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Technology Pedagogy:
Six Teacher Candidates' Developing Pedagogical Models for the Use of Computers in Science Instruction

by

Oddmund Reidar Myhre

A dissertation submitted in partial fulfillment
of the requirements for the degree of

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Doctoral Dissertation

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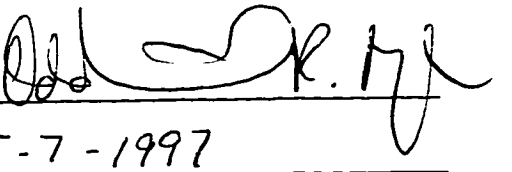
Signature 

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University of Washington

Abstract

Technology Pedagogy:
Six Teacher Candidates' Developing Pedagogical Models for the Use of Computers in Science Instruction

by Oddmund Reidar Myhre

Chairperson of the Supervisory Committee
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This study investigated how teacher candidates' developing pedagogical beliefs and knowledge of technology influenced their perception of such tools in the teaching of subject matter as they complete the initial course work of their professional program. The purpose of the study was to conceptualize more clearly the relationship between prospective teachers' thinking about computer technology and the content of their professional education.

A case study methodology was used to investigate changes in six pre-service secondary science teachers' thinking about technology as a pedagogical tool. Two of the teachers had extensive experience with technology upon entering the teacher preparation course-work, whereas the other four were novice computer users. Data included three semi structured interviews and non-participant observations during the technology course-work. Additional data were collected in the form of interviews with university faculty and cooperating teachers.

Analysis of these data indicated that prospective candidates entered teacher education viewing technology as a tool that supports a teacher centered classroom. As the candidates explored more student centered approaches to teaching, they found less room for technology in their images of their future practice. The data also indicated that the technology course-work was isolated from the rest of the teacher education program and many of the misconceptions

about technology that the candidates brought to their professional preparation were left unchallenged.

TABLE OF CONTENTS

LIST OF FIGURES

ACKNOWLEDGMENTS

I like to express my deep-felt appreciation to my advisor and dissertation chair, Professor Pamela Grossman, for her help and encouragement throughout my doctoral program. Her mentorship can only be described as the best, thoughtful, caring and challenging. I also like to thank Professor Steve Kerr for his support throughout the process of writing this thesis.

Chapter I

COMPUTER PEDAGOGY IN TEACHER EDUCATION

> My goal was to become the ultimate constellation of all the best lecturers I had ever heard. I thought that was what teaching was all about, just being a good lecturer, tell them what they need to know.
> (E3, p. 2)

Six months into his teacher education program, Eric[1] was pondering the beliefs he held about teaching and learning before he had re-entered the university after several years in a dissatisfying job in the banking industry. Although it had been almost twenty years since Eric had been in a middle or high school setting, he knew what kind of classroom he wanted. The images of the teachers he had met in his own schooling were still clear; he remembered very well those teachers he had thought to be good and those he had disliked.

Of course, times had changed. Instead of the films and the slides that his favorite high school teacher had used, Eric expected to use computer technology. Although he had never seen such machines in a classroom, and admitted that he did not know much about how to operate computers, he had seen children working on computers in television programs and read newspaper articles that described how the technology was used in many

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[1] All of the participants in this study has been given pseudonyms in order to protect the anonymity of the participants.

classrooms. Eric expected that the technology would make it easier to get students interested in earth and wind and acceleration and all the other things that a science teacher would be responsible for. Indeed, he envisioned that the technology one day would "take over" classroom instruction, and computers would be used "to learn everything you ever wanted" (E3, p. 16).

Eric's views on teaching as well as on computers in education would change dramatically a few weeks into his teacher education program. Instead of lecturing to the students, he would emphasize the importance of giving "them information for discussion, experience with something, and then lead them to the generalizations, the vocabulary, you know like; yeah, this thing floats and this thing doesn't" (E3, p. 1). According to Eric's image of technology in the teaching of science, such teaching could not be supported by the use of computers. He became therefore increasingly critical of the use of computers and expected his classes to be what he called "low technology" (E3, p. 17), meaning he would like his students to have the opportunity to touch and play with "plants , animals and things" (E3, p. 17), a place where they are "doing science rather then watch representations on a screen" (E3, p. 17). Although he would modify his stance on computers late in the quarter, Eric never regained his original enthusiasm for the technology.

Henry, another student in Eric's teacher education cohort, had also entered the program with strong beliefs about how a good teacher organizes a classroom. But he did not equate good teaching with good lecturing. Through

the college classes he had attended the last couple of years to prepare himself for the teacher education program, he had been introduced to a teaching method he labeled "the inquiry method."

> The basic inquiry method, as I understand it, is that you basically give them these things to work with, and they try to come up with their own questions and come up with experiments to test or figure out the answer.
> (H1, p. 3)

In his own schooling he had found the hands-on activities, the laboratory exercises, particularly memorable. Henry wanted these activities to become the core of his future instruction.

Although Henry had only briefly used computers, he, like Eric, had strong beliefs about the role of technology in a science classroom. His college professor had demonstrated how measuring devices hooked up to computers could make the analysis of certain processes far more accurate. This was how he wanted to use computer technology, as a tool much like the thermometer or the yard stick.

Henry's beliefs about teaching and about computers in education stayed largely unchanged throughout the quarter. He felt that the teacher education classes had confirmed his ideas.

> Having read the articles and talked about the theories, I don't feel it has changed my views very much. I don't know, I will be going to the classroom and do my things, I haven't come up with anything

> in that class to put it: Oh, I shouldn't do this! It hasn't changed anything.
> (H3, p. 17)

Why did the same teacher education course-work seemingly have a radically different effect on Eric compared to Henry? Why did Eric's images of computers in teaching and learning change dramatically, whereas Henry retained the beliefs he had as he entered the teacher education program? What were the effects of the technology course-work they both had completed? One might argue that Henry had a better knowledge about the operation of computers then Eric, but in reality, Eric and Henry were both largely unfamiliar with the use of computers and had in the past used them only for simple word processing. Instead of looking at computer knowledge and science background, the differences in Henry's and Eric's response to the teacher education experience can, among others, be traced to the differences in beliefs about teaching and learning and their developing beliefs about the role of computer technology in education.

The last two decades have been characterized by an increasing dependence on computer technology in the world of work. It seems like everyone, from the youth in the hamburger stand to the nuclear scientist, is using this type of technology to perform their tasks. There are few jobs that do not require some sort of contact with the "computerized world" and employers are increasingly expecting new employees to be familiar with computers. In addition, the home computer is about to become a center for entertainment and

work, as well as a place to gather information about everything from art to industry or to communicate with "on-line" friends around the globe.

Many schools have also entered the computer world. Initially the machines were used to help the administration running schools more effectively by keeping track of finances and students, but, in more recent years, computers have become increasingly prevalent in classrooms and libraries. An unprecedented amount of the school budgets has during the last decade been spent on such devices (Bork, 1991; Ely, 1993), and the expectations are high among many of those who care about our schools that the technology can transform the teaching profession in order to better meet the educational demands of tomorrow's society.

> Having seen the ways in which technology has transformed the workplace, and, indeed, most of our communication and commercial activities, the business community and the public in general are exerting pressure for comparable changes within schools.
> (Means, Blando, Olson, Middleton, Cobb Morocco, Remz, and Zorfass, 1993, p. 1)

School leaders have justified large purchases of classroom computers in two ways: First, students needed to learn how to use computer technology in order to be prepare them for a world that has become increasingly technology dependent. To accomplish this, students were offered computer classes that focused on computer programming and hardware. These classes were often taught by a specialized teacher. Secondly, educational leaders hoped that the

use of computer technology would increase the teachers' effectiveness in the teaching of subject matter such as English, history or science. This aspect of computer usage has become increasingly important with the advent of user friendly machines and with the availability of educational software and the Internet. Suddenly, computers could be used for many purposes in a regular classroom. As a result, it became increasingly important that teachers were able to use computers; word went out that school districts would not hire teachers who could not use this type of equipment. Some schools started to plan for a future where most of the information the students need in their work would be gathered from electronic resources, thus replacing the textbook that during this century has been the centerpiece for what has actually been taught in K-12 classrooms.

Seen from this perspective, it has become increasingly important for teacher education institutions to find ways to provide experiences for all of their students that would prepare them to use technology effectively in their future instructional practice (Dunn & Ridgway, 1991; Fulton, 1989; Parker, 1993; Handler, 1993). Because of the relatively short time these devices have been around, teacher education institutions have experimented with various ways to prepare their students for a still undefined future. The most common approaches have been to provide computer specific courses or to promote the integration of these technologies into already established education courses (Handler, 1993; Strudler, 1991). The assumption has often been that knowing

how to operate the machines would automatically lead to the ability to integrate the technology into a classroom practice. Unfortunately, the attempts to prepare new teachers in the use of technology have in many cases not been very successful (Handler, 1993). As Fulton (1989) observed:

> Although it is reasonable to expect new teachers - those fresh out of teacher preparation programs - to come into the classroom skilled in teaching with technology tools, the data suggest otherwise. Despite the fact that today almost all schools of education offer some form of computer training to their students, this typically consists of a basic "Introduction to Computers in Education" course, not enough to prepare teachers to use computers in a wide range of classroom applications. (p. 13)

This trend follows a pattern that is common for teacher education course-work; many teachers have reported only marginal effect from their teacher education experience on their thinking about teaching (Calderhead & Robson; 1991; Kagan, 1992). Indeed, the value of teacher education is hotly debated. Some would argue that a solid subject matter background is sufficient to teach, especially at the secondary level, whereas others emphasize some of the benefits of traditional education courses. For example, studies on teacher knowledge have indicated that teacher education might add vital aspects to the teachers' professional thinking. Grossman (1990) identified four areas of teacher knowledge that should be considered the focal point for the professional preparation of teachers. She defined these to be subject matter knowledge, general pedagogical knowledge, pedagogical content knowledge,

and knowledge of the educational context, where the last three of these would be uniquely tied to education course-work.

Pedagogical content knowledge refers to the understanding necessary to teach a particular subject matter which draws upon both general pedagogical knowledge and subject matter knowledge (Grossman 1990; Shulman, 1987). One part of teachers' pedagogical content knowledge includes the ability to choose the most effective instructional strategies and tools. The development of preservice teachers' ability to use technology to teach a particular content must therefore be seen as part of the development of their pedagogical content knowledge.

It is from this perspective one needs to look at what it takes to learn to teach with technology. The use of computers for pedagogical purposes can not be separated from the intricacy involved in developing students' pedagogical content knowledge. Instead it adds to the complexity of learning to teach, since before students can develop a repertoire for how to use the computers in the teaching process, they must find time to familiarize themselves with the technology. Although this aspect of the process will diminish as more and more students enter teacher education with computer skills, it is at this point in time a main obstacle for many of the candidates.

Among all the hurdles that teacher candidates would have to overcome in the process of learning to teach, there are at least two that are of special interest when focusing on using computers in the teaching of a particular

subject matter. These two areas are the beliefs about teaching and learning that the students bring to their professional training and, one of the main sources of these beliefs, the students' memories of their own schooling. It has become generally accepted that teachers' knowledge and beliefs about subject matter and pedagogy heavily influence the instructional decisions they make in the classroom (Shulman, 1986). There is, for example, a substantial literature on teachers' pedagogical judgment and decision making (e.g., Clark & Peterson, 1986; Shulman, 1987). Despite this body of knowledge, little is known about the role that preservice teachers' pedagogical beliefs and experiences plays in shaping their relationship to the use of new electronic technologies for instructional purposes. There is a great chance that that candidates' images of themselves as an English, history or science teacher do not include the use of computer technology since so few of them have experienced the use of such devices during their years as K-12 or even as college students. It is well known that many new teachers model their instructional practice after a favorite high school or college teacher. Lortie (1975) labeled this phenomenon "the apprenticeship of observation." Typically, preservice teachers draw on experiences from their own schooling when it comes to strategies for teaching a specific content, their understanding of students, and their perception of curricular sequences (Grossman, 1990; Feiman-Nemser & Buchman, 1985). At this point in time, this apprenticeship has not included the use of computers in the teaching of subject matter. In many ways, the study of how teacher

candidates learn to teach with technology presents a strategic case to research the power the apprenticeship of observation, an opportunity to investigate the role of teacher education course-work in challenging traditional classroom activities and encourage innovative practices.

There are at least three reasons why such information is sorely needed. First, many students have never experienced the use of new electronic technologies in classroom settings and thus lack visions and models of what such pedagogical practice might look like. This is very interesting with regard to theories about how teacher education can overcome the powerful influences of the apprenticeship of observation, because some students will enter the program with models of the use of technology, whereas others have very limited visions of what such instructional practice might look like. What role does prior experience with technology play in the students' attitudes and beliefs about computers in a classroom? Will those familiar with technology approach these devices differently than those who have rarely seen them used in classroom settings? Only by looking at the use of technology from the preservice teacher's perspective can we define how they approach their teacher education experience.

Second, although we know that quite many new teachers reject the use of technology for instructional purposes (Handler, 1993; Fulton, 1989), we have little in-depth data that can illuminate why teacher candidates have difficulties imagining the use of computer technology in their future instruction. Such

information would be helpful in order to design experiences for preservice teachers that address the challenges presented by computer technology.

Finally, since the study is tied to the technology course-work in a teacher education program, the study will also serve as an evaluation of the course experience and the program itself, identifying factors that influenced the students as they complete the technology part of their professional preparation. Although there seems to be a general agreement that teachers need knowledge about subject matter as well as the various aspects of pedagogy in order to be able teach effectively (Grossman, 1890; Shulman, 1986; Wilson, Shulman, & Richert, 1987), there is less agreement on how to structure teacher education programs in order to optimize the preparation of the candidates. As Hollingworth (1989) noticed:

> What is not obvious, though, is what content and pedagogy subject area teachers should know, nor how and when that content area might be presented to preservice teachers in their programs so they can most effectively learn to translate it to students with varying learning backgrounds.
> (p. 163)

Similar questions arise about technology in teacher education course-work. How should such courses be structured? How do they connect to what students are learning in other courses? Such an investigation is necessary in laying the groundwork for the establishment of meaningful technology experiences during preservice teacher education.

Beliefs and Belief Structures

Research in cognitive and social psychology has indicated that teachers' way of thinking and understanding inform their instructional practice (Fenstermacher, 1979; Nespor, 1987). Teacher education students' pedagogical beliefs encompasses all the pre-existing assumptions or images about teaching and learning that the candidates bring to their course-work. Lidstone and Hollingsworth (1992), who looked at beliefs through the notion of schema theory, defined beliefs as follows:

> Beliefs, which are philosophical schemata about teaching and learning, affect the management system one chooses, the subject matter one teaches, the pedagogy one chooses to teach with, and how much emphasis is given to student learning. (p. 41)

She divided teachers' beliefs about pedagogical issues into eight categories: what teachers do, what content is taught, the purpose of education, how learning is evaluated, what classrooms look like, how classrooms are managed, how subjects are taught, and how students learn.

Henry's case represents an example of the stability of beliefs in learning to teach. He entered the teacher education program with strong beliefs in the value of direct experiences, especially laboratory exercises. Although throughout the quarter he was introduced to alternative methods, only the arguments and models that supported his original views caught his attention, and his images of good teaching and learning remained largely unchanged.

Eric, on the other hand, represents an example of how beliefs can change. A few weeks into the program he had redefined many of his original thoughts about classroom instruction.

There is a rich literature that describes how difficult it is to change beliefs (Allport, 1954; Fenstermacher, 1979; Lord, Ross & Lepper, 1979; Nespor, 1987; Nisbitt & Ross, 1980). Some theories propose that that there is a link between the complexity of teaching and changes in beliefs about teaching and learning (Hollingsworth, 1989). Since learning to teach in teacher education encompass so many topics over a relatively brief period of time, many students are not able to focus on all of these areas simultaneously. In order to make sense of the course-work, they will therefore put their emphasis mainly on the areas that they at the moment deem important, whereas they de-emphasize some other parts of the course-work. At the same time there are also studies that indicate how such beliefs can be affected in, for example, a teacher education program. Nespor (1987) suggested an approach that helped the students become more "reflexive and self-conscious of their beliefs" (p. 326). In a similar manner Fenstermacher (1979) suggested that the students were introduced to ideas and readings that challenge the students' beliefs. Grossman (1991) called this type of intervention for "overcorrecting," a practice where the students were students are introduced to extreme samples of educational practice or where the logic of the students' initial beliefs is challenged.

In this study, I investigated both how students' pedagogical values, beliefs and prior technological experience influenced their thinking about the use of computers in K-12 teaching during the first quarter of their teacher education program. Through case studies of six teacher education students, including cross case analysis and a careful examination of their first quarter teacher education experiences, in particular the technology course-work, this study attempts to illuminate several issues in learning to teach with technology. The first purpose is to provide a window from which we can view possible relationships between teachers' prior computer skills and budding images of technology in teaching and learning. Secondly, it attempts to define how developing pedagogical beliefs influence students' thinking about the use of computers in their future instructional practice. Finally, this research tries to define and delineate how the technology course-work influence the candidates' images of computers in education.

As the examples of Henry and Eric demonstrated, students bring to their teacher education program a variety of beliefs about pedagogy and the use of computers in education to the teacher education program. In some cases these beliefs are deeply rooted and very difficult to alter, whereas others are affected by the teacher education experience. The next chapter will discuss the effect of teacher education, especially as it relates to learning to teach with technology, and how students' prior beliefs about teaching and learning mediate the effect of the course-work.

Chapter II

LEARNING TO TEACH WITH COMPUTER TECHNOLOGY

Teachers candidates draw on many sources in addition to their professional preparation when learning to teach. Of particular importance are the candidates' interpretation of their own schooling, memories of teachers and educational activities they participated in growing up (Britzman, 1986; Feiman-Nemser & Buchmann, 1985; Lortie, 1975). These images of schooling will in many instances supersede the impressions candidates receive from teacher education, and thus have a formative effect on their future practice.

At this point in time, some teacher candidates may have experienced the use of computers in their own schooling, but there are still a number of candidates who have not experienced instructional use of computers. Even fewer candidates have seen the use of computers in the teaching of subject matter such as mathematics or science. The exceptions are those who have worked with integrated learning systems. These systems were popular a decade ago and allowed students to work on individual work stations answering questions or solving problems presented by the computer program. Modern computers offer far more interesting perspectives for classroom teaching than what was thought possible a few years ago. Nowadays, computers can be used as communication devices as well as to create colorful

papers and presentations. Students can, for example, access the NASA home-page and get first hand information about space exploration, or they can read the daily French newspapers in their foreign language classes. Unfortunately, few teacher candidates have seen such use of computers in classrooms; their images of computer technology in education are therefore most likely based on outdated technology if they at all associate the use of computers with the teaching of English or science.

If new teachers are to learn how to use computers in their future instructional practice during teacher education, many of the candidates will have to learn computer skills at the same time as they are developing new images of their pedagogical practice. Such expectation will force those responsible for teacher education to ponder questions such as: Is it reasonable that new teachers should be able to guide their students in using Internet resources as they learn about Shakespeare or the Second World War? Should a new teacher be able to utilize the power of the many new computer programs that are available, or manage an electronic bulletin-board? If we can expect such skills from new graduates, what aspects of the enormous field of technology do they need to know? Where are they going to learn it? And even if they are introduced to new technologies, how can we be assured they will actually use technology in their future classrooms?

Teacher education faculty will have to overcome several challenges in order to successfully accomplish such an effort. Among others, they will have

to take into consideration questions like: What are the computer skills that candidates bring to their professional training? How do the candidates' prior beliefs about teaching and learning affect the their thinking about the use of computers in classroom teaching? And, to what extent is the teacher education course-work able to influence candidates' thinking about the use of computers in their future instruction?

