in our activity system toward the object of teaching chemistry with understanding.

As suggested by his physical movement toward students during his lectures, Matthew placed a premium on having “interactions” with students while teaching.

I believe in lecturing to students, I believe in having interaction one to one ... I believe in having interaction going on in the classroom ... I believe that teaching has to come from both of text and the lecture, to put one another, to put the two things in perspective ... (Interview, September 7 2002)

Predominantly, in Matthew’s view, “interactions” were about being “close” enough to students and to “tell them what to learn and what to do”. Matthew argued that a teacher should indicate that “these things are important and other things are not as important, but these are the most important things” (interview, September 7 2002).
So, his conceptualization of “interactions” differed from that mostly emphasized in the social constructivist literature that describes interactions as an important means of involving the students actively in their learning (Leonard, 2000).

It is a common understanding that there are three types of interactions in a classroom—teacher–student, student–material/textbook, and student–student interactions—and the more diverse the interactions in a classroom, the more effective is the teaching and learning (Kahveci, 2001; VanSickle & Spector, 1996). Among these, Matthew seemed to emphasize the teacher–student and student–textbook interactions. However, in Matthew’s case, “interacting” in class seemed to mean “transmitting” information and ensuring that every individual student learned the subject matter. Although in the interviews Matthew emphasized the importance of asking the students questions during class time and encouraging them to think and answer, this approach was not as evident in his teaching practice. Matthew mentioned that “teaching a large class” cut back on his interactions and restricted his communication with the students:

Not with all of the students by no stretch of imagination [is interaction one-on-one possible]. There will be a number of questions that will be answered. I have a class now of about 130 students and during the course of an hour lecture I will probably entertain perhaps ... six to eight questions, quick, short-answered questions, the more questions than that come from help sessions, from recitations and things of this sort.

(Interview, September 7 2002)

In other words, in Matthew’s class the predominant mode of teacher–student interaction was one-way; the flow of information was from the teacher to the student, with again the emphasis on the subject in Matthew’s case.

Ryan: Collaboration and technology. Ryan was in his fifties, and had a very energetic personality. In contrast with Matthew, Ryan did not emphasize the centrality of the subject in the chemistry education activity system. Rather, he seemed to involve the other components, as well, highlighting the interactions among them. For example, Ryan relied on other mediating artefacts than the textbook or lecturing, and also he was in continuous contact with the community of science education to improve his teaching.

Ryan’s teaching approach could be best described by the term pedagogical “bricolage”, meaning “a pieced-together set of representations that are fitted to the specifics of a complex situation” (Denzin & Lincoln, 2000, p. 4). In other words, he did not have as strong emphasis on lecturing, reading the textbook, or problem- but on a “pedagogical mix” of these. He applied a variety of collaborative learning activities and use of technology during his lectures. Lecturing and problem-solving were just two of the methods he blended with his ways of communication. His concern was whether what he was doing in class engaged each individual student in thinking and learning:

I encourage students to read the book because that is a source of information, then I try and... give them my perspective on the chapter and chemistry in general, you know, like
how different things are interconnected and that chemistry is real ... Then I encourage students to work on problems because I feel that is an important way to learn ... 

... I do not think there is any one thing that works for every single person. So, that is why, I think you need a variety of different ways to try and reach your students ...

(Interview, October 7 2002)

Ryan “watched” his students’ learning and made curriculum adjustments so that they became more actively engaged. For instance, as Ryan explained, some students learned better by having a chance to talk about how they were thinking on a problem. In the periods when Ryan allowed his students to try solving a problem in class, he encouraged them to talk with their neighbours. The students tended to ask more questions to the teacher after these problem-solving periods. This type of activity helped engage the students during class, making them more active learners. This role of teaching is in congruence with the “science is for all students” principle of the National Science Education Standards (NRC, 1996).