Knowing How to Use Computers

Teachers draw on their pedagogical content knowledge when choosing the appropriate instructional strategies and tools that provide the best educational experiences for their students as they work on particular concepts (Grossman, 1990). Such tools might previously have been characterized as being technologically uncomplicated, involving the reading of a passage or illustrations on the chalkboard. The advent of computer technology has opened the door to a plethora of new possibilities, opportunities that distinguish themselves from those available in the past because they require that the teacher know how to operate rather complex machines. One can therefore assume that teacher candidates who enter their professional training with some computer experience, have an advantage over those who are computer novices when it comes to finding a place for the devices in their images of instruction. Students with computer skills know something about the capabilities of the machines, and thus have a better grasp on what they can

be used for in an educational setting. A large portion of present teacher education candidates possess some kind of computer skills. Brown and Kester (1993) concluded from a survey of 193 undergraduate students at East Carolina University, that about 50 percent of the students had taken a computer course or had worked with computers at home or on the job. Interestingly, many of the students claimed to have forgotten what they had learned during formal course-work, which mainly was some form of programming, whereas they had acquired knowledge of on their own of features such as word processing which they used regularly. All of the students favored operating systems that utilized icons and pull down menus, systems that today dominates the popular computer market. If half of all college students had some computer experience five years ago, one can, based on the explosion of the number of computers in home and schools, expect this number to be significantly higher today.

One reason why students with computer skills have an advantage over novices is psychological; they have overcome the fear of technology and know how to explore it. Several studies have reported a connection between computer experience and the candidates' liking of, anxiety about, and confidence in using computers. Liao (1993) found in a study of 207 education major students that those who had long experience (e.g. two years or more) with computers and who had been exposed to many different types of operating systems, were far more positive about the use of technology in education than those with very limited experience. Dunn and Ridgeway (1991)

drew similar conclusions from a survey of 103 student teachers. Those who had taken a course in computer studies were more confident in their use of technology then those who had not taken such a class. On the other hand, the study also indicated that candidates who had taken the computer class were no more likely to use such devices during their student teaching. This indicates that computer skills alone might not be sufficient to make use of the technology in regular classroom teaching.

Very little is known about how teacher candidates link their computer knowledge to the teaching of a particular concept. This is not surprising since the candidates receive only limited opportunity to teach during their professional preparation, and evaluation concerns might defer them from experimenting with innovative approaches. Quite a few researchers have, on the other hand, focused on how established teachers adopt computers into their classroom practice. These studies suggested that teachers adopt computers into their classroom routines in stages. Initially teachers are concerned with their own interaction with the new medium and how it will affect established classroom activities. As the teachers become comfortable with the technology, the focus turns to potential use of the computer to promote characteristics teachers would like to see in a classroom such as, for example, collaboration (Wells & Anderson, 1995). Although this might seem to be a logical development, such changes do not occur rapidly nor are they easily achieved. These are processes that might take several years of adjustment and will

require immediate access to technology and substantial technical and administrative support (Becker, 1994; Hadley & Sheingold, 1993; Kerr, 1991; Sandholtz, Ringstaff & Dwyer, 1996). Kerr's studies also indicated that the introduction of technology spurred a changes in classroom organization, and thus teaching practice. Teachers were therefore forced to confront their pedagogical beliefs and their images of good teaching as they adopted the new technology into their instructional practice.

This may explain why there are such profound differences between teacher candidates and established teachers in their expectations when it comes to using computers in their teaching. Even controlling for experience with the technology, preservice teachers are far more likely to think of themselves as using computers then those who are already established in a practice (Marcinkiewicz, 1994). Similar discrepancies have been found between beginning and experienced teachers. Experienced teachers have lower expectations than those coming straight from college (Hannafin & Freeman, 1995).

Pedagogical Beliefs and Technology

When computers are incorporated into the instructional practice the classroom environment changes from being teacher centered to become more student oriented (Kerr, 1991; Sandholtz, Ringstaff & Dwyer, 1996). Many teacher candidates are not familiar with a student centered classroom that is

characterized by collaborative work and an exploration of the many concepts that can be found in the teaching of subject matter. They are more often used to teachers who tell the students what to do and provide the answers for the many questions that arise. Goodlad (1983), who surveyed over 1,000 public school classrooms nationwide for his study of schooling, found that the practices were remarkable homogeneous. The teaching styles were authoritarian and didactic, an educational environment that Sirotnik (1983) described as teaching students "dependence on authority, linear thinking, social apathy, passive involvement and hands-off learning" (p. 29). It is from such an educational experience that many prospective teachers enter their professional training.

As a result, many teacher candidates have a linear view of teaching, believing that teaching consists of providing the correct information in timely manner to the students. Britzman (1986) conducted a series of case studies aimed at eliciting the beliefs that a group of student teachers held about teaching. Based on her analysis, she concluded that prospective teachers bring more than a desire to teach to their professional training. All of their previous experiences in schools heavily influences the way students think about teaching:

> They bring their implicit institutional biographies - the cumulative experience of school lives - which, in turn, inform their knowledge of student's world, of school structure and of curriculum. All of this contributes to well-worn and commonsensical

> images of the teacher's work and serves as the frame of reference for prospective teachers' self images. (p. 443)

In addition, Britzman points out, most teacher education students have only observed the act of teaching from the recipient's point of view, which might lead the students to think of teaching as a set of techniques aimed at delivering information rather then addressing the purpose of education.

> They bring to their teacher education a search for recipes, and often, a dominant concern with methods of classroom discipline, because they are quite familiar with the teacher's role as social controller. (Britzman, 1986, p. 446)

How do teacher candidates' beliefs about teaching and learning affect their thinking about technology? Although the research on this is sparse, there are a few studies that have indicated that there might be relationship between teachers' pedagogical beliefs and their use of technology. In one such study, Honey and Moeller (1990), who focused their attention on inservice teachers, indicated that there was a relationship between these teachers' educational goals and objectives and the ways in which they were able to integrate computer technology into their instructional practice. Twenty teachers, all of them very experienced, were selected on the basis that they had training in the use of technology and had access to use computers in their teaching. Based on a set of interviews with the teachers, the researchers divided them into four groups. Teachers who used computer technology frequently believed strongly in student centered goals and in the value of inquiry methods, collaborative

learning and hands-on practices. These teachers would make a conscientious effort to find applications that supported the kind of student centered practices they liked to see in their classrooms. They claimed that the technology allowed them to spend more time with individual students and, in some cases, that their teaching had changed form being content-oriented to a more process oriented form of instruction.

The teachers who did not use technology could be divided into three groups. Some of these teachers would also have strong student centered goals, but they did not feel that they at this point were comfortable enough with the technology to make use of it in their classroom practice. Second, there were teachers who were more traditional in their teaching philosophy, favoring the routines of the textbook and lecturing. These teachers were reluctant to put the time in to alter an already well established practice, and they were suspicious that by introducing computers, they would lose some of the authority and control they presently enjoyed with their students. Finally, there was a small group of teachers who had similar pedagogical values as the first group, but access to the machines in their particular school made it cumbersome and impractical for them to integrate computers on a regular basis.

Similar findings were reported by Turner and Chauvat (1995) who followed two preservice mathematics teachers over four quarters looking at these teachers' developing beliefs about technology as they completed courses in mathematics education, student teaching, and a post student teaching

seminar. Although both of the students were proficient in the use of computers, and initially believed they would be using technology in their teaching, only one ended up using it on a regular basis during student teaching. The teacher who used computers looked at technology as an opportunity to develop an alternative method of teaching, a way of exploring mathematics in addition to using manipulatives, collaborative work or peer teaching. The non user had a far more authoritarian view of teaching. She saw the teacher's role as being the one who guided the students towards an understanding of the content. The few times she tried to use computers or graphing calculators, she felt that the situation became chaotic and would have liked to be able to give the students more direction in their work.

Although pedagogical beliefs might explain why some teachers have an easier time adopting computers into their practice, there might be other explanations as well. Smith, Munday and Windham (1995) investigated the relationship between personality type and secondary teachers' willingness to use computers. Based on a survey of 138 teachers, the researchers indicated that educators who are creative, analytical, logical and imaginative are far more likely to use technology in their teaching than those who are concerned with interpersonal relationships and the meaning of these.

The Influence of Teacher Education Course-Work

It is quite frequently claimed that our teacher education institutions are not able to adequately prepare new teachers in the use of computer technology. In the same way, many studies have pointed to how little influence teacher education course-work seems to have on the development of teachers' pedagogical thinking (Kagan, 1992; McLaughlin, 1991; Weinstein, 1990; Zeichner & Tabachnik, 1981). Kagan reviewed 40 learning-to-teach studies conducted between 1987 and 1991. Her conclusion was that teacher education programs in general fail to prepare the candidates in the areas of helping them acquire knowledge of students, to be able to use their knowledge of students to modify and reconstruct their personal images of self as a teacher, and to develop classroom routines that integrate classroom management and instruction. Kagan concluded by questioning the very value of having an academic preparation of prospective teachers:

> Perhaps it is time to acknowledge that teaching is not a traditional occupation - not in the clean, technical sense of that term. Classroom teaching appears to be a peculiar form of self-expression in which the artist, the subject, and the medium are one. Whether any academic program of study can truly prepare someone to practice it is perhaps a question that one dares not ask.
> (Kagan, 1992, p. 164)

Although Kagen's work has been profoundly criticized both with regard to the selection of studies and the process of synthesizing research (Dunkin, 1996; Grossman, 1992), similar conclusions have been reported in other studies. Both

Lortie (1975) and Lanier (1985) indicated that established teachers denies the influence of their formal teacher education course-work, emphasizing that what they learned, they acquired during their field experiences.

Analogous conclusions were drawn by Zeichner and Gore (1990) who implied that teacher education programs "are not very powerful interventions" (p. 338). At the same time they also speculated as to whether we are able to identify the specific factors that influence teacher learning and wondered if the influence of teacher education might be much greater than what seems apparent when one looks at how teachers respond to the actual course-work.

On the other hand, there are studies that have suggested that teacher education course-work do shape and influence the candidates thinking about teaching and learning. An Australian study (Dunkins, Precians, & Nettle, 1994) interviewed a random sample of 60 prospective elementary teachers at various stages in a three year teacher preparation program. This study concluded that formal teacher education experiences did have a weak, but statistical significant effect upon the cognitive development of the candidates involved. Among others, the candidates who were at the end of their teacher education program were less concerned with establishing interpersonal relationships with their students and had less custodial concerns than beginning teacher candidates. In their teaching and planning, these teachers would draw on knowledge they had acquired about professional educational contexts rather then more self-focused types of pedagogical knowledge. Although the teacher education course-work

seemed to have some effect upon the candidates' thinking, the practice teaching experience proved to be the most significant.

Grossman and Richert (1988) indicated similar possibilities in an in-depth study of six first year teachers. Although these researchers pointed out that the teacher education course-work as well as the field component seemed to have an impact on prospective teachers, they also emphasized that we know little about what teachers need to know to do their work and how students can best acquire this knowledge. Grossman (1988) pointed to similar findings in another study of six first year teachers, three with teacher education and three who had not completed a professional program. Although the subject matter background of these teachers was comparable, the teachers who had completed a teacher certification program had a deeper understanding of students and a broader pedagogical repertoire to draw from when teaching a particular subject matter. In addition, the certified teachers were far more likely to draw on the experience of their more experienced colleagues then those without, who largely depended on memories of their own schooling as they developed their instructional practice.

A few studies have focused on how students have particularly been affected by the technology course-work they have completed as part of their teacher certification program. Depending on the content of these courses one would assume that the participants became more comfortable around computer

technology at the very least, and maybe be able to develop some models for what the machines can be used for in a classroom situation.

In a British study, Sanders (1992) followed a group of 42 candidates from their technology course-work during their professional training through these teachers' first year of teaching. The candidates were assessed on their skills and confidence prior to the course, during their course-work and during their first year as teachers. Although only 10 percent of the students claimed to have not used computers before entering their course-work, nearly one third of the students were unable to start pre-loaded programs without help. All of the students claimed to have gained confidence from the course-work which mainly focused on introducing the students to the machines available and some software packages. During the first year of teaching, 75 percent of the teachers who had computers available to them reported to have used the machines in their instructional practice, despite the fact that more then half of them had expressed that they desired more confidence in the use of technology. Most of the teachers reported their use to be limited to word processing and few other application programs.

Similar findings were reported by Handler (1993) in a survey of 133 education graduates. This study was designed to collect the teachers' perceptions of the purpose of their preservice technology course-work, the value of this, and the ways in which they were currently using computers in their classrooms. Of the respondents only one in five reported that the teacher

education course-work adequately prepared them to use computers in their teaching. Handler identified three factors that seemed to have an impact on feeling prepared to use computers. Students who had completed a computer class, especially those with some prior technology experience, during their professional preparation, were far more likely to feel prepared than those without such a class. In addition, the students who felt prepared to use computers where those who had seen the use of such devices most frequently in their methods classes and during their student teaching experience. Of particular importance was the opportunity to observe the use of computers in a classroom situation.

In all of the studies above, the researchers were unable to pinpoint how candidates developed their image of classroom use of technology as they worked their way through their professional course-work. Handler (1993) recommended that we take the time to "listen" to our teacher education students as they wrestle with these questions in order to better our understanding of how teachers learn to teach with technology.

Conceptual Framework

The conceptual framework for this study is based on an understanding that the development of teacher education students' images about the use of technology for instructional purposes can be traced to an interaction between experiences and beliefs they bring to their professional training, and

knowledge they acquire during the teacher education program. Of particular importance are the computer experiences they have during the technology part of their training, but also other experiences, especially during their methods classes and their field experiences are considered formative (See Figure 1, p. 31). This development takes place in a context that is dominated by the students' perception of the role of technology in school and society, and by the characteristics of the college. Such characteristics would include the emphasis the particular college puts on the use of computer technology and how accessible such devices are to students and faculty.

Candidates who have extensive experience with technology, even though they might not have seen such tools used in classroom settings, have an easier time envisioning a pedagogical use for such devices. Technology knowledge is based on a general understanding of the different technologies and how they work. Such insight could be, for example, how the different parts of a computer are connected and what type of tasks they perform. In addition, such knowledge would include the limitations and capabilities of the different types of hardware and software. An example would be an understanding of how the memory capabilities of a computer affect the type of software that can be run. This knowledge is more closely related to engineering than to teaching (Heinich, 1991). The technical aspect of hardware might be a source of frustration for some of the candidates since K-12 education traditionally has been a technologically deprived field, and many enter the profession partly

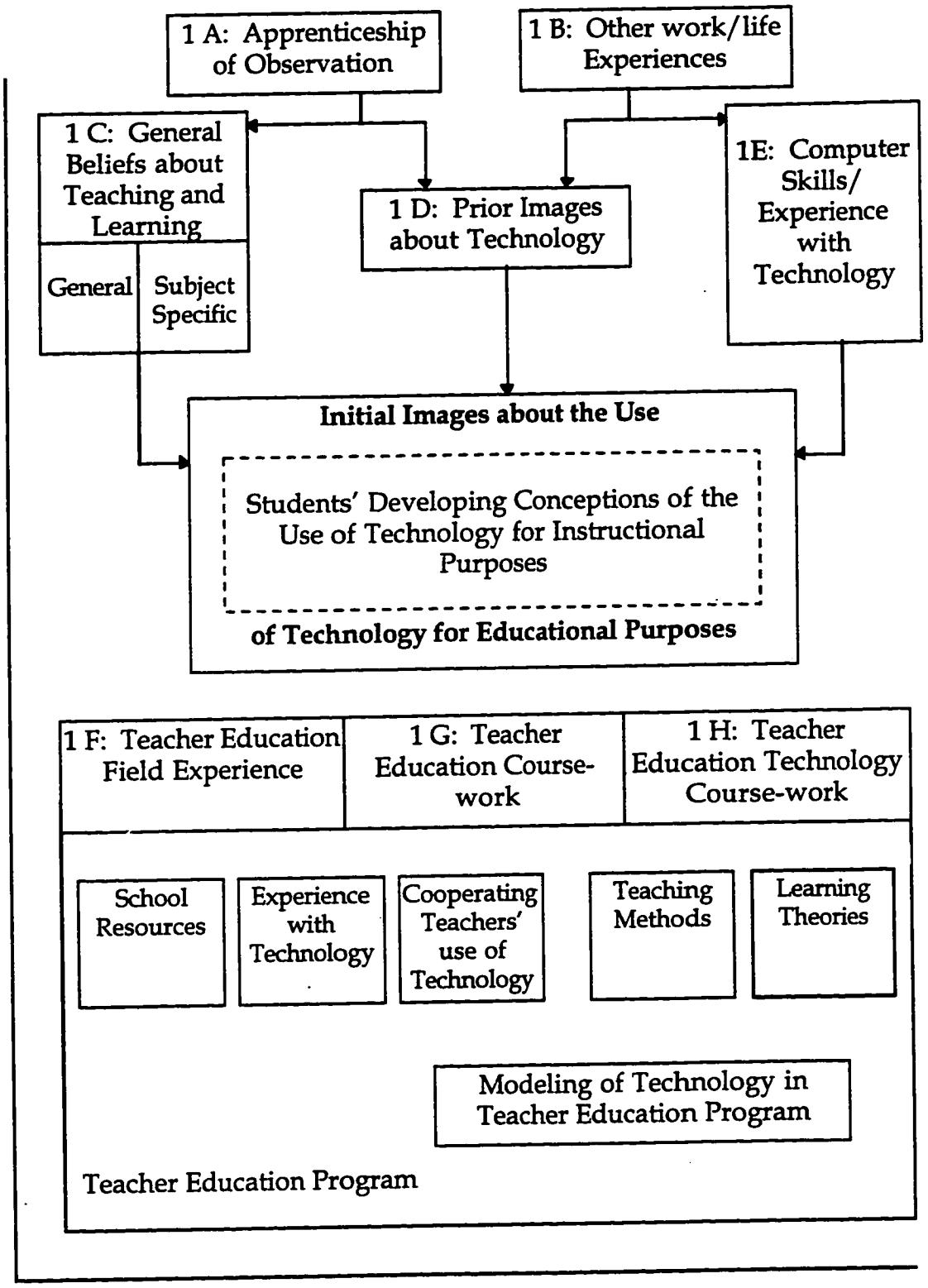

Figure 1: Conceptual Framework

because they thought they would not have to deal with complicated technologies.

There are several sources, rooted both outside and inside the teacher education program, that help form teacher candidates' thinking about the use of computers in their future practice. In addition to the candidates' knowledge of the computers themselves, these sources include four areas of particular interest: prior beliefs about teaching and learning (including beliefs about the use of computers in learning environments); the teacher education field experience; the teacher education course-work; and the teacher education technology course-work.

First, many students enter their professional training with very strong beliefs about teaching and learning (See Figure 1 C, p. 31); these images will most likely not include the use of computers in the teaching of subject matter, especially for candidates who graduated from high school ten years or more ago. Based on what the literature indicates about students' prior beliefs about the use of technology for educational purposes, one can imagine these convictions function as a screen through which new ideas about classroom use of computers are evaluated. For example, when a new way of using technology for instruction is introduced, the students will interpret the new approach in light of their beliefs and either accept, modify or reject the new concept.

The vision of how computers might be used will often be based on what they have seen in their own schooling or what they have picked up from TV

programs or newspaper articles that have featured educational use of computers. Even though the candidates might envision themselves as future computer users, they are not seeing these machines altering the way they imagine their own teaching practice. The candidates might think of using the computers more then what their favorite teacher did, but they do not see themselves as doing different things with computers that might alter their image of themselves as teachers (See Figure 1 A and D, p. 31). For example, a prospective English teacher may look back at his or her high school Language Arts teacher as the model he or she wants to copy. Let us say that this teacher was an able story teller that kept the students thrilled with tales about famous authors and their poetry. The students only briefly encountered new technologies in the form of simple word processors when they had to write papers. With such an ideal to look up to, there might not be any room for alternative teaching approaches that includes computers in the preservice teacher's mind. It becomes very difficult for that particular candidate to imagine a different type of teaching situation where, for example, computers can be used for multiple purposes such as group editing, to outline a story, or, if connected to the Internet, as a source of information about a wide variety of literature and authors.

Another source that influences the candidates beliefs about the use of computers in their future teaching practice, is their understanding of subject matter (See Figure 1 C, p. 31). Candidates' understanding of subject matter

includes their conceptions and beliefs about the subject area as well as their understanding of subject-specific concepts and procedures. One can, for example, imagine that teacher candidates in the field of science who view scientific principles as facts, may feel strongly that there is an objective truth to be found in science content. These students might therefore want to emphasize memorization and "drill and practice" as important components of effective science instruction. With regard to the use of technology, one can expect these prospective teachers to be positive about the use of software (e.g., tutorial programs, games, etc.) that support this view of science teaching, but much more reluctant to use the computers to explore a topic, for example, via the Internet.

A third source that might have influenced the candidates' prior beliefs about computers in school settings is the general debate that is going on with regard to schools and the perceived need for schools to become more effective. The use of computer technology is playing a central role in this debate and has become the focal point for many political initiatives. The arguments as to why we should use computers in classroom teaching are many and differ widely. Some have argued that certain computer activities develop students' logical and intellectual skills, whereas others have warned that the many images would decrease the children's creative development. Others have argued that the world has become so dependent on technological devices that we have to familiarize our children with such machines in order to stay competitive as a

nation. The alternatives are many, and it is almost impossible not to form some kind of opinion about what role technology will play in a future society. Whatever thoughts about the role of technology in the society and education candidates have encountered, these sources will influence how and to what extent they think it is important to find ways to integrate computers in their future instruction.

During the candidates' teacher education experience there are in particular three parts of their training that affect their developing conceptualization of the use of technology. I have already pointed out the importance that apprenticeship of observation plays in forming students' thoughts about schooling and pedagogy before they enter their professional training. Student teaching seems to play a similar role (See Figure 1 F, p. 31). New teachers are inspired by what they see as they are placed in various school settings. Candidates who see technology used during their field experience will be affected by this, especially if it is done well. On the other hand, if they do not see the use of such devices at all, it might lead the students to believe that this is something that a few people at the university are concerned with and not really necessary for a regular classroom teacher. Another possibility is of course that they might observe in classrooms a use of technology they find so ineffective or redundant that they recoil from trying to use it further.

The same can be said about the teacher education course-work that is commonly part of a teacher education program (See Figure 1 G, p. 31). If

technology is considered an integral part of the content of the courses and the methodology modeled by the professors, such modeling will influence candidates' perspectives of the use of technology in education. An absence of such models will have the opposite effect.

Of all the courses that preservice students have to fulfill in order to earn a teaching degree, the technology classes promise to be the forum where students are directly challenged to think about the role technology ought to play in schools (See Figure 1 H, p. 31). During these classes the students would normally be challenged to learn more about the technology itself and to explore possible instructional opportunities for such devices. Depending on the scope and context of these courses, candidates will form new ideas about the use of technology as their comfort level with the machines increases and they are presented with examples of how technology can be used for pedagogical purposes. On the other hand, if the students enter their professional training with few models of what technology can do for their instructional practice, and they see little use of such devices during the rest of their training, then they might view the technology classes as irrelevant and not really connected to the pedagogical practice they want to establish when they start their teaching career.

At the same time, we know that good modeling and information about computers in the teaching of subject matter might not be sufficient to alter the images of teaching and learning candidates bring to their professional

preparation. In order challenge these images, teacher education must challenge candidates' established beliefs. Teacher education course-work and student teaching must enable the candidates to question the images they already posses in addition to providing alternative teaching models. Only then can teacher education expect to have a formative impact on the students' thinking about the use of computer in classroom teaching.

This literature review suggests that there are several sources that are likely to influence candidates' images of the use of computers in their future teaching. The most important are connected to their computer skills, their beliefs about teaching and learning, and the experiences with computers in education that teacher education is able to provide. In the following chapter I will outline a methodology for studying six secondary science teacher candidates' interpretation of the impulses and knowledge they encounter as they are completing the technology part of teacher education course-work.

Chapter III

METHODOLOGY

For many years research on teacher education was largely focused on the effect of teacher techniques and teacher behavior. Over the last decade, a new strand has evolved where researchers have directed their attention towards the cognition, beliefs, and mental processes that underlie teachers' activities (Doyle, 1990). Rather than the quantitative methods that have traditionally been used to document the effects of a course or entire programs, many of these studies have paid attention to a small number of cases, utilizing qualitative research methods in an attempt to illustrate how teachers learn to teach.

One area that has caught researchers' interest is an investigation into the ability of teachers to teach a particular content, where and how they learn these methods (Feiman-Nemser & Parker, 1990; Grossman, 1989; Shulman, 1987). A key component of this pedagogical content knowledge is the ability to represent subject matter to students.

> Representation involves thinking through the key ideas in the text or lesson and identifying the alternative ways of representing them to students. What analogies, metaphors, examples, demonstrations, simulations, and the like can help build a bridge between the teacher's comprehension and that desired for the student?
> (Shulman, 1987, p. 16)

Out of the many studies that have focused on teacher thinking, only a few of these have investigated how computer technology figures in teacher candidates' beliefs about instruction. As Kerr (1991) stated:

> In particular, the literature in educational technology is remarkably silent on such questions as how teachers learn not only to use computers, but also how to integrate them into the curriculum and the flow of classroom activities that realizes that curriculum.
> (p. 122)

Case studies are particular useful in eliciting this type of information. Such studies allows the researcher to paint a picture of what kind of beliefs about technology and pedagogy a small group of teacher candidates possess as they enter their professional training. This methodology also allows the researcher to gather in depth data about the possible transformation and growth of these images of technology and teaching as the candidates progress throughout their professional training.

Case Study Methodology

A case study methodology was used in this research since the purpose was to generate hypotheses regarding teacher candidates' images about the use of computers in the teaching of subject matter, and to investigate how these beliefs are connected to the candidates' developing thoughts about schooling and pedagogy as they complete their professional preparation in the use of computers in teaching. Such information is useful in order to broaden our

theoretical framework about the formation and organization of teacher candidates' pedagogical knowledge (Wilson & Gudmundsdottir, 1987).

A case study methodology implies that each individual case becomes the unit of analysis. The data collection process for case studies follows many of the same strategies commonly used in other qualitative research, using interviews, observations and other ways of eliciting information about individuals and their thought processes. While looking for patterns and themes that might evolve from the data, the researcher attempts to elaborate on the characteristics of the particular case, identifying those that can prove to be useful in a cross-case analysis.

The design of this study encompasses a collection of in depth studies of six secondary science teacher candidates. Four of the candidates were novice computer users whereas the others had a variety of experiences with such technology. All of the candidates were prospective science teachers enrolled in the same cohort in a teacher education program. By looking at candidates with similar subject matter concentration, I hoped to increase the chances of finding patterns of influence that could be attributed to the teacher education experience rather then to the traditions and nature of academic subject areas. In addition, by looking at students from the same cohort and by maximizing the differences in computer background of the candidates, I hoped to increase my chances of identifying patterns evolving as a result of the technology course-

work and the other classes the students were involved with during this particular time period.

Informants

Six informants were selected out of a group of fourteen aspiring secondary science teacher candidates initially questioned about their experience with technology and their beliefs about teaching and learning. All of the teachers were science majors, enrolled in a fifth year teacher education program at a university in the Pacific Northwest.

The informants were divided into two groups depending on their experience with computer technology. None of the candidates had any formal training in computer technology. Initially, three of the candidates were identified as experienced computer users, meaning that they had used computers for a more than one purpose (e.g. to run application programs, as a media device, to connect to the Internet, or for programming purposes), but as it turned out, only two of the participants, Frieda and Beth, had worked with computers in a wide variety of situations ranging from programming to the use of several application programs. The third person, Eric, had used computers for word processing and for e-mail, but so sparingly that he could not immediately sit down and start doing either of these things. Frieda and Beth were also the only ones who had used computers extensively in a work

situation. The other participants were novice computer users, meaning that they had used computers for word processing only.

In addition to the candidates' experience with technology, I also attempted to look at differences in the potential informants' beliefs about teaching and learning. I had hoped to identify characteristics about their views on what it means to teach science and how this can be best accomplished (e.g. by telling the students about the particular content or by having the students involved in activities). It soon became apparent that it was impossible to determine such beliefs during the brief selection process, but it should later become evident that such variety did exist among the informants (See Figure 2).

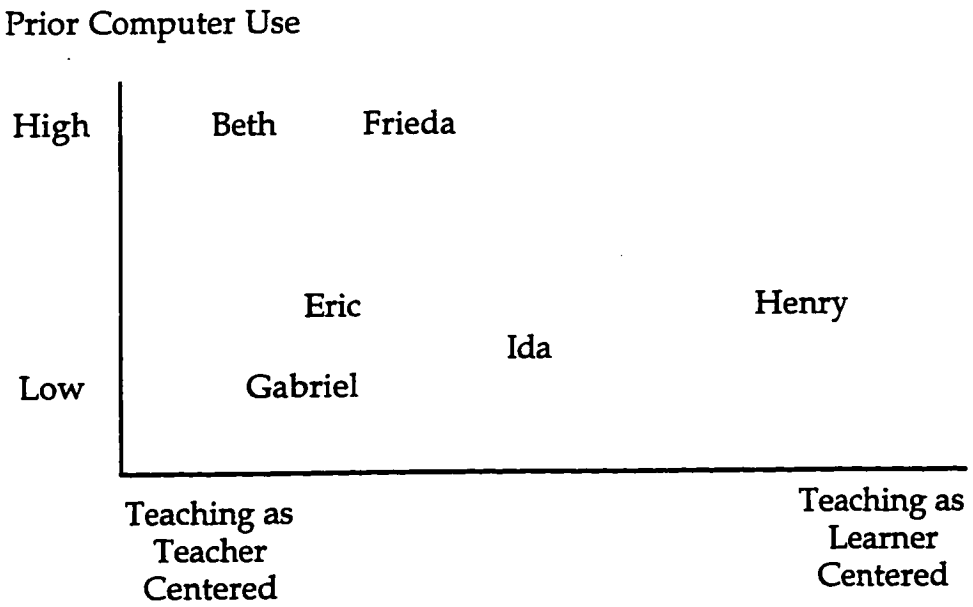

Figure 2: Perceived characteristics of candidates upon entering the teacher education program based on data gathered during the first interview.

With the exception of Frieda who had been substitute teaching for a few days, none of the candidates had any classroom experience as teachers.

Although it might initially seem like I was able to control for subject matter background, there might be a possible threat to the validity of the study by accepting science majors as a unified group. Science teachers could be, among others, chemistry, biology, physics, or geology majors, and although these disciplines share some commonalties, each also has its own distinct identity. There is a chance that some of these domains have different traditions for the use of computer technology in their research and measurements. As it turned out, some of the informants had more than one science major, and three different science domains were represented in the group. These were chemistry, physics, and biology.

There is also a great chance that prospective science teachers are different from other subject majors when it comes to the use of technology. One can imagine that science majors might possess a greater predisposition to use technology than for example an English or a Social Studies teacher because of the traditions of using technology mediated experiments in especially physics and chemistry. By choosing science teachers I might therefore have increased the possibilities of finding candidates that had experience with and had thought about how they would use of computers in their future classrooms.

Data Collection

In addition to the very short and informal interview that was used to select the informants, data collection included a series of three semi-structured interviews and classroom observations during the candidates' technology course-work. These interviews were designed to elicit information about the candidates' beliefs about teaching and learning, their views on the role of computer technology in the teaching of science, and the sources of these beliefs. There is always a chance that the informants report the answers that they believe the interviewer wants to hear during the conversation. It was hoped that the inclusion of classroom observations would enable me to overcome some of the limitations of self-report data.

The type of questions asked also posed a potential threat to the validity of the study. Since these candidates were just starting their professional preparation, there is a great possibility that the candidates had not reflected extensively on some of the areas covered in the interviews. The questions might therefore have caused the informants to construct the responses offhand. For example, some of the questions in the initial interview probed for information about the candidates' thinking about the use of computers in education. For some of the candidates, such questions might have inspired them to develop new images as they were speaking as well as eliciting information about established convictions. It was necessary to take this phenomena into consideration when I was analyzing the data and look for

evidence across different types of reports as I probed for characteristics of the individual candidates' thinking.

The first semi-structured interview (See Appendix A for interview protocols), which was conducted before the students had started their teacher education course-work, was designed to collect data on the candidates' initial conceptions of teaching science, including prior beliefs about teaching and learning and their images of the use of computers in their future instructional practice. In addition, the interview also sought to elaborate on the candidates' prior experience with computers in education as well as in non-academic situations.

The second interview, which was conducted right after the candidates' second field experience about seven weeks into their program, probed to elicit information about changes in beliefs about teaching and learning and the use of computers in science teaching. This interview included a card-sort task aimed at gathering data on the sources of some of their pedagogical beliefs and their images of the use of computers in their future classroom instruction. During this exercise, the candidates were given cards with the titles of all the courses they were presently involved in, including their field work experience, and first asked to rank the courses according to which they deemed most influential with regard to their thinking about teaching and learning and elaborate on their decisions. The students were also asked to perform the same ranking with regard to which courses were most influential on their thinking about

computers in education. The card-sort served as a stimulus for discussions about the candidates' beliefs about teaching and learning, their images of the use of computers in their future teaching, and the sources of these beliefs and images. These discussions also served as a source of information about how the candidates' pedagogical beliefs influenced their pondering on the use of computers in the teaching of science.

The final interview was conducted immediately after the candidates had completed their first quarter and thus their technology course-work. Like the second interview, this interview attempted to elicit information about the candidates' developing teaching philosophy, especially as it relates to the use of computers. In addition to direct questions about their beliefs, the candidates were introduced to three scenarios where computers were used in the teaching of science. The informants' responses to these served as a starting point for the candidates to elaborate on their thoughts about the use of such devices in a classroom situation.

In addition to the interviews, the data for the case studies also included classroom observation during the candidates' technology course-work. I participated in all of the activities alongside the candidates during these classes. This participation allowed me to gather data that the candidates would provide as they were involved with computers and were introduced to examples of how these are used in classrooms. Field notes from the observations recorded

candidates' immediate responses to the technology and their thoughts about the use of computers in their future practice.

Data were also collected on all of the courses, including the field experiences, that the candidates were involved with in order to trace possible sources of the candidates' thinking about the use of computers in science teaching. Interviews were conducted with the faculty who were teaching the courses the candidates were taking at the university, and with the cooperating teachers the students had met during their field experience. The focus of these interviews was on the content of the courses or field experiences, their goals for the candidates and as to whether they in their courses touched upon topics regarding the use of computers in education. In addition to the interviews, I collected documents handed out to the candidates during the courses, such as book-lists, articles and syllabi. The purpose of these data was to allow me to triangulate some of the data provided by the students during the interviews.

Data Analysis

Data analysis has been an ongoing process since the first data were collected (Glesne & Peshkin, 1992). Initially, I developed rudimentary coding schemes and memos in order to capture candidates' responses and probe for possible patterns (Miles & Huberman, 1984). These initial memos recorded immediate personal reactions to the data, and they proved useful in recording

the direction of the study and in determining information gaps while gathering data. More analytic memos were developed after all of the data were available.

The data analysis can be divided into two main steps; the first involving a careful elaboration of the individual case, and a second step of cross case analysis. While looking at the individual cases, a uniform coding scheme was developed that was used on all of the interview data. The coding categories, which had been developed and refined throughout the data collection process, included categories for both candidates thinking about computers, pedagogy, and the sources of their images of teaching and learning and classroom use of computers. Codes for candidates' beliefs about computers and pedagogy included: computer skills; beliefs about the use of computers in the teaching of science; beliefs about learning theories; beliefs about learning environments; beliefs about subject matter; beliefs about teacher knowledge. Those codes categorizing sources of candidates' beliefs included: prior experience with computers in schools; experience with computers during teacher education in methodology and learning theory course-work; experience with computers during field experience; experience with computers during the technology course-work; other professional experience with computers; interpretation of own schooling; teacher education course-work; field experience; and other professional experiences.

When an interview was coded, the content and general themes were summarized in a format that were used for all the interviews. The purpose of

the summaries was to reduce the amount of data and as an introduction to the analytic process. These summaries contained pertinent quotations made by the candidates as well as concluding paragraphs that included my own tentative reactions and hypotheses. In some instances these concluding words would inspire conceptual memos, and thus make the summaries an important part of the analytic process both as a way to preserve data and as an introduction to the interpretation of the qualitative data of the interviews.

As is common in case study research, the data that made up one case were thoroughly analyzed before proceeding to the next case. I developed an initial draft of each case after completing the coding for one complete set of interviews and observations. During this process I attempted to preserve the most important citations and comments while reducing the amount of data. After all, the purpose of case studies is to paint an in-depth portrait of each case based on the data available. Although my choices about what to include reflected an effort to build a particular argument with regard to the candidates developing images of computers in teaching and learning; it was my hope, that by including as many quotations as possible, the reader could make his/her own interpretations based on some of the raw data.

I completed two separate cross case analyses on the data. In one case the two candidates with extensive prior computer experience were compared to those with limited skills, whereas in the other, I divided the cases into two groups based on their images about teaching and learning. These cross case

analyses followed an identical plan. First, I completed the preliminary analysis of the sets of data referring to each group, for example, those with extensive computer background. During this process I looked for patterns and themes common to all of the cases involved and then summarized these in a conceptual memo. In addition to the memos, I plotted the coded data into charts in order to get a clearer overview of the sources of the candidates' beliefs about teaching and learning and their images of the use of computers in their future teaching.

After this initial analysis was completed, I looked for patterns and themes across all the groups. At this point, previous summaries of the individual cases as well as relevant memos proved to be extremely valuable as I sought to confirm and disconfirm possible hypotheses. In some cases this process would lead me to re-evaluate data that I had initially discarded as unimportant during an earlier stage of the analysis, thus underlining the importance of a well structured database for qualitative studies.

During the process of analyzing the data I relied on conceptual memos and charts in order to piece together data and to portray possible patterns and themes (Miles & Huberman, 1984). By continuously writing memos beginning at the very start of the data collection process, I developed a rich source of ideas about topics that at one point seemed interesting or theoretically significant. Often I would revisit previously discarded ideas found in earlier memos as I probed for patterns and themes at a later point in the analytic process. The charts, on the other hand, played a somewhat different role as an analytic tool.

These overviews were used to display the data and played an important role in uncovering missing data. On some occasions charts would lead me to take a closer look at the original data, and thus spur me to rethink parts of my conceptual framework.

The analytic process proved to be a very time consuming effort that required a constant re-evaluation of possible patterns and themes found in the raw data. Before I go on to present the findings of the study, it is necessary to introduce the individual cases and the teacher education program that they participated in. Again, qualitative research does not attempt to generalize to a population, but serves as a window that allows the researcher to raise potential hypotheses and to expand on theoretical frameworks. An in depth description of the cases is essential in order to do so. I will in the next two chapters outline the teacher education program followed by a description of the individual cases.