The National Science Education Standards also propose teaching science as inquiry in which students actively interact with their teachers and peers, to “establish connections between their current knowledge of science and the scientific knowledge found in many sources ...” and to “engage in problem solving, planning, decision making, and group discussions” (NRC, 1996, p. 20). This is echoed in how Ryan spoke about engaging students during class: “I think it is important for students to see a connection between this abstract information and the real world”.

I did give them some time to try and solve a problem, in class. You know, where they could talk to their neighbour, let’s say I went over like a sample calculation, then I give them a similar sort of one, so instead of they are having to put it off [trying it] when they got home ... So, that engages them a little bit more, [and] I noticed that there were generally quite a few more questions right after that, than there would have been in a normal five minutes ... (Interview, October 7 2002)

By providing time to attempt a calculation similar to the one he completed, students were allowed to become more actively involved. Indeed, Ryan encouraged them to talk to their neighbour if there was something that they did not understand. In contrast, Matthew gave quizzes as homework, but did not allow any class time for problem-solving. So, during our observations, Matthew did not seem to emphasize in-class problem-solving and peer interactions in the same manner Ryan did.

Ryan utilized technology in his teaching to open up opportunities for different activities in class. In other words, from a social constructivist view of point, he used “facilitating techniques” (Dunlap & Grabinger, 1996) to ensure that his students were learning actively. For example, Ryan’s use of the web site BlackBoard, which was “founded to transform the Internet into a powerful environment for the education experience” and used by thousands of institutions in 145 countries (BlackBoard, 2004), gave him opportunities to “facilitate” learning instead of “transmitting” knowledge. Ryan offered extra credit to students who created a web site that indicated their goals for the course and an example of how the chemistry they were learning in the classroom pertained to the real world in an attempt to enhance their
metacognitive approach to the material. Students who chose to do this updated the web site at the beginning, midway, and at the end of the course. By Ryan reading and commenting to his students on their web sites, he learned his students’ goals and motivations and how they related chemistry to their own lives. He could then bring his understandings of his students’ perspectives into the classroom, for example, by how he introduced a topic or examples that he chose to make a point. About 100 out of 160 students posted web sites.

It [my purpose in having them use technology] was to get them used to [using] technology, learning how much information is out there and empowering them to have their own [Web] page. I know some students wrote like, “Wow, I did it, you know, and I always ... I knew that it was possible, but I had no idea how to do it!” So that gives them a chance. (Interview, October 7 2002)

Ryan’s beliefs about teaching were in harmony with his use of technology in practice. He utilized technology as a tool to create activities in class, which he intended to facilitate student learning in a more student-centred environment. Ryan’s schemes of teaching chemistry were resonant with the other components of the activity system and, unlike Matthew, had equal emphasis on the subject and the other components.

Technology in the Professors’ Teaching

Matthew centred his teaching on his ability to explain. For him, teaching involved the effective communication of an explanation for students. For this, he believed in his “own powers”, and in his own personality to communicate in the classroom. Because of his emphasis on the subject, technology or the mediating artefacts became minor factor in shaping his teaching; moreover, his argument was that technology could easily get in the way of his teaching and that it had a potential to hinder student learning. When Matthew used technology, such as the projected screens in the lecture hall, he usually used it to simply gain attention for his lectures or problem-solving.

Technology up to a point can, yes, [can enhance teaching and learning]. In the sense that ... the technology will allow you to have [a] better visual display, that can be an enhancement ... the facility in which a lecture takes place can be a better environment, that can enhance learning, to the degree the computers become part of the learning process, that can be an enhancement, things of this sort, that kind of technology, but ... I do not believe that they [technologies] really will supersede a person who is skilled in the field talking to a group of people who want to learn that field.