Chapter IV

CONTEXT AND CASES

Although teacher education programs across the nation share many commonalties, especially in the type of classes they require (Rieck, 1992), they also have distinct identities that influence the teacher candidates' pedagogical thinking. The particular program that the candidates in this study attended had characteristics that are atypical. For example, it leads to a Masters of Arts in education degree, and it takes five quarters to complete rather then the three or four quarters that are common to "fifth-year" programs. In order to receive an overview of the program I will briefly describe the program overall before I introduce the individual cases.

The Teacher Education Program

The candidates in this study were part of the second cohort of a restructured teacher education program located at a large Pacific coast research university. Compared to many other programs, this was a rather small enterprise, accepting only about 120 students each year in the secondary teacher certification program. The university had adopted rigorous entry criteria as part of an effort to secure "the best and the brightest" into the teaching profession. Among others, the university required that the candidates had

completed an undergraduate major upon entry, a prerequisite that ensured strong subject matter backgrounds among the prospective teachers. Less then ninety students had been accepted into the program this particular year. Thirteen of these aimed at becoming secondary science teachers.

Since the program was located at a large university, the candidates had ample access to library and computer resources. All of the candidates were upon entry provided with an Internet account, and they had access to several computer laboratories, one of which was reserved for education students. This laboratory, which was used by the students for their individual work as well as for the technology component of the program, contained mostly Power Macintosh computers, but a few machines running on a DOS/Windows platform were also available.

The candidates had to complete a series of courses typical for teacher education programs. These courses focused on everything from multicultural education to learning theory. In addition to the academic classes, the candidates were placed in various classrooms in nearby middle- and high schools for a period of time every quarter. During the first quarter, which is of particular interest to this study, the candidates completed three university classes in addition to two field experiences. The first of the field placements consisted of a three week block before classes started and consisted mostly of classroom observation, whereas the second field experience, also a three week block, took place around midterm. The university course-work included a

course called "Dilemmas in Teaching and Learning" which focused on learning theories, a methods course where a portion of the time was set aside for technology classes, and a mini-course highlighting issues of abuse. Of these, the "Dilemmas in Teaching and Learning" course and the methods class require a little more elaboration since the candidates often referred to these classes as very influential.

The cohort was divided into two groups for the learning theory class. Two of the informants in this study, Frieda and Ida were in one class, whereas Beth, Eric, Gabriel, and Henry were in the other. The professors had to some extent coordinated their classes. The readings were similar, although they did not overlap entirely. Both of the classes focused on questions like. What goes on in the mind of the learner during instruction? Why is there invariably a gap between what is taught and what is learned? How do teachers' expectations influence what students learn? How is knowledge organized in the heads of teachers? How do common sense ideas about intelligence, development, and learning leave indelible marks on students' self-esteem and self image? (S#1, p. 1). In these classes considerable time was spent on having the students reflect on their perceptions about teaching and learning. The candidates would read articles and participate in activities aimed at "creating confusion" (UF#1, p. 2) in the candidates' thinking about classroom teaching and thus provoke the students to confront their prior beliefs about such issues. Although the use of computers in teaching was not a separate topic in these

discussions, the course would prove to influence several of the informants with regard to their thinking about the use of machines in classroom teaching.

All of the prospective science candidates participated in the same methods class. This was a class rich in activities and filled with practical advice as well as pedagogical ideas. For example, on one occasion the candidates were asked to find out where they could acquire necessary laboratory equipment and so on. Theoretically the class focused on the importance of exploring scientific concepts. As the professor expressed it.

> Science is a verb as well as a noun. Science is something you do, it is a human enterprise. And the doing part of science is the knowledge you gain while doing it, so we are trying to develop that idea. So, therefore if they are going to teach science, they are going to get kids involved in "scienceing", that is what scientists do. We would never teach writing without having kids write, we should never teach science without having kids science.
> (UF#3, p. 3)

Although the technology course-work was constructed to be integrated into the methods course, it was in reality taught as a separate class by a teaching assistant. As a result, the methods professor did not touch upon topics related to the use of computers in the teaching of science, but assumed that these areas would be covered in the technology portion of the class. The technology sessions were calculated to be worth two of the five credits assigned to the methods course.

The technology classes lasted one hour and fifty minutes and were held in the education computer laboratory twice a week throughout the quarter. These classes would mainly emphasize basic hardware skills and introduce the students to common application software such as word processing and spread-sheet programs. A typical class started with a discussion of articles that had been handed out the previous class. These materials would often provide examples of how computers were used in classroom situations. After the discussion, the instructor would introduce a piece of hardware or software that the students could experiment with. During this time of exploring the students would sometimes accidentally stumble over a piece of software or a World Wide Web site that affected their thinking about the use of the computers in their own teaching practice.

An example of this happened in the first technology class. In this class some of the students were looking for science related material on the Internet. One of the candidates found a site that allowed the visitor to simulate the dissection of a frog. This simulation was very directive and crude, using poor graphics that made it very difficult to identify the different parts of the animal. In order to look closely at the frog, the students had to follow the directions closely, there was virtually no opportunity for individual exploration. All of the students in the classroom were soon viewing this particular web site. Despite the shortcomings of the simulation, especially if one compare to modern programs that allows the user to seek their own path, many of the

students left the classroom thinking that this was what a simulation program looked like. During the interviews many of the candidates would refer to this program when they talked about simulations.

Although most of the computer experiences focused on basic skills, the candidates were also introduced to more advanced features, such as the creation of web pages using Hyper-Text Markup Language (HTML). On one occasion, a science teacher was invited to talk about how he had used computers in his high school science class. In this presentation the teacher showed how he had let the students use Hypercard to create versions of the periodic table. He saw this as a way of making the students familiar with the various elements, a strategy that would engage in particular students who had a hard time memorizing the names and atomic numbers of chemical substances.

Since the candidates in this study were part of the same cohort, they had a coherent and common teacher education experience. Only during the field work did the students see different types of practice depending on which school they were assigned to. Although the candidates in this study went through the same classes, they varied in their response to the university course-work and the field experiences during the first quarter in their teacher education program. The next section will describe two sets of student teachers; one group had prior experiences with technology, while the other group entered teacher education without much background in technology.

Group One

The two candidates discussed in this part, Frieda and Beth, had both quite extensive experience with computers. Although none of them had seen computers used in the teaching of science, they had both used various forms of technology in their scientific work. In their initial thinking about the use of computers in teaching and learning science both of these candidates built upon how they had seen such tools used in work situations. Throughout the quarter, on the other hand, Frieda and Beth would develop an independent vision of what role computers ought to play in classroom situations.

Frieda: The Scientist

Frieda had already had a short career as a scientist before entering the teacher education program. She claimed that she had always been exited about science and kids, and during her undergraduate years, she had been insecure about whether to become a teacher or scientist. It was her hope that she could combine both of these interests by becoming a high school teacher. Unlike the other candidates, Frieda had had access to computer technology for as long as she could remember. Her parents let her and her siblings use the home computer while she was growing up. She had come to view these devices as a way of simplifying work whether it was doing research or balancing her check book.

Intellectual Biography and Entry into Teacher Education

Frieda had always been a faithful and clever student. After high school, she went on to study marine biology on the recommendation of her high school science teacher. During her undergraduate years she also attended a couple of education classes, one in educational psychology and the other in the teaching of science. Upon completing her bachelors degree, she was immediately hired as a laboratory technician at a major south eastern university. A few months into her new job, she enrolled in the Masters program at the same university as a full time student. One year into her graduate course-work, Frieda took a summer job as research assistant studying sand crabs. Her masters thesis grew out of this experience, and she received her Masters in Marine Science with the concentration in marine biology and chemistry the following year. After her graduation, she worked for two years as a marine biologist for the state of Florida.

Frieda, who always seemed to be intensely involved with whatever she was working on at the moment, claimed to have been enthusiastic about science since she was in high school. Her science teacher had been her favorite high school teacher. Despite the fact that Frieda had moved far from the place she grew up, she kept in contact with this teacher on a regular basis.

> I think she and I just clicked right while I was in high school and she became like a mentor to me. I actually keep in touch with her now and it is not so much that she helped me decide what to do in life, it was just that she was there for me and was

> enthusiastic about my choices. And although she is standing behind me, I think that's what impressed me about her and plus that she is so exited about science.
> (F#1, p. 3)

Although Frieda was interested in computers, she had few images of how to use them in a teaching situation upon entering her professional preparation. Her teaching models were based on what she had experienced in high school. She wanted to copy the best of her teachers and avoid the mistakes of the teachers she thought had not done a good job in the classroom.

Unlike the other candidates, Frieda had some very limited experience with classroom teaching. She had been substitute teaching for a few days while working on her Masters degree. Frieda had really enjoyed that experience. What finally pushed her into teaching was a desire to work with young people and at the same time continue her interests in science. Initially she was planning to become a high school teacher as her favorite K-12 teacher had been, but after her first field experience, which took place at a middle school, she became more and more interested in a career at that level. Before this experience, she had been afraid of not being able to keep the students' attention at the middle school level, but observing her cooperating teachers made her believe that maybe she could do it.

> At this middle school that I was at, I was able observe a teacher who had a very positive discipline policy, a proactive. I guess a policy with mutual respect. They worked together to solve problems, not to set out to punish. Now I think I have a better

> idea of what discipline means, but I think it is going to be a big point with me.
> (F#1, p. 5)

Frieda's favorite high school science teacher represented the instructional model that she initially wanted to copy in her future practice. Thinking back, Frieda was fascinated by her enthusiasm for science and wanted to follow in her footsteps.

> ...she was so great, I wanted to become that type of teacher.
> (F#1, p. 1)

> She was just enthusiastic, I think, I think of her.. she was not only enthusiastic, she was very inspiring to me. She was very into science, she pushed me to do science fairs, to do all the extra science parts.
> (F#1, p. 3)

In addition to being her professional inspiration, this teacher had helped Frieda receive a scholarship so she could go to college. Frieda hoped that by playing a similar role she could contribute to the society as well as develop her own professional interests.

Conceptions of Teaching and Learning Science

Upon entering the teacher education program, Frieda looked at science as a collection of facts. Her view of how students learn science was based on an interpretation of her own learning combined with engaging assignments and laboratory assignments for the students. In her view, the secret to good teaching was excellent presentation skills. She believed in a very directive

form of teaching where the teacher played the role as the deliverer of information. The assignments and laboratory activities served as an additional way of introducing and clarifying concepts such as gravity and atoms to the students. Since many students do not immediately take an interest in many of these topics, Frieda viewed it as essential that the teacher is able to provide colorful and engaging presentations in order to grab the students' attention. This is how Frieda described her beliefs about teaching upon entering her professional preparation after she had completed her first field experience:

> I thought I would be the kind of teacher who went into the classroom who was really straight and had some cool assignments to do, and didn't lecture in terms of boring lectures. I would have these cool lesson plans and stuff. It would be a very directive class.
> (F#1, p. 1)

> I probably would have used models. I would have said: See here, the sun is shining, blah, blah, blah. I would never have said: You guys, figure it out.
> (F#1, p. 2)

During her first field experience, Frieda was placed with two teachers who defined themselves as constructivist or learner centered teachers. Throughout these three weeks, Frieda would establish a close relationship with one of the cooperating teachers. She continued to visited this teacher's classroom once or twice a week throughout the quarter. Together they would discuss issues regarding teaching and learning that were introduced in the university classes.

In their teaching, the teachers she had met would emphasize the students' need to explore the content on their own and allow them to construct their own ideas about the concepts they were studying. Frieda, who quickly agreed with this notion, thought this could be accomplished in an environment where students were challenged to think about some of the same problems that scientists ponder over while trying to describe nature. In stark opposition to the type of instruction that she had initially proposed, she would soon claim that the teacher should not lecture or present the answers to the students, but rather play the role as a facilitator, helping the students to get started with their thinking about the various concepts. She referred to a teaching episode she had observed during her first field experience as an example of this.

> There was a teacher who was teaching the phases of the moon. She said, what do you think causes the phases of the moon? She gave them a tennis ball, she opened the classroom door so the sun was shining in through the door. And she said. Figure it out, so she left the problem to the groups and they spent about an hour coming up with hypotheses about why. She said nothing, she said just figure it out. And then each group presented their hypotheses.
> (F1, p. 1-2)

As Frieda worked on conceptualizing the meaning of constructivist teaching, she particularly emphasized the teacher's responsibility to address students' misconceptions about scientific concepts. Her first cooperating teacher had pointed to this as a defining characteristic of constructivist teaching. As a result, Frieda was very provoked when she felt she did not receive any

direct support for this view in the university course-work or during her interaction with other teachers. On one occasion she had observed a teacher who claimed to be constructivist but who, according to Frieda, did not address misconceptions among the students. In addition she was also critical of this teacher's way of trying to guide the students towards the "correct" answers. Frieda claimed that there could not be any "correct" answers in a constructivist learning environment.

> He said he was teaching constructivist, that he is a constructivist teacher. And it didn't sit well with me, you know, I don't really know what it is, but I didn't think it was that because I didn't think misconceptions were addressed. And it seemed more like discovery learning, kind of, and I guess it came to the point where I learned about the difference between discovery learning and constructivism.
> (F#2, p. 9)

Her suspicion about this teacher's instruction had been confirmed by interviews she did with students in the class. These students had claimed that they did not have to think during this teacher's classes; they had told her that this was a very easy class where they easily could get a good grade without doing much work.

> They really had no clue why things were happening, and, but they could get an A and that was kind of the way it was.
> (F#2, p. 11)

Frieda developed the view that a good learning environment would allow the students to draw their own conclusions. Students should not be

rewarded for their ability to come up with correct answers but rather for their ability to make their own judgments based on the information they are able to obtain.

> That the teachers are asking a lot of questions and are guiding the kids in a right direction without giving them the answers. Eh, one in which the kids don't see as someone they need to court to get an A or to get the right answer. One in which they see as the goal is understanding, coming to their own conclusions. Eh, one that is not, I kind of, I want to say regulated by grades.
> (F#2, p. 5)

She also contended that only in such an environment would the students be able develop a deep understanding of scientific concepts.

> Ok, my opinion now is that to learn something is not what is traditionally thought of as learning something. It's not to memorize, it's not to list things, it is to truly understand the very basics of what is being taught. Eh, the true concept behind everything, eh, it's to be able to not only do that situation or to answer that one question or whatever, but to apply that broad concept to a variety of different tasks, eh, and I think, the most important of those tasks are the how does this apply to me, everyday lifetime things.
> (F#2, p. 5-6)

At the end of the quarter Frieda started to question whether constructivist teaching would be appropriate in all situations. She was not sure if it would always be possible to address the misconceptions of the students. As an alternative to letting the students discover scientific concepts on their own through their classroom experiences, she would again claim that in some

instances it might be useful to let the students work on things in a more traditional way, hoping that they will be able to grasp the underlying concepts of what the teacher was be trying to convey to the students.

> Because I think that there are something that you are not going to be able to present to the kids that is going to make them use misconceptions, since that seems to be what constructivism is based on. Then I am still going to teach those things even though I will not be able to address misconceptions necessarily. So I guess it is more of, more experientially based like that we have been talking about in the science methods class, on how to get hands on work experience, that's the best thing. (F#3, p. 2)

In particular, Frieda saw it as difficult to teach concepts that cannot easily be worked on in a lab environment. As an example she mentioned atomic theory, and thought that in situations like that, the best solution would be to just present the information to the students.

> But I feel that there are things that is going to be difficult to, the kids, no matter what you have them do. Talking about atomic theory, it almost have to be a presentation, because whether it is me standing up presenting it or it is a kid standing up presenting it, an report, this is what an atom is, there is no real experience there. (F#3, p. 3)

Her pondering on issues like these, prompted her to continually question her assumptions about what it means to teach science, questions she continued to wrestle with throughout the quarter.

Conceptions of Computers in the Teaching of Science

Although Frieda claimed to have much to learn with regard to computer technology, she had considerable experience with a wide variety of applications and operating systems. She had used technology extensively at home and in her work, both in the laboratory and as a marine biologist. In her work she had used computer programs to work on statistics, drawing, spread sheets, word processing and a few business application programs. Although she was self-taught, with the exception of a programming class she had taken in seventh grade, she was comfortable using DOS, Microsoft Windows, Macintosh, and to some degree, UNIX platforms.

The Internet, on the other hand, was something new for Frieda as she entered the teacher education program. She had never used e-mail and was not familiar with how to search for information on the World Wide Web. During the quarter she quickly picked up on how to utilize these aspects of computer technology. Reflecting back at the end of the quarter, this is what she felt she had learned from the technology course:

> I am more fluent on the Internet. I can type in a word and look for stuff and get information. And I hope I have the skills now to determine what is bad, you know, I am skeptical of that. I haven't learned any major things, I have learned how to use Hypercard, briefly.
> (F#3, p. 24)

Although Frieda had never seen computer technology used in regular teaching, she entered teacher education with great hopes of what the

technology could contribute to K-12 teaching. In accordance with her initial beliefs about teaching and learning, she thought that computers would allow the teacher to make colorful presentations or to involve the students in motivating activities that could underscore the concepts the teacher would try to convey to his or her students. By using computers the teachers could make the instruction more engaging and effective. She had seen an example of this in a TV program.

> I saw a program where the students were working on simulations about global warming and stuff. They could basically pull out the program and alter the temperature or whatever and see how it affect the earth. That seemed like a pretty cool thing to do, they can't really do it in real life.
> (F#1, p. 8)

After the first field experience, when Frieda started to question her initial beliefs about teaching and learning, she grew increasingly critical of what role computer technology could play in the instructional practice. She was especially concerned that the use of computers might hinder the students' developing their own ideas about the subject matter.

> But I still think along the line that it might keep the kids from figuring things out themselves because the computer can do it for them. I don't think that's the right way to go.
> (F#1, p. 8)

It should be noted that, when not prompted otherwise, Frieda's image of students working with computers was one of tutorial programs. She envisioned computers taking on the role of what she had come to see as a poor

teacher, one who presented a topic and then asked the students to answer questions about the content or follow the instructions in a laboratory exercise. According to her, it would be virtually impossible for students to construct their own knowledge with such a teaching strategy.

> I don't want kids to sit at a computer and answer computer question and give the right answer back. I don't want it to be a Skinner type instrument, and I don't really see how it's not going to be.
> (F#2, p. 18)

> I would really have to think about it, because I don't like the idea of them hitting return and then keep getting new screens. You said the kids could ask questions, so the kids can sit there and type in, so how is this different than any animal, I doubt they could do that because the computer is not set up for that, I would assume, I don't know how, anyway, so I don't like that, it is all the correct answers un-compromised going on there, you know. So, this is where the heart is, there is where it always is, put it there and you will be fine.
> (F#3, p. 15-16)

Although she had an especially hard time visualizing the use of tutorial programs in classroom settings, she could see the use of computers as an efficient way to gather information and as a scientific tool. She thought that the Internet could become a promising source of information, allowing the students to explore topics independent of the teacher and the textbook.

> I am sure they would have good pictures that would be really neat and I heard that scientist are setting up like a question and answer thing, I think that is definitely, you can't get much more closer to the actual stuff than doing it yourself, so that's great, and

> then if the kids realize that this is NASA, this is why we are accepting this.
> (F#3, p. 19)

In addition, from her job experience she could easily identify with how computers could make experiments more accurate or enable the students to better see small particles. She was particularly impressed with an electronic microscope that could be projected to a large screen via the classroom computer that she saw used by one teacher she had visited.