... I write everything as I go along on a projected piece of paper so that I can explain it as I go, so that I can show them what I am doing when I am doing a problem. (Interview, September 7 2002; emphasis added)

Indeed, there seemed to be a real conflict for Matthew in the educational value of technology and the most recent technological developments outside the classroom in the “real” world. In our dialogue with him, Matthew often stressed a number of disadvantages that the developing technologies had brought in the classroom. He
saw the need to “be heard over” the technology that his students used for entertainment or learning outside the school setting. His basic assumption was that technologies were mostly providing “surface learning”, which Chin and Brown (2000) describe as memorizing facts, reproducing terms and procedures, and not being able to make connections between these facts and the real life. According to Matthew, technologies offer only the potential of surface learning, and would give the students the illusion that they learned more than they actually did. On the other hand, he saw students’ enthusiasm to use technologies including those for entertainment as a barrier to see “this reality”.

Unfortunately, I think the students view one of these tutorials, video CD-ROMs, and they feel that they understand things more deeply than they do. And then they get to an exam and suddenly things are not quite as clean and shiny as they were in the video.

... I mean, we compete with video games, and televisions, and radio, and everything else, that, that are constantly communicating to students... (Interview, September 7 2002)

Matthew’s argument, although in retrospect seems a common one among teachers, was surprising at the time. Indeed, at the outset of the study we as researchers assumed that technology would universally be accepted as a tool for enhancing learning. However, given Matthew’s emphasis on the role of an effective “communication” of “good explanation”, such an understanding of the influence of pop culture on students’ consumption of technology and the sometimes superficial approaches to learning it can engender are compelling.

In contrast, in Ryan’s case, technology, as a mediating artefact, served his object of teaching chemistry with understanding. In light of his teaching beliefs that it is important to reach every single student and engage him or her in the learning process, Ryan utilized technology in his practice in a way that ensured a variety of activities. First of all, he used the web site BlackBoard to communicate with his students. He uploaded course documents such as the syllabus, and information about the demonstrations that he did in class. This information included detailed descriptions of the experiments performed and its associated chemical equations. He also used BlackBoard for reminding students of important dates, such as those for the examinations. Second, in addition to encouraging the students to work on problems in groups in class, he employed virtual collaborative teaching by fostering them to participate in online group and class discussions. For instance, Ryan’s students could access each other’s web sites that they posted on BlackBoard and learn from other students’ connections between chemistry and the real world. He also encouraged them to use other BlackBoard features such as electronic mailing to send emails to more than one peer at once by just checking the related boxes, and also the chatting platform. He also put his students in collaborative groups in BlackBoard so they could communicate easily as a group. Third, during class, Ryan often referred to other web sites that had animations and interactive visual representations related to the topics.

It is interesting to note that both professors pointed to the PowerPoint presentations as being problematic. Each explained that these presentations simplified the act
of teaching chemistry, and gave the illusion to the students that everything is as it is on the slides. In other words, these faculty members saw such presentations as a barrier between the students and the teacher’s input to their learning; in their presence, the teacher lost his voice as either a lecturer or facilitator. According to Khalifa and Lam (2002), PowerPoint presentations are mostly “linear learning materials” and do not generally contribute to student learning. However, Ryan had found a way to “activate” his slides, for example, by hyperlinking to web sites with relevance to the chemistry under study or to digital demonstrations of chemical principles, mainly from the University of Wisconsin web site (http://genchem.chem.wisc.edu/demonstrations/). However, he did not use PowerPoint slides extensively in his teaching; instead, he preferred them to be tools for fostering student–student interactions, thereby encouraging his students to use them.

I think PowerPoint slides, they are good because it forces you to organize it, as the presenter and get the information together, and plus you can hyperlink to Web sites, you know, to make it easy to go from one thing to another...

... And plus they are having to construct meaning, to use words and sentences both on the PowerPoint presentation and when they speak to their peers ... and it is different, you know, they are having that opportunity to speak with their peers. (Interview, October 7 2002)

Email communication was a second prominent technological tool in this study, and one that both professors found very useful in terms of enhancing interaction with their students. They emphasized its significance especially in cases of having large classes, in which one-on-one interaction with the students was less likely. However, they diverged in their perspectives and in the way they used email. Matthew used it primarily for answering questions coming from the students related with the subject matter and as a tool for announcing schedule arrangements. On the other hand, Ryan used email as a lens for getting to know his students better, in addition to answering content-related questions.