> I like those microscopes that you can project up on a screen. I think that's really cool. I saw one in one school. So basically if one is looking for one organism and only one can find it you can show it to the whole class, I liked that.
> (F#2, p. 18)

At the end of the quarter, when Frieda started to question some of her previous thoughts about constructivist learning theory, she would again find room for the use of technology to make good presentations, especially when the instruction is focusing on topics that are not easily worked on in a science laboratory. Once again, she would suggest the use of multimedia as a way of conveying information to the students or use simulation programs that would allow the students to virtually explore concepts that can not be easily worked on with the resources normally available in a high school.

The Influence of the Teacher Education Program on Frieda's Thinking about Computers and Teaching and Learning

The field experience had a tremendous influence on Frieda's thinking about teaching and learning. Her initial field experience was especially important since she had met the teacher who introduced her to constructivist learning theories and with whom she stayed in close contact throughout the quarter.

> I went to the junior high and talked to good teachers and spent time with them and now, they introduced me to constructivism and how open ended questions are and then watching those students work in that situation was amazing. I was, I didn't think it was possible to do what they did.
> (F#1, p. 1)

This contact set the tone for how she interpreted most of her experiences during the quarter. When asked to rank the experiences that had influenced her the most with regard to teaching and learning during this quarter, she identified the first field experience as being by far the most influential.

> I think the big thing was, there are two teachers at that school that really influenced me, and that math teacher, I still, I go back to her after school to talk to her and seeing how discussions, what's going on, as well as how, it's been very helpful for me. I think if I hadn't met her, it might not have been as productive as it is. Eh, so that's the major thing. And then this last one it was interesting to see how constructivism is interpreted so that was very helpful.
> (F#2, p. 16)

According to Frieda, the second most influential class was the science methods class. She appreciated this class because it provided practical ideas that she thought she could utilize in her future role as a teacher.

> ...little neat stories that we could incorporate, and these little brain teaser things, just little things along the way that I could see myself using in class. (F#2, p. 16)

Compared to the other two university courses, Frieda was very skeptical about the learning theory class. She accused the professor of being too academic and not related to what goes on in school.

> And maybe I am being a little bit cynical, all those academics they don't know what is going on in the real educational world, that is probably what most teachers think, at least that seem to be the impression that I have gotten, and I think he knows what is going on in classrooms because he [the learning theory professor] has done a lot of studies in classrooms, but he is not helping me as a student in this program to apply it. (F#3, p. 12)

Despite her criticism of this class, it was this class that prompted her to research many topics related to teaching and learning. On a weekly basis she would search for additional literature that could cast light on some of the topics covered in the class, and she would discuss these with her the cooperating teacher she had met during her first field experience. Often she would claim that this teacher provided better and more useful information then what she could find in the assigned articles and during the discussions in the learning theory classes. For example, at one point the class had been discussing the role

of culture in education. After the class she had talked to the cooperating teacher about her opinion of this topic.

> And I was interested in what her view was, because I was thinking that this was kind of how does a teacher teach to each. And she basically said, which I think was a much more hands on idea, she said you don't have to look at it as you are teaching to a culture, you have to look at it as you are teaching to individuals, but not individually.
> (F#3, p. 8)

As in most cases, Frieda would deem the cooperating teacher's judgment as far more useful then what had been proposed in the university course-work.

Frieda did not see much use of computer technology during her field experience. This was particularly interesting since one of the classroom she visited, the one that belonged to the teacher who introduced her to constructivism, was a designated Apple Classroom of Tomorrow [2](ACOT). As a result, the teacher and the students in this room had ample access to computer technology, although the school had yet to establish Internet connections for the classroom computers out of concern that the students would try to access web pages that would be deemed inappropriate by some parents groups. Despite this, the only use of computers Frieda had seen in science classrooms was students who were typing up reports and similar types of activities.

The technology sessions had enabled her to be able to use the Internet to

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[2] The Apple Classroom of Tomorrow project is a research collaboration between universities, public schools, and Apple Computers Inc. In this case, the classroom had been equipped with a number of computers.

search for information, but with the exception of small introductions to certain application programs, she claimed that she did not learn anything that would inspire her to use more computer technology in her future instruction. Throughout the quarter, she saw it as very difficult to combine the use of technology with her ideas about constructivist teaching, and expected that she would limit the use of computers to topics which she finds difficult to introduce to the students in a constructivist way.

> When there is no way I could do it with an experience for the kids, and I don't want to stand up there and lecture, and I had to present it, I might possibly use it (computers). I think I have basically learned to use it more as an information gatherer. (F#3, p. 24)

During the quarter Frieda went on a roller coaster with regard to her thinking about teaching and learning and the use of computer technology in classrooms. She would over a few weeks completely reject the beliefs she had brought with her to her professional preparation and then moderate these views further into the quarter. Her image of computers was one of a presentation tool or a learning machine. Although she was very much aware of the role that computers could play in laboratory work, she would always talk about the machines as a tutorial instrument when not prompted otherwise. Frieda might have been so used to using computers to write and compute and record accurate measurements to find such use worth mentioning. She was unfamiliar with the use of computers as media devices, and it was the image of

a learning machine that provoked her and led her to be very critical of the use of computers in her future instructional practice.

Beth: The Bright Student

Beth, the youngest of the candidates in this study, had gone directly from high school to college to her teacher preparation. A sometimes quiet and soft spoken person, it was her desire to use her future teaching career to help young people getting a good start in their life.

> I always liked science and math. And I really wanted to work with people and have the opportunity to influence kids lives and maybe help them out and that's really interesting to me.
> (B#1, p. 1)

Although she had spent most of her last four years working on her degrees, Beth had for two years held a part time job in a chemistry laboratory at the university she attended. In many ways she represented the new generation of teacher education students - young people who have had ample access to user-friendly computer equipment and who take the presence of such devices for granted.

Intellectual Biography and Entry into Teacher Education

For as long as she could remember, science and mathematics had been Beth's favorite subject areas in school. After high school, she completed her undergraduate degree at a major Northwestern University. Her main focus had

been organic chemistry, but she had also minored in math and had taken several classes in biology. Upon completing her Bachelor of Science degree, she decided to work towards her teacher certificate at the same university. She had chosen to continue at the same university since it would allow her to hold on to her part time job in the chemistry laboratory and live with her parents, something that she hoped would help her avoid borrowing money to finance her education.

As for so many teacher candidates, Beth's high school teachers had played an important role in encouraging her interest in science and mathematics. She had loved the practical side of science that she had experienced doing laboratory work in her high school science classes. According to Beth, science and mathematics represented an orderly area of study, free from the ambiguity and interpretations that she felt characterized many of the other subject areas.

> I thought science dealt more with facts and truths
> than most other subjects....
> (B#3, p. 1)

This sense of order was important to Beth and one of the main reasons why she had studied science in the first place, and a major reason why she enjoyed working in the chemistry laboratory at the university.

Beth had been investigating several possible careers after completing her undergraduate degree. She knew she wanted to do something that would enable her to nurture her interest for science, but she also wanted to do

something that could benefit people whom she considered had been more unfortunate in their life than she had. Beth hoped that, by becoming a teacher, she could help children who found themselves in difficult family situations or who were living in poverty.

> I think that I can teach them things that they don't know. Many of the students might come from poor families and do not get the support at home and I think teachers can be a positive role model and support the kids.
> (B#1, p. 1)

With no teaching experience, Beth continued to be ambivalent about whether to become a teacher until she was about to start her professional preparation. She had spent several hours talking with an aunt who worked as a teacher in a different state in an attempt to investigate what teaching was all about. Beth had even gone so far as to visit her relative for a week and spent the time observing in her classroom. During this time she was allowed to teach a class. Encouraged by her ability to keep discipline and communicate with the students during this short experience, she decided to give teaching a chance.

Conceptions of Teaching and Learning Science

Upon entering the teacher education program, Beth felt that science, unlike many of the other subject areas taught in schools, was a very practical study. She would claim that by studying science we would better understand the environment and all the technology we use to make our lives more

comfortable. This was also what she wanted to emphasize in her future teaching of science.

> The many practical applications of it. So the students continue to see that science affects their everyday life and to be exited about it. Generally how science relates to all of these objects and how that enhances our understanding of all parts of our lives.
> (B#1, p. 2)

Beth thought that students would take an instinctive interest in studying science since this subject area attempts to describe who we are and almost everything we do. In addition, Beth felt that science was a subject are that was more defined, and thus easier to grasp than, for example, English or Social Studies.

Teaching, Beth would claim, is a matter of transferring information to the students. A good teacher would be able to convey scientific concepts to his or her students by engaging them in a variety of laboratory exercises and by having the teacher perform engaging presentations. She imagined her teaching to focus on scientific facts and methodology.

> It [my teaching of science] would probably be far more factual based, students would have to learn what has been discovered before and techniques of testing.
> (B#3, p. 2)

> [To learn science means] to know how to, the general foundational things like chemical structures, formulas and so on. Understand some of the more fundamental calculations. I would like to cover areas that can be covered during lab work so they can see those processes.
> (B#1, p. 4)

Although Beth did not have the same close relationship with her high school teacher as Frieda had, some of her former teachers were role models for the way she imagined herself as a teacher. When talking about her high school experience she emphasized first the personality of, in particular, her physics and mathematics teacher.

> In high school, my physics and math teacher was my favorite. The classroom, there was nothing special about that, but her style and personality; she seemed to be very relaxed and kept kind of a lighter atmosphere so when things got rowdy, she would talk about it and then continue on, and make sure we all understand. She taught the basics and taking it a step further by giving us a test to check our understanding.
> (B#1, p. 3)

According to Beth, a good learning environment is characterized by what she labeled a "relaxed" milieu, much like the one she had experienced in her high school physics and mathematics classes. She emphasized the importance of the teacher's ability to communicate with the students, being able to connect with them in areas beyond what is usually described in employment contracts.

> I like to be as much of a friend as I can and still be professional in my teaching methods and the way I relate to students. I like to be available to them and help before or after school, talk to them about their work, talk to them about anything.
> (B#1, p. 2)

Beth's initial pedagogical strategies were based on what she thought worked for her in high school. She would especially favor laboratory work which she claimed helped illuminate the practical side of science.

> I think they [the students] are learning a lot more then just reading out of a book, and the lab experiences that I have had, I have really enjoyed and they really stand out in my mind.
> (B#1, p. 1)

Much like her favorite high school teacher, she also wanted to provide colorful introductions to the students. Her high school teacher had been talented at using analogies and providing a variety of problems for the students to work on. During her first field experience she had observed a teacher that she thought was a good example of this. This teacher was able to get the students' attention with her original presentation of rotations and revolutions.

> The teacher was explaining the difference between rotation and revolution in astronomy and she demonstrated it by rotating and revolving around the classroom, and then let a few students do it as well.
> (B#2, p. 5)

The reason why she thought this was such a good example was that this gave the students multiple impressions, rather then just reading about something. This argument is similar to the one she often used to justify the emphasis on laboratory work in teaching science.

> It is something that the kids will remember, seeing the teacher kind of dancing around the room, and it was just a concrete example beside the dictionary definition."
> (B#2, p. 5)

Throughout the quarter the readings and the discussion in especially the learning theory class, provoked Beth to question her initial assumptions about teaching and learning science. She would increasingly de-emphasize the need for memorization or scientific techniques. Instead she would underscore how important it is that the students are able to transfer scientific knowledge to other situations. Only when the students are able to make such connections will they be able to change their perspective and learn something.

> [The purpose of teaching science is] to get away from a lesson with maybe a changed perspective or, I don't think that you necessarily need to have a set of facts that you have memorized or something, but just that, maybe a new way of looking at things, a deeper understanding, some sort of change in thinking.
> (B#2, p. 3)

The idea that science is not a collection of truths compelled Beth to disband her initial focus on presentations in the teaching of science. Although unsure about how to teach science without telling the students about the various concepts, she would put increased emphasis on open-ended laboratory work in order to find ways for the students to discover things on their own.

> If it [science] wasn't necessarily truth, it [my teaching] would be focused more on what they could discover in labs and the process of the discovery rather then ideas or theories.
> (B#3, p. 2)

Conceptions of Computers in the Teaching of Science

Beth had substantial experience with technology. Most of what she knew, she had picked up on her own, but she had received some training during her college chemistry classes and through her part time job in the chemistry laboratory. In her laboratory job she used computers that were attached to different measuring devices in order to control ongoing chemical procedures. Beth had also seen the use of computers in the teaching of science.

> I have seen a lot of good demonstration in my classes in chemistry, and I have seen professors who have used computer models to show reactions and to compute models.
> (B#1, p. 2)

> I have seen them used together with the overhead to show students different dimensions of graphing and such. And I have seen students use them to plot graphs from the temperature curve and what happens when the temperature is changed.
> (B#1, p. 6)

Beth was familiar with several application programs such as word processing, spreadsheets and data bases. In addition, she was comfortable with Macintosh as well as DOS operation systems. Beth had also used several features of the Internet since she started college and used e-mail on a regular basis. She had used the Internet to search the World Wide Web for information she needed in order to write papers and for e-mail. Beth had owned a computer for several years and she has had access to the advanced computer technology at the university throughout her college career.

> I have used them [computers]to present models, spreadsheets and databases. I have used them for lab write ups, using graphing and that kind of stuff. I also used computers attached to different measuring devices in order to control procedures in a lab setting.
> (B#1, p. 5)

Beth did not see much use of technology in high school; what she had experienced in educational settings stemmed from her college education. She initially believed that computers could be used to improve the demonstrations and explanations a teacher give to the students. In her own field she saw the use of computers as particularly useful in providing images of chemical models.

> When it comes to chemistry it enables you to show models and to spin the molecules so you can see them, I think that is real helpful. You can do graphing and all those kind of stuff.
> (B#1, p. 5)

Beth's image of computers in education was consistently one of a tool that could be used to support the teacher in his or her presentation, or as a device that could be used to perform more accurate experiments. Although Beth never rejected the thought of using computers in her future teaching at any time throughout the quarter, she found it bothersome that she had seen so few models. During her field experiences, she never saw any use of computers. She was therefore very much in doubt about where to place technology in her image of good teaching.

> I have a hard time pulling it [the use of computers] in to the classroom. It [the technology sessions] is giving me an introduction or something. I was familiar with e-mail and the Internet a little before, so that wasn't very helpful. But I am having problems pulling it in because I haven't seen it used in a classroom.
> (B#2, p. 11)

At the end of the quarter Beth started to question whether chemistry represented a type of subject matter that should be considered different from, for example, biology. The reason for this view was that she claimed that chemistry is based on models and connections that are not visible to the eye. It would be too ambitious to expect that students would be able to discover such models on their own, and she could see herself telling the students about what is known and using computers to visualize these ideas. This was what she had seen the researchers in the chemistry laboratory do, and she wondered if it would be necessary to adopt a similar model in the teaching of science in her future practice.

> I have seen programs that can do a little animation and I guess that could be a starting point for classroom discussion, and you can see representations of things that one might not otherwise. Chemistry things are so small you can't see it, so a computer could be a good tool for simulating that. And I think I would like to use that and even as far as technology as just tools, in our methods class we have used a lot of boxes with something inside them to talk about building models. These are things I want to use.
> (B#3, p. 14-15)

The Influence of the Teacher education Program on Beth's Thinking about Computers in Teaching and Learning

Beth claimed that, during the first quarter of her professional preparation, the science methods class and the learning theory class had influenced her the most when it came to thinking about teaching and learning. Although the field experience and the technology course-work had also provided new ideas, only the first two had confronted her initial beliefs about what she thought to be good classroom practice.

The methods class had directly challenged her idea that science was something to be memorized, sets of formulas and laws. Instead she had participated in activities where she had to construct new ideas and propose possible solutions to problems she did not know the solution to.

> The science classes that I have taken [before entering teacher education] were mostly a lot of memorization and, so we didn't necessarily do science or get the big picture in those classes. In this class [the science methods class] we have done a lot of puzzles and thing to get us to think about the way scientists construct models, so it kind of opened my eyes.
> (B#2, p. 9)

The learning theory class had confronted her thinking about teaching and learning in much of the same manner. She had started to question whether it was appropriate to just tell the students about scientific concepts, if they would really be able to learn that way. One of the most compelling stories that she told about this development took place during her second field experience.

For a couple of weeks she had observed a teacher whom she had considered a good teacher. This teacher was entertaining, used nice pictures, and had well organized laboratory exercises that went with the unit she was teaching. In connection with an assignment she had for the learning theory class, Beth interviewed some of the students after having observed this teacher in a particular lesson. She was surprised to find that despite the well organized presentation complete with follow up activities, the students she talked to had not been able to understand what the class was about.

> After watching what I thought was really good teaching, some of the girls hadn't learned anything. (B#2, p. 10)

> I asked them a lot of questions, I had about forty minutes with them in two sections, and they couldn't answer my questions, they hadn't learned through memorizing facts, they didn't have a grasp on the concepts. (B#2, p. 10)

Beth was uncertain of how to explain this, but it made her question some of her initial conceptions of teaching and learning.

Unlike Frieda, Beth was never provoked by the idea of using computers in the teaching of science at any point through out the quarter. One reason for this could be that she consistently thought of computers as tools and never associated them with machines that would actually introduce concepts to the students. Her vision of how technology ought to be used in K-12 education was mainly based on what she had seen in her work. In her case, the influence of

her work experience with regard to how to use technology was far more powerful then what she had experienced in the teacher education program. In many ways, this "work experience" model stayed with her throughout the quarter. She had seen how scientists used computers and she hoped that similar uses could take place in an educational setting.

> The lab that I work in uses it [computers] quite a bit, a lot of different programs, and so, they will use molecular drawing programs for presentations they do to make slides and things, and so there is a lot of uses that I can see from that that might be helpful. And as far as working with instrumentation in the lab, I want to at least try and simulate that for my students if I couldn't have the actual instruments so they see how much more it is used in industry. (B#2, p. 18)

The technology course-work had very little influence on Beth's thinking about computers in her future teaching of science. She was already well versed in the use of computers, but she had picked up a few things, especially with regard to the Internet.

> There is a lot more out there than what I thought there was. Like I have been familiar with e-mail and things before but to a very limited extent I think, I had no idea that there were listservs and newsgroups or, that it was such a good source of information and communication. And the Internet, I knew it was there but I didn't realize the potential what all you can do with it. And I guess I am just getting aware of how much more there is out there that you could use in the classroom or otherwise. (B#3, p. 13-14)

During her field experiences she had been struck by the absence of computer technology. Even if the computers were available, she had noticed that they were rarely used. On one occasion she had seen two computers that were stationed in her cooperating teacher's classroom. Although the teachers expressed some pride in being equipped with such devices they were never used during the three weeks she visited. The teachers had mentioned that they were about receive Internet access, a happening that had seemed to create some concern among them since they worried that the students might access inappropriate material and wondered how they could block such searches. During her field experience she had heard about special classes such as the media group, but she was never able to observe any of these. Except for these occasions, technology had not been a topic in Beth's interaction with cooperating teachers and their students.

The experiences of Frieda and Beth both suggest that the technology course-work contributed very little to their images of computers in the teaching and learning science. Other course-work, especially the learning theory class and the field component, played a far more important role in altering their pedagogical views as well as the perceptions of the use of computers in their future teaching. The differences between the two, moreover, illustrate the ways in which initial conceptions of teaching and learning, images of computers in teaching, and the reactions to the teacher education experiences contribute to develop a particular understanding of computers in

teaching and learning. In the next chapter, we will encounter four teachers who were unfamiliar with computers upon their entry into teacher education and who had to learn how to use the technology at the same time as they developed pedagogical models for how to use computers in their future classrooms.