One of the things is that you learn your students’ interests [through electronic mails] because they write to you that... something about their lives, what major they are in ...

So, I feel that communication helps me understand them, where they are in their learning ... what their questions are... (Interview, October 7 2002)

By Ryan “knowing his students more”, he could tailor the classroom-learning environment to make his students more active learners. For example, students wrote of their concerns with bioterrorism (after the September 11 bombings) and saw a connection to understanding it better having learned some chemistry of materials and how DNA can be used to detect certain organisms. By learning his students’ interests, Ryan could also address their interests in class, through examples chosen to demonstrate chemical principles. Another aspect of the email communication was that it challenged the distance usually present between the teacher and the student in a traditional, or teacher-centred, classroom. Thus, we see email and web-based communication as another mirror to reflect each of the professors’ teaching beliefs.
Although it was a technology-enhanced classroom, from both professors’ perspectives the lecture hall did not seem to be an ideal place to teach chemistry. According to Matthew, the equipment in the lecture hall was a “technological overkill”, whereas something simpler, such as an overhead projector, would meet his needs as he was lecturing. Neither found the balcony useful, because it distanced them from their students, and it was difficult to communicate “up there”. Ryan emphasized the difficulty of involving the students upstairs with the ongoing activities downstairs. However, he indicated that the cameras on his table made possible for the students in the balcony to observe the demonstrations through the projected screens.

Teaching large classes seemed to be a disadvantage for effective teaching, and the two faculty members agreed that interacting with each of their students was difficult in such an environment. Both of these professors’ beliefs about teaching and learning shaped their practice of teaching, but for Matthew the technological aspects of the hall failed to mesh with his conceptions of learning as the personal delivery of an effective explanation. For Ryan, the role of the hall’s technology was more complex, as his student-centred beliefs about teaching shaped his practice, thus he employed strategies including the technology of the hall in an attempt to partially compensate for its physical structure. Yet, his effort was not leading him close enough to an ideal student-centred teaching and learning environment because there were some other interfering factors that were beyond his reach, factors which we will discuss later.

Impact of the Learning Experiences on the Professors’ Teaching Beliefs

As teaching beliefs shape practice, indeed learning experiences shape beliefs. Our data support the impact of learning experiences on teaching beliefs. Matthew indicated that he learned chemistry by reading the textbook, listening to the lectures, taking notes, and solving many problems. Matthew explained clearly that he was teaching very similarly to “the way he had learned” chemistry because he believed in the effectiveness of his chemistry teachers’ teaching approaches. His image of an ideal teacher was that of his undergraduate instructors, and the “role models” his teachers represented heavily influenced his teaching beliefs.

I am doing things similarly to what I consider to be the best of my teachers as an undergraduate. I am doing things rather similar[ly] to what they did, because what they did was very effective and I am trying to be effective in the same way. (Interview, September 7 2002)

Although Matthew certainly used technology in his scientific research, such as X-ray diffraction and analytical methods, he did not seem to make a link between technology and pedagogy, primarily because of his own history as a learner.

In contrast, Ryan referred back to a middle school teacher as being an important referent in teaching, as this teacher “got him thinking”. This teacher motivated Ryan so much that Ryan “got hooked on learning” early on. For instance, the middle school teacher had the students do “contracts” on topics of interest to them, in which they could explore and make connections to the classroom. Ryan learned
what it takes to motivate students to learn, using his experiences in learning, starting with that middle school teacher. It is interesting to note that while these two professors have similar undergraduate experiences, and that Matthew, with the more traditional approaches to teaching, refers back to those experiences, Ryan refers back to a middle school teacher as a major influence. Both seem to apply their cultural schemas to new situations, in this case teaching undergraduate chemistry (Sewell, 1992), but the schemas they choose to do so are not alike.