Chapter V

THE COMPUTER NOVICES

Few candidates presently entering teacher education have never seen or used a computer. This was also the case with the four prospective teachers who were characterized as computer novices in this study. Common for all of these candidates was that they had used computers for a very limited number of purposes, mainly word-processing. Eric, Gabriel and Henry had all used computers in some form in their previous job career, whereas Ida had used college computers while completing her undergraduate degree a couple of years ago.

Eric: From Banking to Teaching

Eric was the eldest of the candidates. After spending more then twenty years climbing the career ladder in the banking industry, he had made the decision to become a teacher. Although a difficult resolution, especially when he considered he had to go back to school full time for a period and enter a profession that was substantially lower paid than what he had become accustomed to, he hoped that he in his future job would be able to avoid the stress that he had felt over the last few years. In addition, his wife had given

birth to their first child, a daughter, a few months earlier, and he hoped that he would have more time to spend with them.

Unlike the other candidates who all considered becoming high school teachers, Eric was determined to become a middle school teacher from the beginning. He had volunteered working with middle school aged children over the last few years, and he really liked spontaneity and the challenges of this age group. Having been an avid outdoors man for several years, he found it natural to focus his attention on becoming a science teacher, hoping to combine his love for nature with his interest in helping teenagers.

Intellectual Biography and Entry into Teacher Education

Eric, who was in his mid forties, went to high school in the early seventies in Arkansas. Glad to be among the first graduates in several years who did not have to worry about being drafted to the Vietnam War, he continued on to study psychology at a university in the same state. Insecure about what to do with his degree, he took the first job he was offered, which happened to be in the personnel department in a local bank. Eric had since worked in various positions in many different banks, although most of his tasks had dealt with human resources. During these years he had been employed by several different banks and lived in many cities throughout the nation as the companies merged and new opportunities had come about.

Eric claimed to have always taken an interest in plants and animals, all kinds of living things. This interest had become increasingly important to him over the years as he spent more and more time hiking and exploring the mountains and the forest that surrounded the city he was living in. When he decided to go back to school to become a teacher, it was therefore natural for him to pursue a career that included this interest. Unable to immediately finance a life as a full time student, he had spent many evenings and weekends over the last two years completing a Bachelors of Arts in Natural Sciences from the same university he was now attending for his teacher certification. This particular degree was aimed at students who were planning a career in teaching, and in Eric's case it consisted of classes in chemistry and biology. Eric had completed his degree in the spring, left his job in the banking industry, and entered the teacher education program the following fall.

One of the main reasons Eric chose teaching as his new career was the opportunity to work with youth. He had several friends who were teachers and he had for several years worked with teenagers through a project with the Sierra Club. Together with other volunteers, Eric took inner city youth on nature trips, hikes where the teenagers would learn to camp and enjoy the fresh air and the beauty of the mountains. Although these trips did not include any formal instruction per se, they allowed him to work with young kids and become a mentor for these children in a more informal way.

> I guess I wasn't really happy with what I was doing, I ended up spending a lot of time volunteering to

> work with kids because I like it and I find it personally rewarding. Just because I think it is important and I like doing it and I get satisfaction out of it. So to work as a teacher will fulfill both needs, providing an income and giving me personal satisfaction.
> (E#1, p. 1)

In addition to having an opportunity to work with youth, Eric viewed interacting with youth as an opportunity to bring about social changes, to improve society. To be a teacher would be his way of making this nation a better place to be in the future. Eric thought that teachers played a key position in shaping the attitudes and the behavior of the next generation. He hoped to play a role in positively influencing the kids he hoped to interact with in his future position as a teacher.

> Well I guess for me I feel it [the school] is the best place to solve problems and to generate solutions to problems is with the youth, that is what we should focus our attention on our society. It is rewarding to make sure there will be some good people.
> (E#1, p. 2)

Conceptions of Teaching and Learning Science

Initially Eric had hoped to combine excellent presentation skills with practical tasks, especially projects that would allow the students to put their hands on plants and animals. He saw it as essential to include hands on activities as a way of making the information presented to the students come alive and keep the students from getting bored by the teacher's speech.

> I think in eight grade I will like to do activities that can keep them busy, I want them to enjoying what they do so that they will continue to do it, you know. As long as they keep working on projects if you divide them well, they are going to be learning. (E#1, p. 2)

These projects would be very concrete, exercises where the students would follow directions handed out by the instructor.

Eric had clear ideas about how he wanted to relate to students. These beliefs were rooted in his view of the teacher as the leader of the class and the one who is delivering the information. He over and over emphasized the importance of firmness and excitement, characteristics that he found in his own favorite high school teacher.

> Eh, I think you don't have to be everybody's friend. You have to set yourself apart. They have to know what the rules are and who is in charge, especially middle school age kids. They need to know exactly what the rules are and what the boundaries are. (E#1, p. 5)

> So you have to by excitement get some excitement about it [science], set goals, and you have to tell them up front where you are going to go with your class and why that is important to them. You have to try to make it rewarding and or exiting. (E#1, p. 6)

Through the learning theory class Eric was introduced to arguments critical to his initial beliefs about teaching and learning. He was especially provoked by the constructivist ideas he encountered, and he would spend a lot of time and energy for the rest of the quarter wrestling with the meaning of constructivist teaching and what it would look like in a classroom setting.

Soon he would define himself as a believer in constructivist teaching, a way of teaching that he interpreted to mean far more student involvement than what he previously had perceived necessary in teaching. The students were no longer receivers of information who needed to be entertained, but active learners that must somehow take responsibility for their own learning.

> Constructivistic, meaning trying to let the students teach themselves, to guide that process, to facilitate it in any way that I can, but to let them make the connections within their own minds and in ways that work for them.
> (E#3, p. 1)

To accomplish this Eric envisioned himself involving the students in discussions about the concepts he was going to teach, let them work on solving problems and then lead them to the generalizations that he would like to see the students make.

> I think, rather then giving them the concept or term or the facts or whatever they are first, give them opportunity for discussion, experience with something and then lead them to the generalizations, the vocabulary.
> (E#3, p. 1-2)

Eric realized that this form of teaching could be difficult with middle school children but he saw it as essential for learning to take place. Students must be actively involved in determining what to work on and how to explore the subject matter in order to teach them effectively.

> The hardest part I think will be getting the kids input on how to construct experiments, where to go, get those first ideas, and a lot of it can depend on what kind of background they have, what kinds of

> teaching experience they have. What it will be ideally: we will work at something, talk about it, and then we will say; what do you think caused this? We all have different ideas, and then we will go out and test those ideas. That might not even happen, they may sit there and look at me dumbfound, and then I might have to say; here are the things that may explain that, which one do you believe. Get in three piles kids, and then let us figure out how to test those.
> (E#3, p. 3)

During the first half of the quarter Eric claimed, based on his assumption that the teacher was the main source of information in a classroom, that a good teacher should first of all possess good subject matter knowledge, know something about teaching and learning, and be able to provide multiple representations for the students. The purpose of teaching was to find ways to convey information to the students.

> You have to have good knowledge of your subject area, you also have to have good knowledge on teaching, teaching methods.
> (E#2, p. 2)

> You are going to be able to read them and see what they are thinking ahead, help them deal with that, know how to get in - get information in and how to get information out
> (E#2, p. 2)

As Eric was attempting to define what he meant by being a constructivist teacher, he would de-emphasize the notion that a good teacher needed to be strong in his or her subject matter knowledge. Since he had come to view teaching and learning as teachers and students setting out on a joint exploration of scientific topics, he would increasingly emphasize the need to be able to

communicate and work with the students. Together the teacher and the learners would continually acquire insight into new areas as they worked on different parts of the subject matter. At the end, he saw the teacher's role as an motivator, someone who constantly encouraged the students to explore further.

> You have to have some knowledge of your discipline, it is not truly the most critical thing, I think knowledge of teaching is probably more important at my level.
> (E#3, p. 6)

> But I think keeping your energy real good about what you are doing is really important, because they see that and I always knew where my dead teachers were and where my exited teachers were and it affected the way I felt about what I was doing.
> (E#3, p. 7)

Conceptions of Computers in the Teaching of Science

Eric had very little experience with the use of computer technology before entering teacher education. In his former work he had used mostly word processing and had seen some business applications, but never used these extensively. Most of what Eric knew about computer technology he had learned on his own. Since he did not own a computer, most of this trial and error had taken place on machines he had access to while working in the banking industry.

When Eric completed his K-12 education there had been little computer technology available in schools. The technology sessions in the teacher education program represented the first time he was introduced to examples of

how such devices could be used in the teaching of science. Eric had, on the other hand, seen the use of other types of technologies such as film and slides while he was in school. He deemed these tools very effective. His favorite high school teacher had used such tools extensively, and Eric had found these experiences to be exciting and inspirational in his own learning.

> A lot of the exiting things that he did were slides and movies, well I don't think there were videos back then. And some would be the television probably hooked up to PBS and I didn't know the technology back then, I was just watching, and some were just films that he could get out of the library, the public school library, slides, and we did hands on work with chemicals, experiments.
> (E#1, p. 8)

Eric's initial image of instructional use of computers was one of machines that can take on the role of transferring information to the students. In concordance with his initial pedagogical beliefs, he was therefore very emphatic to the use of technology in education. He viewed the use of computers as very positive, especially since the use of such tools could make education more exciting for the kids. He claimed that we should give the students computer activities that "are going to teach them" (E#1, p. 12). As and example of such an activity he would mention the frog dissection program he and the other students had encountered on the Internet during the first technology class.

> It saves a lot of frogs, it gives everybody a chance to participate, I think one of the greatest things is that it gives them immediate feedback whether something

> is right or wrong. A teacher can't do that for each student.
> (E#1, p. 11)

In the same way as Eric changed his view of pedagogy during the quarter, he also radically changed his perception of the role of technology. Eric became increasingly critical to the use of computers in education, seeing them as an intrusion when used in a wrong manner, a device that would be a hindrance to teaching.

> I think I had an idea that, much like the public out there think, that we an make a teacher proof curriculum, that you can probably use a computer to learn everything you ever wanted. Looking back at that I think, so much of my college work, I was teaching myself. Doing research, finding things out, a lot of it done either on the computer or in the library and I thought if they would just put all the books, hook them all up, you know, I wouldn't have to go to class, I could watch my teacher on the screen, I could ask him questions on the screen, I could even get away from even having to come to school, get on the bus, spend that time, and I guess I assumed that that could happen at every level, and I don't believe that at all anymore.
> (E#3, p. 16)

This shift runs parallel with his changing perception of pedagogy, as learning no longer becomes a question of providing information to the students, his vision of what computers can do in classroom settings was gradually altered.

Although he would refuse the use of computers as a device that could take on the role of the teacher and teach science, he developed an alternative image of what computers could be used for in his future practice. This time he would see them as tools that would enable teachers and students to better

communicate their ideas. He especially liked the use of multimedia for this purpose.

> The strength of it is that everyone can use their preferred way of interpreting, receiving and digesting information so it accommodates different learning styles. The fact that it is multi modal gives them [the students] more experience with a topic from different directions and it help develop a richness there.
> (E#3, p. 13-14)

Eric also liked the idea of using computers as tools that can enable students to make more accurate measurements than without such devices and to keep track of projects the students would be working on. Although he envisioned simulation programs to be much like the frog program he had seen, namely very directive with little opportunity for individual exploration, he would use such approaches in certain cases. For example, when told about a program that allowed the users to keep track of falling objects, he thought this could be a useful approach as an additive to doing the real thing. He definitely would deem such a simulation a better approach then just talking or reading about it.

> It [a computer simulation program] is certainly better then just giving them the formula and having them just do calculations on paper because it's still got some visual. They get to pick what object falls and they get to see a variety of things, they get to view it. It is certainly not as rich as physically doing it yourself, just picking it up, feeling it, all those things give you sensory input and enrich the context that you put these things in, to feel a bowling ball is different from to see one on a screen. It is certainly much different to be in a car crash then to watch one, the experience just isn't the same. So, in a lot of situations it is probably the best you can do, and in

> other situations it is probably better then anything else you can do, but as opposed to physically doing it, it is probably not quite as good.
> (E#3, p. 15)

The main reasons for his skepticism about simulation programs were that he imagined such programs as being very directive and limited in their scope. In his view, they were usually not open ended and would not allow the students to ask questions. As a result, he became very critical of the frog dissection program that he so enthusiastically had supported in the beginning of the quarter.

> If they just go through the motions, learn specific things that they need to know to pass the test, it doesn't develop much understanding of the working of the interior of the frog or the purposes of the organs the working purposes of the functions of the organs, then I don't like it. But, I think, I would rather be doing it on a discussion basis. What do you think this organ is? Why would it be there? I mean, it is there and it is connected to this and you see these things, what do you think this does? How would you figure that out? What shall we do next? I don't know if the computer is giving them this, if it is allowing them to ask these questions and to touch pools and toads and try and figure these things out.
> (E#3, p. 9-10)

The Influence of the Teacher Education Program on Eric's Thinking about Computers in Teaching and Learning

Initially, Eric's image of teaching and learning was heavily influenced by the activities he had been involved in the Sierra Club and by his favorite high school teacher, who also happened to have been a science teacher. When Eric

talked about what kind of teacher he wanted to become, he essentially described this teacher's practice as he had perceived it.

> I think the first one that had a big impact on me and set the stage for me for science, was my earth science teacher. We were in a new building so we had a real nice science room. Good work stations, and it was in a good neighborhood so we had lots of equipment, we got to dissect little pigs, we got to play with burners and had lots of equipment. He was considered to be a rather firm or strict teacher, and he had you do things that you can not even do anymore. He would have you do things that actually physically hurt if you acted up. Make you stand up against the wall or have you squat down your back against the wall for about an hour so your legs were burning. So he was strict, but he really liked it and he had a lot of energy, and he did fun things, we did exiting things.
> (E#1, p. 7)

The first quarter of Eric's teacher education experience had substantially influenced Eric's thinking about teaching and learning. He would himself claim that his views changed completely. When asked to rank the experiences that had influenced him, he declared the dilemmas in teaching and learning class as the most instrumental in the changes that had taken place.

> Probably my dilemmas class [learning theory class] more than anything. I really wish that I had kept a journal so that I could see it. You know I am forty plus, so I am getting a little older, and for me to switch a hundred and eighty degrees from what I believed coming in is phenomenal, I don't know if it speaks highly of her [the professor] or highly of me, or the whole program or what, but I am a little flabbergasted myself. I think grappling with what good learning is, what real learning and understanding are, did the most to change me, because once I felt that I was getting a grasp on that,

> then I started looking at; how do you get somebody there? In order to have a richness of understanding, to move towards what I define as good learning, which is the use something out of context, transfer to new situations, make connections between this discipline or subject and that one, and than make generalizations or what we sometimes call intuitive leaps.
> (E#3, p. 2)

In addition to the learning theory class, he deemed the science methods class and the field experience as partly influential. He had received practical advice in the science methods class that he thought would be useful, and he had during his field experiences met teachers that he thought represented good models for his own practice. He was especially impressed by one teacher that claimed to be constructivist. For Eric this teacher represented a picture of the qualities a teacher ought to have.

> She was real good at bringing a lot of energy into the classroom, she was always excited , she was always moving, she was always engaging, and it was hard not to watch her when she taught, she was so active. I talked to her about what she thought was good [teaching], and she even mentioned that you can't fall asleep during my class because I am walking by your desk every couple of minutes, you know, and I will clap your desk and make sure you are awake. She was real clear about telling people what they were about to do, not a lot of details, but in broad terms, this is what we are going to do, and then attempting, and this is always the hard part, I think she was effective at it, but you don't really know, trying to tell them why it is important to them that they know this, how it will help them, where it will fit in their lives, and then letting them go do this discovery type constructivist learning.
> (E#2, p. 8)

When it came to the use of computers in the teaching of science, Eric would point to the technology sessions and the field experiences as the experiences that had influenced him the most. The technology sessions had introduced him to new software and hardware and few examples of how to use computers in an instructional practice. In addition to the technology sessions, Eric was struck by the absence of computers in the classrooms he visited during his field experiences. One of Eric's cooperating teachers had explained that computers were not a priority in her practice. She did not use them, and, in addition, the school had few computers available for classrooms and it was cumbersome to sign up for the computer laboratory. This experienced confirmed Eric's belief that computers were not an essential tool in middle school science classrooms.

> There was as far as computer technology, there was non in the classroom that I ever saw. They presented a film on a VCR run through a projector onto a screen.
> (E#3, p. 16)

He had, on the other hand, seen students use the computers that were available to them in the library, and he also assumed that some of the students completed their assignments on their home computers. This was a use of computer that he found increasingly beneficial, a practice that could would not disturb a constructivist learning environment.

> Projects, preparation of demonstrations, a lot of that work can be done on a computer to speed a lot of that up. Doing repetitive work or math that they already should know, that can be done with

> calculators or computers. So, there is a lot of room for it.
> (E#3, p. 17)

Eric was a person who initially thought that a good teacher should be the ultimate lecturer and presenter of information, an instructor who could provide a wide variety of learning experiences to the students in order for learning to take place. In his initial vision of teaching, computer technology played an important role as the presenter of information, an instrument that in an entertaining way could provide students with the information they were supposed to remember. As his view of teaching changed, so did his view of the role of computer technology. Rather then being a source of information, the teacher should take on the role as a coach, a facilitator, that could evaluate and guide the students in the right direction. No longer did he believe that computers can fulfill such a task. Instead he started to see computer technology as something that can be used to support instruction, to help the students in accessing information and to present findings.

Gabriel: The Former Ranger

It had been more then eight years since Gabriel last had been a student when he entered the teacher education program. When he was in high school, computers had been cumbersome devices to work on, and the emphasis had been on programming languages such as BASIC or PASCAL. Although Gabriel had used computers a little, he had never owned one, and admitted that he was

intimidated by the machines because he had very limited experience with them. He had felt comfortable using the features he was familiar with, but at he same time he was aware of that there was so much more the machines could be used for that he was not capable of doing.

> I don't feel comfortable because I haven't used it [computer technology] so much, I want to use it more, I got a computer here and I am using just a small part of it.
> (G#1, p. 9)

Intellectual Biography and Entry into Teacher Education

Gabriel entered teacher education after having spent seven years as a biologist with the US Forest Service. He claimed that the last couple of years had brought substantial changes to his work. There had been large cut backs in federal budgets and much talk about lay offs. He had therefore started to look for an alternative career.

His work in the Forest Service had included quite a bit of work with students from local schools. In addition, he wanted to utilize his undergraduate degree in Wildlife and Recreation Management. He had found his work with schools very rewarding, and saw his entry into teacher education as an opportunity to do the part of his Forest Service job that he loved on a full time basis.

> As I worked, especially over the last few years, I worked more with schools and we had programs where they met us out in the field and we put on some kind of program or something to help. Many

> of the students were between sixth and twelfth grade. And I was starting to like that a lot, working with the students and everything.
> (G#1, p. 1)

Gabriel wanted to target his teaching career towards high school and junior high school students. He liked this age group, and he was somewhat familiar with these students since they represented the age group he had worked with previously.

Although most of what Gabriel had done with students before entering the teacher education program was tied to what he had prepared for them in out-door environments, he had at some occasions visited classrooms and worked together with students in school.

> Sometimes we brought the program into the classroom, and sometimes they would bus them out to the field outside where we did different kinds of programs.
> (G#1, p. 1)

Conceptions of Teaching and Learning Science

When Gabriel entered the teacher education program he viewed teaching, much like the other candidates, as the process of conveying the correct information to the students. In order to do so, he thought it was important that a teacher presented the information in an entertaining and clear manner. In addition, Gabriel had himself learned a lot from laboratory work, and he saw it as important that teachers develop well choreographed hands-on activities for the students as a supplementary way of presenting the various concepts. He

thought that his favorite college teacher represented a good model for the practice that he wanted to create for himself.

> He kind of got up, a college professor, he was up there lecturing and stuff with chalk boards and some times with overheads, and of course we had a lot of labs, and I think that's what helped me, was hands on labs.
> (G#1, p. 6)

Gabriel had found the classrooms he could remember from his own high school years as utterly boring and uninspiring. In his teaching, he wanted to do it differently, and ensure that his students would want to study science when they entered the room. To do so, he wanted to utilize some of what he had learned in the Forest Service, namely to use a lot of props and examples to spur the students' interest.

> I want it [the classroom] to be inviting to the sciences, not necessarily biology, but whatever, I like it to be so that when students come in to the classroom, they would like to come over here to check out this or to check out this over there, you know, kind of an exciting atmosphere.
> (G#1, p. 2)

In addition, Gabriel deemed it important to create a less formal atmosphere between the teacher and the students. He saw it as essential that the students were not afraid of asking the teacher questions. In order to create such an environment, he would, among other things, allow the students to use his first name. He had, as a high school student, had a couple of teachers who allowed him to do so, and he had felt that his interaction with these teachers had benefited from this approach.

> I remember with my teachers, they were, I often felt uncomfortable asking them a question, they were the type of people who wanted to answer questions in class and not when they leave. I want to be a person whom the students feel comfortable asking and not like a ninety year old adult that they can not relate to or something.
> (G#1, p. 3)

At the same time, he was aware of the importance of classroom control. He wanted the students to be clear about when they had to listen and when they could talk.

> I mean fine that there should be fun, but we need to have some rules too, I mean it is not only for safety, but also for respect. Respect for me as a teacher, and I'll have respect for you as a student. You know, if I am standing up here and I need their attention, then please listen to me, and then at other times we can talk with each other and work things out with each other, but when I am up here [in front of the class], you need to have that respect.
> (G#1, p. 4)

Upon entering his professional preparation, Gabriel would emphasize the importance of knowing the basics in science. After a year with him as a teacher, Gabriel hoped that his students would walk away with some basic knowledge of physics and chemistry. He also wanted them to develop a positive attitude toward science since he assumed that some of the students would enter his class with a negative perception of what science is.

> I want them to understand that it is not awful to take a science class, it is not boring, it might possible be difficult, but I like them to walk away with a flavor of what science is. If it is biology, general science, or chemistry or whatever, I want them to walk away

> with a flavor that this isn't so bad, that I have learned a lot, and I see how this relates to everyday life. (G#1, p. 4)

A few weeks into the quarter, Gabriel had changed his view of what constitutes good teaching. He had been introduced to alternative thoughts about teaching and learning, mainly in the learning theory class. Instead of focusing on how to present the information to the students, he would now emphasize the importance of enabling the students to discover scientific concepts on their own.

> I think how, what are the best ways for students to learn, and I think, from what I have learned in some theories, it is not the old stand up and deliver method, it is more let them learn through their own ideas and their own discoveries. And they are going to walk away with better understanding and probably, you know, remember it. (G#2, p. 3)

An example of such teaching would be to involve the students in making hypotheses as well as trying to explain scientific phenomena in their own words. He envisioned the students involved in multiple hands-on activities, and actively participating in the design and development of learning experiences.

> I think students learn more with hands on but also by trying to discover things on their own and not me standing up there and say: Today, this is what we are going to learn and this is how we are going to do it. Maybe let them discover what they are going to be learning, for instance, if this is the problem, I present the problem, let them design the lab to solve it instead of me [saying]: Here is your worksheets for the lab, follow these steps, make sure you read

> the steps and follow them carefully because it could be dangerous or something, and then just let them do it cookbook.
> (G#3, p. 1)

He had seen an example of such teaching during his second field experience. Gabriel compared this way of learning or working to the way "real" scientists work.

> I think the students were learning chemistry the way that chemists do chemistry in that they are making predictions, they are making observations, then they are extracting more information and they are re-evaluating their predictions, changing their minds if they got to, I mean, that's ok. And then making future predictions, and then, you know, be curious tomorrow about what is going to happen again: Is my prediction right?
> (G#2, p. 9)

Notably, Gabriel retained his belief throughout the quarter that there are some truths that students ought to find as they do their scientific work. According to Gabriel, when students have learned something, they have discovered scientific concepts and are able to apply these to situations outside the classroom.

> I would say to be able to take a piece of information, I don't know if piece of information is the right term, but whatever the concept that the structure is presenting, or helping to present, or help the students discover it, taking that concept and being able to apply it down the road, to be able to remember it and to be able to apply it down the road in a new situation. So it is like a piece of information that you keep building in your schemes of knowledge.
> (G#2, p. 4)

In order to facilitate such a learning environment, Gabriel emphasized an accepting classroom environment where students could feel free to talk and search for answers. He thought it would be essential that the student got a chance to voice his or her opinion about the phenomena they were studying in order for them to be involved in the learning process. Gabriel wanted therefore as a teacher to stay back and allow the students to find the necessary information and to allow them to ponder on how to explain the concepts they are studying.

> I hope that my classroom is really open and that everybody feel free to voice their opinion and change their opinion if they want, and that there is a student to student interaction and not always a teacher to student or a student to teacher interaction. So when they talk, they talk among themselves trying to solve some problems and not always looking to me for the answer cause I might not know the answer.
> (G#3, p. 2)

Gabriel was very much aware that his insistence on keeping a relaxed atmosphere in the classroom might lead to some problems with regard to classroom control. Although he was uncertain about how to approach this problem, he hoped that he could as a teacher be able to find a balance between the need for control and the freedom that he thought would be necessary in order for learning to take place.

> But as far as classroom management, I haven't worked that out yet. In my mind right now I think that is challenging, how can you be, I mean, obviously you got to be in control, but you also want to be in a sense, I don't know if colleague is the

> right word, but in a sense when you working on, I mean you want discussion in a classroom, not just teacher student, sometimes the teacher has to fade down a little bit, but the teacher got to be right up there at times when things are out of control.
> (G#3, p. 6-7)

When Gabriel entered the teacher education program, he viewed his role as a teacher more or less as someone who could effectively pass on scientific information to the students in such a manner that they may remember it. As the quarter went on, he would increasingly emphasize that his role as a teacher was much wider. Many of the teachers that Gabriel had met during his field experience had pointed to the fact that teachers play a role in the socialization and personal growth of their students. This view was in particular emphasized by his cooperating teacher during Gabriel's second field experience. According to this teacher, the primary role of his position was not to teach his students science, but to ensure that the students could handle the social and ethical problems they were confronted with as adolescents and to become good citizens in their local environment. Gabriel would increasingly adopt the same view, referring to himself as an example of a person who had done reasonably well in science although he claimed to have learned very little during his high school experience.

> We are not teaching scientists, we are not teaching biologists, we are teaching citizens, so I don't expect them to be, you know, I don't remember much of what I did in high school biology.
> (G3, p. 7)

Conceptions of Computers in Teaching and Learning Science

Since Gabriel had very limited knowledge of and experience with computers, he had initially great difficulty coming up with a vision for potential usage of such devices in the teaching of science. He had seen computers when he was in high school and college, but these had only been used for programming purposes and he had never seen the use of modern machines in a classroom setting.

> To teach with it [computers], that's what I am not really completely sure about yet. When I was in school, there were no computers there, and then when I was in college, we were using the Apple II and the Macs were not really coming out yet. That's what I am really not sure about in my mind, in what way we can use the computer as we teach. I don't know exactly all that I have available to use or can use.
> (G#1, p. 9)

When he was asked to speculate about what he thought might be possible, Gabriel mentioned to have heard about simulation programs and such things, but he was unsure about what such programs would look like, and whether they would be more effective then traditional methods used in the teaching of science.

> I guess that the first thing that comes to my mind. although I have never seen that, but using computers for simulated programs. I have heard about a program that allows you to dissect frogs, but I don't think that this can replace the real thing, it might be a good introduction. I also see it as an important

> tool in how to make your presentations, it is not just a question of projecting things on the screen. (G#1, p. 9-10)

Throughout the quarter Gabriel explored several ways of incorporating the use of computer technology in a fashion that could support his developing view of teaching and learning. As he no longer believed that teaching was a matter of conveying the information to the students in an effective manner, he started to question the use of some game like computer programs that claimed to be educational. He thought that such usage might provide an easy out for the teacher, but would not necessarily benefit the students in their learning process. He would compare such programs to watching TV, the students might enjoy the experience, but they would not be actively involved with the concepts.

> I think for a teacher who want to skate through life real easy, and who is obviously not very concerned about what they are doing with their profession. You know, I can show Bill Nye one day, I can have them sit on the computers the next day, I can have them look through microscopes the next day. I mean, in a way don't have to get up and teach if I wanted to, I mean, there is enough out there that would keep the students happy, the kids are doing something, and maybe in their minds even more fun than trying and discuss things, discover new things (G#2, p. 22)

On the other hand, Gabriel realized that although he himself is not that well versed with computers, there are many students who are. Teachers should therefore allow the students to use the computers in the learning process, and

in some cases, he hoped that there could be programs that he hadn't seen yet that could prove to be very effective. Gabriel could envision letting the students work on programs, even games that promised to teach science, if these experiences were followed up by a discussion about their relevance. The computer programs would then be used as an introduction to a topic rather then becoming the curriculum the students are supposed to learn. The situation he wanted to avoid was one where students were working on individual work-stations providing answers to questions raised by the computer program. He had in his learning theory class read about B. F. Skinner's teaching machine (Skinner, 1954), and he envisioned computers fulfilling a similar role.

> When you talk about higher technologies such a s computers and stuff, I am struggling with that a little bit because actually in the back of the my mind I have thought several times. Now how would I use the computer to teach different things like, would I have all the students go work on a program on different computers where they are sitting there looking at it? Because in a way, I think that is a barrier between the students, I mean, not interactive between the students, they are sitting there just like with the old, you know, Skinner and his black box. But, I think there are programs out there that I think the students can use, I wouldn't use it all the time, but if there is enough programs so they can do work with it and maybe the next session discuss it with each other, what they did, what they have learned, the struggles that they were having with it. So I definitely know that there is a lot out there, and it is definitely a benefit, I am just not sure how I am going to apply that in there yet.
> (G#2, p. 21)

Like the other candidates, Gabriel did also increasingly emphasize that the computers represented a tool that could help the teacher and the students with many practical tasks. He could see the machines used to make better visuals when introducing a new topic, to enable students to make accurate measurements during experimentation and, of course, support the students in their writing.

> I think that is a good tool for a teacher to use, to do demonstrations to the class, you know, using the computer and showing up on the screen.
> (G#3, p. 14)

> I mean it [the computer] is a lot more accurate than with a stop watch and when something hit the ground and you click on it. So in a way it is a lot alike what scientist do, they use computers to do the actual experiment, I mean, we can drop the ball in computer screen, there are programs that does that, does it all, but in a way we are doing it just using the computer and it is just a tool, a very accurate good tool.
> (G#3, p. 16)

The Influence of the Teacher Education Program on Gabriel's Thinking about Computers and Teaching and Learning

Gabriel claimed to have changed his views on teaching and learning drastically throughout the quarter. When asked about these changes, he would trace them to in particular two of his teacher education classes and what he had been confronted with during the field experience. Of his teacher education classes, he deemed the class that introduced him to learning theories as the

most important. This class had spurred his thinking about what learning really meant and led him to his emphasis on allowing the students make predictions and discuss possible solutions to problems in the learning process.

> I think that [the learning theory class] is my favorite class so far, because when I came into this program, now I can't remember what I said in my first interview, I had some ideas of how I might want to teach, I had some ideas about what I thought would be a good teacher. Because before we had that class we had our first observation, and what I thought was a good teacher, kind of like what he was doing, and this class has turned me almost like the whole way around.
> (G#2, p. 13)

In addition to this particular class, he had also appreciated the practical advice he had received in the science methods class and how this class had underscored what he learned in the learning theory course.

> I think [what I learned in the science methods class was] just how science in general can be represented in the classroom. You know, it is not like I obviously thought, maybe memorizing and have these multiple choice test, so in this class we are learning, you know, different kinds of methods and models of how to present science.
> (G#2, p. 14)

During his field experience, Gabriel had the opportunity to observe a wide variety of teachers. He was impressed with the many different ways that teachers could approach the same topic and still seemingly be successful.

> I think the big thing that has influenced me was to see all the different teachers and styles out there, which I think is good, because if a teacher had the same type of teacher period after period, how boring that would be. But, it is just all the different ways of

> presenting the same type of information, and I just the think the resource of being a teacher, just seeing all these styles is one thing we did, you know, people in this program, I have friends in science and I may teach something about cells, you know, completely different that my peers would do. (G#2, p. 15)

When it came to the use of computers, Gabriel claimed that the technology course-work had influenced him the most with regard to the use of computers in the teaching of science. When he entered the teacher education program he had not felt all that comfortable around computers. The technology course-work had provided him a basis that allowed him to become more confident when he approached the machines.

> The first thing is that it has made me more comfortable with using computers and the technology that computers have, and like I said before, it is not making me an expert in any of the programs, but it is getting me familiar with it so that if I had the opportunity to use something like that, if I want to use such a program in my classroom, I definitely feel a lot more comfortable about doing it. (G#2, p. 19)

The practical knowledge he had gained from the these sessions was mostly in the form of an introduction to various programs and the Internet.

> I think what they have done, it is a very kind of a broad class where we are getting lots of different things, different ideas on what we can use. First of all, getting on the World Wide Web was very exciting. The wealth of information out there is kind of like, oh, there is so much information, we can never use it all, we can never stop getting information if you wanted to. But, the different

> programs that we became familiar with, you know grade machine and different stuff like that. (G#2, p. 17)

Like most of the other students, Gabriel did not see much use of computers in the classrooms he visited. The schools had no computers in the classrooms, but all of them had well equipped computer laboratories. He never saw these used in the teaching of science. The cooperating teachers had explained the absence of computers in the teaching of science as a question of access to machines and programs. The teachers had felt that it would be difficult to organize the use of computers when you have maybe access to one or two that you can bring into the classroom. If they wanted to use the lab, this had to be planned weeks in advance, and they had been unsure of the quality of the programs that they might have available to them.

Unlike many of the other candidates, Gabriel had found the technology course-work quite useful. He felt that he had been introduced to technologies that he did not know before he entered the teacher education program, and although increasingly critical to certain use of computers, he was continuously searching for ways to find a place for the technology in his future instruction. A reason for this could be that he did not possess much computer knowledge before he entered the program, and he remained unaware of the many uses of computers throughout the quarter. He did not see any use of computers during his field experience, and his hopes and visions for technology resembled the optimistic predictions that are often presented in mass media.

Henry: The Scout Leader

Henry, in his mid twenties, was eager to become a teacher as soon as possible. He felt that he already possessed the necessary knowledge and skills to handle a classroom situation, and was throughout the quarter frustrated with how little new information he was introduced to as the quarter progressed. Unlike the other students, Henry had through some of his earlier college classes already become acquainted with many of the philosophical and pedagogical ideas that dominated the first quarter of the program. His case represents therefore a compelling example of a person who was not challenged in his beliefs during the teacher education course-work.

A few weeks before he started his professional preparation, Henry had received a Commodore 128 computer from a friend. This was the first computer he had owned, and he had spent a few weeks learning how to use it for word processing purposes. Outside this, Henry had minimal experience with computers.

Intellectual Biography and Entry into Teacher Education

As long as Henry could remember he had been interested in science. Some of his fondest memories of growing up were those of him and his father assembling model kits and playing with electronics. Together they had spent many a late evening at the kitchen table taking apart and fixing everything from the toaster to the tape recorder. Science, in particular physics, had been

Henry's favorite school subject. During his early years he had loved preparing for science fairs and later he had developed a particular fondness for laboratory work. He liked having the opportunity to put his hands on things, touch, feel and play with instruments.

Insecure about what to do after high school, Henry joined the navy for four years. He had disliked military life from the beginning. Most of his days had been spent doing manual work and he had found the lack of privacy burdensome. A sometimes shy and private person, Henry had found it difficult to share the life of his comrades in the barracks.

Henry became increasingly concerned about what to do with his life as military life was coming to an end. In many ways he wanted to become an engineer, but he had also a desire to work with young people. As soon as he had been old enough, his father had enrolled him in a local scout unit. He had enjoyed working his way up the ranks to become a boy scout leader in his local patrol while in high school. The memories of planning outings and teaching the young kids evoked good feelings in Henry. What he had been doing in the scouts had been meaningful and satisfying.

> Well, for a long time, ever since I was in elementary school, I have enjoyed helping other people with their homework and help them understand that eh, eh, help them out, and in boys scouts, I have been helping training younger scouts.
> (H#1, p. 1)

Henry hoped that by becoming a teacher he would be able to work with youth in a similar manner to what he had experienced as a scout leader. During

the last year in the military, he had taken college classes in physics. He continued these studies for a year after he was discharged from the navy, attending classes in physics and chemistry at a community college not far from where his parents lived. During this time he researched teacher education programs in the area, and found that one university offered courses aimed at students who wanted to become high school physics teachers. Henry enrolled in this program and earned his Bachelors before he entered the teacher certification program at the same university.

Conceptions of Teaching and Learning Science

According to Henry, science was a much more practical area of study then other academic subjects. He claimed that through science we are able describe things that happen around us.

> Well, I think that physics. That the forces they deal with, motion, and that sort of stuff. They [the students] actually deal with that sort of stuff on a daily basis. All of chemistry and biology and everything, how they affects our life.
> (H#1, p. 4)

The physics classes Henry had taken to prepare him for the teacher certification program had influenced him tremendously with regard to his beliefs about teaching science. Already upon entering the program, Henry talked about enabling the students to receive a general understanding of science as the focus of his teaching rather then the facts and laws that the other candidates emphasized. According to Henry, the purpose of teaching science

was to entice a curiosity among the students about the world, allow them to search for possible answers, much like how researchers attempt to explain the world without claiming to have the definite answers.

> Eh, [what I want to see in my students is] some sort of basic understanding of what science is, what physics is, what math is depending on whatever I am teaching. To have some idea what it is, and what people who do that job, or that type of job or profession, actually do.
> (H#3, p. 7)

Henry's vision of what he labeled "the guided inquiry method" was very important to him; this was the way science ought to be taught, something he could justify because it had worked so well for him while he was a student.

> When I was in high school taking the physics classes, I like physics, I always thought there should have been more lab instead of listening to the teacher talk in the classroom. In college, the physics classes I took, 407, 408, 409, I really liked the courses where students were working using guided inquiry, on developing their own ideas and then coming up with the right answer. And then talking about it in the class. I think I might like that in my classroom, using a lot of hands on type experiences.
> (H#1, p. 2)

Although Henry emphasized the importance of inquiry in his view of teaching, one should notice that this inquiry was not without aim. He firmly believed that there are certain truths out there that we ought to guide the students towards; indeed he viewed his role as teacher as a guide leading his students to certain truths.

> I like them to look at me as somebody, not necessarily as having all of the answers, but having

> the authority to find the answers or, come up with the answers, or, in order to do that, not necessarily give them the answers but let them try work on it , but help guide them.
> (H#1, p. 4)

Another important aspect of Henry's pedagogical view was how he wanted to relate to students. He wanted to have good control, at the same time as he was accessible to the student. His favorite high school teacher had operated in this way, and Henry really liked that.