Like all teachers, the activity systems that the professors participated in their earlier education have strong influence on the way they teach (Gess-Newsome et al., 2003). Ryan had been acculturated to teach more traditionally using mainly lectures until he was tenured, and then he started to become involved in science education where he found the courage to teach in more engaging ways. In addition, given Ryan’s continual involvement in educational efforts, it is important to note that Ryan’s evolution of his teaching is a conscious, deliberate, and ongoing effort.

Discussion

The two cases presented in our study help us understand the activity system of teaching chemistry and the role of technology in that process. As described, the technological emphasis in the university’s philosophy links to its cultural schemas and resources (Sewell, 1992). According to Sewell, resources are effects of schemas, and schemas are effects of resources. The agents within the university are empowered by the structure for the purpose of its reproduction, or to make possible its transformation. However, our study suggests that agents do not use resources, especially technology, in the same way. We attribute this discrepancy to the different cultural schemas our two cases held. For example, while Ryan used technology for active teaching and learning of chemistry, Matthew utilized it as a limited tool or medium in his teaching.

Our cases point to the importance of the subject in this system, portraying three themes of the two chemistry professors: their teaching beliefs, their learning experiences, and their perceptions of using technology in their teaching. Our data suggest that the professors’ pedagogical content knowledge is a stronger predictor of their using technology to teach than their “perceptions of learning technologies”, as Cope and Ward’s (2002) study had suggested. In other words, it is their awareness of pedagogical issues blended with their schemas, or beliefs that shapes their practice.

In the discussion that follows, we examine the patterns associated with these three themes (their teaching beliefs, their learning experiences, and their perceptions of using technology in their teaching) across the two cases and in the light of the related literature. We frame our findings within the activity theoretical framework to get a better sense of the activity system and where the tensions (contradictions) in this system are.

In Matthew’s view, teaching was about one’s “own personality” and “own powers of communicating”. In other words, he believed that the teacher, or the subject, was in the centre and the rest of the resources was in supportive nature, having a weak
influence on the “quality” or effectiveness of his teaching. The underlying assumption was that if the teacher knows the content and has a “proper” personality for teaching, then he or she can teach everything to the students. It depends on the students’ efforts how well they understand and learn. Teacher-centred teaching or often referred to as traditional teaching manifested itself in this professor’s practice as he lectured and solved problems during class time.

Although Matthew strongly believed in lecturing with a strong emphasis on problem-solving, Ryan seemed to have an integrated teaching approach knit with his beliefs of using technology for teaching. Looking from a social constructivist perspective, he believed that utilizing technology was an effective way of teaching; in other words, it helped to have his students develop responsibility for their own learning through a variety of activities and assignments.

Our evidence suggests that Ryan developed his teaching beliefs from early exposures to and experiences of learning science, and his being involved in contemporary science education, which emphasizes social constructivism as the prevalent teaching and learning theory. Thus, Ryan’s beliefs as a teacher departed from traditional teacher-centred teaching towards student-centred teaching.

Matthew’s teaching beliefs were more in congruence with a teacher-centred teaching approach, making the use of technology largely unnecessary in his teaching. In contrast, he was open to new technologies as a research scientist. However, his openness to new technologies in his research failed to carry over into his teaching. Certainly, his familiarity with technology failed to allow him to reconceive the patterns of social relationships he expected and supported in his classroom (Cuban, 2000, as cited in Salpeter, 2000). Indeed, despite the availability of potentially transformative technological tools, Matthew did not conceptualize anything superior to his own “powers of teaching”.

Matthew described his experiences of learning chemistry as reading the textbook, listening to the teacher, and solving problems. Just as was the case with the scientist/teacher in the study by Southerland et al. (2003), Matthew also indicated that the method that his own teachers had taught chemistry is very similar to the one he uses to teach chemistry. In other words, he took his own chemistry teachers as model teachers. On the other hand, Ryan did not place much emphasis on his own undergraduate chemistry teachers, but on his interest and continuous involvement with the science education community.

Although a discrepancy was present between the views of the professors regarding teaching with technology, there was consensus regarding the benefits of email communication with their students. Basically, they used it to support their students’ learning outside the classroom. Another consensus was about not using PowerPoint presentations in their teaching. Both of them argued that using pre-made presentations led to surface learning and that chemistry was a much “deeper” subject. They viewed these kinds of presentations as an inefficient tool for teaching since they “silenced” the teacher.

Drawing from our findings, we illustrate the contradictions arising in the activity system of teaching chemistry in Figure 3. The activity theory served as a lens of
looking into the emerging contradictions, and it also provided a "language of describing and understanding" (Issroff & Scanlon, 2002) these contradictions and their possible resolutions.

The contradictions preventing the system from a healthy functioning exist in multiple forms. Based on our findings about the discrepancy existing between the chemistry professors' beliefs of teaching, we conclude that a contradiction (1) exists among the chemistry faculty members (subject) at that institution. Indirectly, this has a negative impact on the sense of community in the Department of Chemistry and may look like an inconsistency from the outside. The contradiction is apparent once we take into account that Matthew has held recognition for excellence in teaching, and his chemistry colleagues named him a distinguished teaching professor. In his way of using technology, Ryan contradicts with his colleague, even though his university promotes the use of technology. The Department Chair indicates that "many chemistry faculty members utilize technology in the classroom and make their courses available through the Internet", but it emerges that not all faculty members use the technology to the same degree, for the same purposes, or in the same way.

The culture of teaching chemistry in the department, which in our study does not appear to be in line with educational reforms proposing student-centred teaching and which is specific to itself, forms another contradiction (2) with the motive of
teaching chemistry with understanding, the object of the system. Faculty members relying on their traditional, unexamined methods and not on the ones consciously and deliberately emerging from science education research create a contradiction (3) between the subject and the mediating artefacts. Also, the insufficient level of collaboration, reflection, and communication (division of labour) among the chemistry faculty members about issues associated with teaching and learning represents a tension (4) hindering an effective “consensus-based” teaching and learning of chemistry. Indeed, not only are such issues not a focus within the department, they are generally not considered when interacting with other departments, such as education, or the wider university.

The rules and object contradict (5) each other, as well. An implicit finding is that establishing large classes as units of teaching and learning has no value other than economic gains for the institution. In our study, even Ryan who had an approach of teacher-centred teaching, experienced inconveniences directly related to the size of his class. Another finding of our study reveals that a “poor” design of technology-enhanced classrooms (mediating artefacts) may hinder (6) teaching and learning (object), regardless of the teaching approach employed.

The contradictions in our system need to be resolved to ensure effective chemistry education and the establishment of new learning communities and development of new intellectual tools as outcome. We present our comments on these processes of transformation in the following section.

Implications and Conclusions: Toward transformation

We propose some possible resolutions regarding the contradictions that we were able to detect, which we believe are at the same time important issues in the science education community. The following suggestions address the numbered contradictions in Figure 3:

(1) Science faculties need to work in collaboration with each other and exchange ideas of how their teaching could be re-envisioned. The communication within the departments should be improved, and the faculty members should agree on a consensus-based teaching approach taking into consideration pedagogical assumptions and concerns.

(2) The culture of science departments needs to be challenged in a way that the faculties are supported in reflecting on the efficacy of their teaching, closely examining their students learning, in an effort to move past a reliance on “teaching as they were taught” and substantial content knowledge.

As seen in the case of Ryan, one way of challenging the prevalent culture is to combine the solid scientific background of science faculty with pedagogical background. This may better ensure that teaching and learning activities of science are in congruence with the most recent teaching and learning theories in education instead of being patterned solely on the basis of the scientists’ own learning experiences.
As a strategy, graduate students in science departments might be required to take pedagogy courses from the colleges of education at their institutions, since many of them are required to serve as teaching assistants for at least one semester. This is starting to happen within the National Science Foundation (2004)-funded GK-12 programs. Some of them will become tenure-track faculty at colleges and universities, and will be the ones in the future teaching science to undergraduates, for science, engineering, and science education majors. Representing “exemplary” role models in terms of enacting the student-centred approach to teaching for science education majors, especially, would ensure the quality of science teaching in K-12 classrooms, as well (NRC, 2000). In this case, resolving contradiction (2) merges with resolving contradiction (4), since it involves collaboration, or division of labour within and between communities.

(3) We predict that resolving contradiction (2) through a structured examination of teaching and learning would naturally lead to the implementation of teaching strategies supported with technology, since when utilized effectively technologies can enhance teaching and learning and shift the classroom practice from a teacher-centred to a more student-centred approach. By changing the traditional role that education has played, technology enhances more independent ways of seeking knowledge (Amiri, 2000).

(4) Collaboration among departments and acting collectively may help move toward more effective science teaching. The collaboration between science departments and colleges of education can be established in many ways. One way is having a “critical friend” (Southerland et al., 2003), a colleague from outside one’s department, who can help a faculty member reflect upon the efficacy of teaching approaches. Also, this could be accomplished by requiring science graduate students to take pedagogy courses as we point in the possible resolution of contradiction (2), or via means of science education graduate students working with science faculty on enriching the science courses (Abbas, Gilmer & Goldsby, 2002).

(5) Clearly, large class sizes are an economic reality for many institutions. However, the limitations of such classes must be honestly evaluated so that instructors and the institutions can consciously reflect on ways to best accommodate learners within such classes.

(6) As Cohen and Castner (2000) argue, and we find in this study, some of the technology-enhanced classrooms have a poor design and are not convenient for practical use. These classrooms need to be renovated so that faculty members are able to do simple things simply. The primary design goals need to be simplicity and reliability.

Overall, our findings suggest that the culture of science departments needs to be challenged in a way that the faculties begin to examine the efficacy of their teaching practices, rather than relying on “own methods” and a substantial content knowledge. Such openness may naturally lead to implementing technology-enhanced teaching strategies, which when utilized effectively can shift the classroom practice.
to a more student-centred approach. Perhaps the role of science educators in this process can be to take an initiative in establishing an effective collaboration between science and science education departments. In addition, our findings related with the other components of the activity system than the subject suggest that institutions must honestly evaluate the limitations of large classes, and keep the design of technology-enhanced classrooms simple and reliable with feedback from faculties and students so that an effective science teaching takes place.

References


Understanding Chemistry Professors’ Use of Educational Technologies


Appendix. Interview protocol

1. First, I would like to read you a passage from Kvale (1996) explaining my purpose of interviewing you. Here it is:

   I want to understand the world from your point of view. I want to know what you know in the way you know it. I want to understand the meaning of your experience, to walk in your shoes, to feel things as you feel them, to explain things as you explain them. Will you become my teacher and help me understand?

2. What is your teaching method? Could you describe it?

3. In your opinion, what is the best method of teaching General Chemistry?

4. How did you learn chemistry?

5. Do you use technology in your teaching of chemistry? If yes, how?

6. Do you believe that technology enhances teaching and learning? Why?

7. Do you think the structure of the lecture hall is good in terms of enhancing learning? Why?
   a. What do you think about the balcony?

8. Is there any e-mail communication between you and your students? If yes, to what extent?

9. Do you use the classroom support software BlackBoard in your teaching? Why?

10. Do you use Internet during your teaching? If yes, how and why?

11. In your opinion, what is technology?