> Eh, I think that my chemistry teacher that I had in high school, I thought he was pretty good. He knew the subject and he did lots of labs and he didn't always answer my questions, we could sometimes ask questions and , when he didn't answer, I would try and get him after class and try and ask him again, I loved that contact.
> (H#1, p. 7)

Despite Henry's commitment to the inquiry method, he would also adopt some very traditional aspects of teaching. Among others, he would readily accept paper and pencil exercises and even write ups and summaries, since he claimed to have learned a lot from such exercises himself.

> And most of the time I had no understanding of what I was doing. I just did the things they told me and kept track of the things they told me and afterwards when I was writing it all up I might start understanding what have happen.
> (H#1, p. 7)

But most of all, Henry wanted to involve the students in discussions and experimentation. The purpose of such activities was to enable the students to

form their own opinions about scientific topics as they were actively working on and pondering these.

> In general people, I think, learn best when they are involved in personal experiences. I think a lot of my job is going to be trying to get them, eh, trying to set up such personal experiences in a classroom, or, you know, as homework, or, you know, outside the classroom that they can bring back to class these ideas and experiences and then to some extent reflect upon those experiences and bring out what they have observed, what the implications are and teach them that way.
> (H#3, p. 1)

Parallel with Henry's thoughts about how students learn, he emphasized the importance of providing competing ideas in order for the students to form their own opinions about the topics they are focusing on. Textbooks would therefore represent only one source of information in his future classes.

> I think you can get a lot more out of discussing what the book said, bringing up other ideas, not letting the book become the one and only source, because the book is only one interpretation of what might be going on. And a student reading that, different students might pull a different interpretation out of reading the same chapter or the book, and they might mix ideas up or they might have skimmed over it and missed ideas that the book brought up, and the book might skip certain things that the teacher or a student might think is important.
> (H#2, p. 10)

In order for students to have the opportunity to explore scientific concepts, Henry emphasized a learning environment characterized by acceptance and openness. The students' opinions are essential to the success of the courses.

> A good learning environment. I think it would be one that you are not afraid to take risks, you are not afraid if you are right or wrong, to state your opinion and to put it out there for scrutiny.
> (H#2, p. 3)

In such an environment, Henry saw the teacher more like a facilitator of learning experiences, a person who allows learning to take place rather then a source of information.

> If I could be just kind of another person in the classroom, that might have more experience then them in a particular subject, but it doesn't make me be any more correct in my thoughts or statements, you know, I like them to question my assumptions and, as I would like them to question other authors or people who they are talking to, that I am some sort of facilitator in their learning.
> (H#3, p. 9)

Conceptions of Computers in Teaching and Learning Science

Henry was a novice computer user. He had only briefly used computers to write college papers and for some data base activities. Henry had no experience with the Internet or with other uses of technology such as simulations and multimedia as he entered the program. The use of such technology was therefore not part of his initial image of what technology could be used for in K-12 classrooms.

His vision of what computers can do in classrooms was based on what he had seen in his college classes. During these classes he had used computers to

do measurements and calculations, a use he thought was excellent because it allowed the students to do accurate observations.

> Not that there was a lot of technology in there, but there were other times when they had us work with some different computer programs using the mouse, using sensors to measure the speed of an object coming towards you other sensors and stuff like that. (H#1, p. 2)

Throughout the quarter Henry would mainly view computers as a tool that could be used for measurements and to store data. He had great difficulty imagining the computers as media devices that could provide the students with pictures and video or to access information. Although he knew that the machines had such capabilities, he was very critical about the use of computers to present information or simulate experiments in the teaching of science. The main reason for his skepticism was that he thought that a simulation program would never be able to provide the same experience for the students as a laboratory exercise would.

> I could see getting some basic knowledge, ideas of where some different parts might be, and even what the different functions of what those parts might be, but at the same time, it is kind of two dimensional, I feel, it might not answer a question a student has, so by just using the computer as the sole source of this lesson, the student has no way of asking the questions nor does that program the ability to try and answer it, and I think that even with the best artist or anything, there is something about opening up, I mean, I myself have never dissected a frog, but I mean, I have played around with dead animal stuff. When you ran around in the playground or something, and you came across a bird or something, to work with the program is not like

> being able to touch and see the parts in a three dimensional. Feel the texture and seeing how it is actually connected.
> (H#3, p. 11)

He was afraid that by using the computers to teach concepts, they would just become a colorful alternative to traditional school work, not much different from reading a book.

> Using the computer that way [multimedia presentation or simulations] I wouldn't see any difference between that and just giving them a book to read, pieces of paper to cut out and put together and answering a work sheet. It is basically doing the same thing, but in a different way.
> (H#3, p. 12)

The Influence of the Teacher Education Program on Henry's Thinking about Computers and Teaching and Learning

Henry claimed to have received very few new ideas from his teacher education course-work. Most of what he heard, he claimed to have understood before entering his professional preparation. The course-work had mainly provided him with a vocabulary that would enable him to better present the ideas that he already possessed.

> I don't know if it [my thinking about teaching and learning] has changed by all that much, but I think by reading the articles and talking about teaching theories and methodology and stuff like that, I think it has given me more of a vocabulary or helped me be able to, I don't know, firm it up in a sense, that now I can try and put word on it, I can attempt to explain it to somebody else and rather then it just being ideas just bouncing around in my head. But I

> think a lot of the articles, the things they said were basically, or the things I picked out of them anyway, were things that seemed to agree with how I felt. (H#3, p. 2)

If he were to mention something that might have provided him with some insight, it would be the field experience. The field experiences were particularly valuable since they provided an opportunity for hands on experience with teaching and learning in contrast to the talking and discussion that took place during the on campus course-work.

> It is kind of the same thing as trying to talk about something versus being there doing something. It is almost like you are doing an experiment by being out there in the field, in the classroom you are seeing the students, you are seeing how they react, you are seeing the teachers and what they do and how the students react to the teachers, how the teachers react to the students, and you talk to the teachers about what they are trying to do, the different ideas that they have. Not that the teachers you have in the classroom haven't been teachers and they might have ideas too, but you are not getting the interaction, you are not seeing how the students are reacting, and then the teachers can talk about what they were doing and why they were doing it. (H#2, p. 13)

During the field experience he claimed that the successful teachers he saw used the hands on approach to teaching and learning that Henry believed in. He would use these observations to confirm his own views. Good teachers, he claimed, were characterized by high energy and by facilitating the class in such a manner that the students had opportunities to explore the various concepts.

> I'll say the ones that seemed to have a lot of energy [were the best teachers], and some of them had some

> good ideas, they seemed to want to get the students more involved, hands on, experiment type of stuff rather then sitting in their desk talking about things or showing a demonstration in front of the class. The students could actually do the demonstrations, and be involved, and make the measurements versus having the measurements told to them. (H#2, p. 14)

In addition to what he had gained from the field experience, Henry had also found certain aspects of the science methods class as very useful. In particular Henry enjoyed the many practical ideas that the instructor had used in the class.

> Well, we talked about, the big thing I think we have talked about is the model building. How it relates to science in general, you build these models and they may or may not be true but as far as we know at this point, this model seems to represent those things we know. And then we have done some interesting exercises in there and we are trying to come up with building models and then talking about how we might use that in our classroom to explain science and what science is, what scientists do. (H#2, p 16)

Henry claimed to have gained little form the technology sessions beyond an introduction to the World Wide Web. During the observations Henry spent a large portion of the classes surfing the World Wide Web, and chose often not to follow the regular instruction that took place. Indeed, he did not view it as very useful to spend time learning any programs while in the teacher education program because he figured that the programs that he would find in schools would be different and that he would have to learn those when he got to a classroom situation.

> The technology sessions, I don't feel that I have gotten a whole lot out of that, not much useful, because, I mean, we talked about the World Wide Web, which I am not real familiar with. I mean, I have spent some time digging through it, but I haven't found a whole lot particularly useful there. I feel there is a lot of potential there, but I haven't had the time to dig through all that much of it yet. And, I knew it was there before, it is just that I never sat down, it is not like the class taught me how to do something with it, and as far as using computers, I mean, I have used word processors, I have seen different types of filing programs before, well, I haven't really learned anything new there that would have changed any of my views about it, I mean, something that I love to use when I get to a classroom.
> (H#2, p. 11)

In the same way as the other students, Henry saw some computer technology during the field experience, but this technology was never used by teachers or students during class time. Instead these machines were used for administrative purposes.

> There were computers in all the different classrooms, that teachers use them for word processing, keeping track of different things.
> (H#2, p. 20)

Unlike the other candidates, Henry's thoughts about teaching and learning science stayed remarkable stable throughout the quarter. Instead of feeling that his initial beliefs were challenged by the course-work and the field experiences, Henry found that the articles and the professors confirmed the views he brought to the program. This was also the case with regard to his image of computers in education. Although Henry had only brief knowledge

of how to use the machines, he was convinced that the main impact of computers in the teaching of science would be as a tool that would allow more accurate and elaborate experiments and nothing he saw would challenge that belief.

Ida: The Social Worker

Although Ida was interested in science, her major reason for going into teaching was not to teach science per se. She saw the teaching profession as a way of helping people. In her opinion, the goal of teaching was to help the students work on areas that they found interesting, things that would be meaningful to the students in their immediate situation. When reflecting back at the end of the quarter on her initial reasons for entering teaching she described her stand in the following way:

> I was just very interested in promoting, motivational interest in education, more because I had worked in social work and things like that, and I had seen many kids in the community, and was more interested in developing curiosity and these kinds of things. Diversity and all those issues that are perhaps more politically or psychological.
> (I#3, p. 1-2)

Although her emphasis was not primarily on subject matter, she also hoped to become a good science teacher as well, an educator who could her students to take an interest in some of the more traditional scientific topics as they were searching for meaning within their educational experience.

Intellectual Biography and Entry into Teacher Education

Ida had a Bachelor of Science where she physiology with minors in psychology and neuroscience. After completing her undergraduate degree, she had worked with at risk youth in an inner city environment for a couple of years. During this time she started to think about becoming a teacher, partly because she saw education as a way to help disadvantaged kids get out of the difficult position many find themselves in.

> I wanted to have a job in education or social service. I saw how people had so many problems, but I think that education is a positive thing, the more education, the less clean up is necessary from social services. In many ways people can, you know, I think education is the first positive thing, the more they have the less dependent they will be.
> (I#1, p. 1)

It was Ida's hope that she could contribute to helping these students. She wanted to be able to interact with at risk students before they drop out of school, and maybe help them on a way that can potentially guide them through the difficult teenage years.

> And I thought if there was one way we could get these somehow interested in school or somehow interested in something, maybe they wouldn't continue this way of destruction.
> (I#1, p. 1)

Ida had no teaching experience in K-12 classrooms. As a social worker she had, on the other hand, participated in various recreational activities with young people.

Conceptions of Teaching and Learning Science

Initially, Ida viewed teaching and learning as a question of personal growth. She claimed to have few thoughts about how to teach a particular subject matter, instead she looked at her teaching career as an extension of her practice as a social worker.

> I think I want to be there to help them out to find out what their interests are. What I mean is that I will be there to help and guide them in what is interesting to them.
> (I#1, p. 2)

She readily admitted that some of her views are somewhat idealistic. In her view, the most important aspect of teaching and learning was to create an environment that could spur personal growth among the students, a place where the students could find their place in the society. Her main concern for her future students was to help them set and reach the personal goals they would set for themselves rather than focusing on ensuring that the students would learn a particular curriculum content.

> I think it is really important to concentrate on contribution, what the students can to with themselves in this world, how are they going to take care of themselves, how are they going to make the most of themselves so they can contribute to this world, in contrast to when they leave high school and it becomes more or less a shock. It is important that to start early and know that some of the best things in life is to have something to be interested in. Some of the kids are at an early stage developing a consumer type mentality, they should try and make the most of it and try to figure out what they

> want to do with themselves, I am kind of an idealistic type.
> (I#1, p. 3)

In order to accomplish this, Ida saw it as essential that there is good communication between teacher and students. She claimed that her favorite high school teacher could stand as an example on how to relate to students.

> He acted as he was talking to adults, a really interesting person.
> (I#1, p. 4)

This teacher was able to communicate with the students at an equal level and he gave the students the opportunity to pursue their own interests.

> He was one of them, he was just interested in the meaning of everything. It came across that he was really understanding towards people. It was more like, in his classroom, there is a starting line and a finish line, and everyone does not start at the same spot. He was just really good at relating to everybody and he did a good job of conveying information, the students did not have to do a lot, he was a good teacher.
> (I#1, p. 4)

Initially, Ida found it difficult to identify any particular teaching strategy that would be more effective than others. The reason why she found this difficult was that she claimed that since children learn in so many different ways, it is impossible to come up with one particular way of doing it.

> I have not thought much into those kinds of things. You see I think that's such a difficult thing to say because in a classroom there are so many different variables involved. Because some of the kids are interested and some are not, of course, ideally, it would be nice if they could be interested in the subject matter. You know if I had a classroom, of

> course I wish as a teacher, but that might not be the case that the students are at all interested in the subject, so it is hard for me to say.
> (I#1, p. 2)

The main purpose of Ida's teaching was to make learning meaningful to the students. She really disliked teachers who lecture or just tell the students about the concepts they are going to learn. During her time as a student, she had seen several teachers like that, and she claimed to have learned very little from them. Instead she wanted a form of teaching that related the content to the students' everyday life, something they could understand. In her view, if the teacher does so, than the students will want to learn.

Throughout the quarter Ida continued to ponder what it means to learn and what characterizes good teaching. She would increasingly adopt the vocabulary she encountered in the learning theory class and eventually describe herself as a constructivist. Ida was, on the other hand, very careful in how she defined her constructivist views. In her view, constructivism meant to take into consideration that students have very different learning style, to pay attention to the individual differences that exist among students.

> I think that it is perhaps where the students discover the knowledge and sort of form it in their own way.
> (I#3, p. 1)

In a constructivist classroom she envisioned a very active environment that is not teacher directed. A good teacher is able to let the students use their own creativity to explore the subject matter.

> A good learning environment, I think, is where the students have the freedom to pursue what they are inquiring about and to be creative about that, and the teacher can help them along, and also as a source, if knowledgeable enough to be a source, to help them in their search.
> (I#2, p. 2)

> I guess [a good teacher is] trying to get the students to talk and to be active and to pursue interests and things like that.
> (I#3, p. 4)

After the second field experience Ida became increasingly aware of the need for some classroom control. This question continued to be a problem for her and she started to realize that maybe teaching would require a different relationship with youngsters then what she had become accustomed to during her time as a social worker.

> You know, it is not like when you are in a job or as a student, or in the jobs that I have had as a social worker where you have other people that perhaps you can cooperate with. But when you figure you are the sole teacher with many youths in a room, you really have to be the authority of all those people, that's many people, even thought they are younger.
> (I#3, p. 8)

Although subject matter knowledge played a role in Ida's image of the role of the classroom teacher, she continued throughout the quarter to see teachers as persons who are helping students grow as humans rather then subject matter instructors. She was therefore not sure of how to react to what she learned in her classes in the teacher education program. She had a hard time relating these experiences to what she thought important in the work of

an educator. She would sum up her thoughts at the end of the quarter in this manner:

> I guess I am still trying to figure that out [what the purpose of the teacher education program is], hopefully it will play a role and teach me something I don't know yet, because other wise it is not worth while, right.
> (I#3, p. 9)

Conceptions of Computers in Teaching and Learning Science

Ida had very limited experience with technology. She didn't own a computer, and she had used computers mostly for word processing in connection with school work. Despite her lack of computer experience, she had initially great hopes for what computers can do for education. It was very difficult for Ida to pin point what she thought computer technology could do in educational settings. In her view she associated computers with cool things, an area that students would be interested in. Computers and related technology represented fun and interesting activities that could keep the students attention, something that many students would be interested in.

During the quarter Ida was introduced to some new application programs as well as basic features of the Internet in her technology classes. Although she claimed to be fascinated by the technology, she continued to be uncertain about how to use it in educational settings.

> In terms of the technology, I have it in the technology class, it is helpful to learn how to manipulate these things a little more, especially for

> me, because I am not really aware of that, I do not have much experience with that. And how to use that, to educate students, I don't really know, because it is completely new. Like somebody mentioned in the class today, it is not using that in the replacement of something else like a book, it is using it in such a way that it is maximizing the potential of thinking, I don't know.
> (I#2, p. 17)

She continued throughout the quarter to question what the technology could be used for in the classroom. Ida saw information sources such as the Internet and CD-ROM's as not much different from using a text book.

> It is not really anything different from reading it in a book or something like that, right.
> (I#3, p. 14)

According to Ida, the best use of computers would rather be as tools that can help students do their work more effectively. The use of computers could free the students from complicated calculations and help them organize information.

> I think in terms of computers it is probably better to use them for things like, you know analytical kinds of things, you know.
> (I#3, p. 20)

> Well, perhaps it can be utilized, used to show a lot of relationships that might not be particularly obvious or perhaps it can be a short way to do a lot of mathematical stuff that will make it easier to see more application work or relationships.
> (I#3, p. 21)

When talking about the use of computers in the teaching of science, Ida would frequently refer to the frog dissection program she had seen during her

first technology class. She found such an approach interesting, but she was also skeptical to whether such a program could be as good as traditional teaching where the teacher provides the information and the direction. She assumed that the teacher would be able to reply more directly to the students' needs and questions, whereas a computer program, would only be able to respond as well as the creators of the program are able to predict possible questions.

> And it [the frog dissection program] is, interactive more so then the book, so I thought it was pretty interesting, but on the other hand I thought it was too limited, I think a lot of the whim of whoever had made the application, you know. If they decided to include that or not, you know, perhaps they decided to include one definition of a part or an organ, but it is, I found the definitions to be sort of limited or there was no connections between them and things like that and I thought that, you know, it is not comparable to having, for myself as a student, it wouldn't be comparable to actually having somebody that I could actually ask, like a teacher, you know, or some sort of, a frog to pick apart. (I#3, p. 12)

Another reservation that Ida made with regard to the use of computer technology in classrooms was that she thought the students would become more passive. She would compare it to the use of television.

> I think it would be more exploiting the media anyway, so it is out there, and just using it for what you can, like turn on the television or something. (I#3, p. 21)

Ida became increasingly critical to the use of technology as the quarter went on. She had a hard time differentiating the use of computer technology from other types of media, such as television. In addition, Ida admitted that

with her knowledge of technology it was very difficult to have any clear cut opinions about its potential.

The Influence of the Teacher Education Program on Ida's Thinking about Computers and Teaching and Learning

Ida was initially heavily influenced by her background as a social worker. She viewed education as a way of preventing kids from making poor choices for their life and a place to develop general life skills rather then specific subject matter knowledge.

> I got a pretty big personal agenda. I think that people should be interested in educating themselves pretty much though. Whatever I could, however I could be a positive influence so as to perhaps help make students want get more education or to learn more, learn more is actually more essential then formal education, I think, because I think a lot of people perhaps do very well in this world without going to formal education even though I was never raised that way or don't take that choice for my life. But I think that they must have, that they must be interested in learning. And then I also have ideas about, you know, equality of races, gender and all that kind of stuff, so I think it is good to promote, you know, girls in the science classes.
> (I#3, p. 6)

She had, during her year as a high school student, a teacher that she liked a lot. When Ida was initially asked to describe what good teaching would look like, she would refer to this teacher. The qualities she liked about this educator was his ability to present the material in non traditional ways and how he

related to students. This teacher was able to look at students as individuals and to take an interest in the students that went beyond classroom instruction.

> He was just kind of eccentric, he did things that was just unusual. He was really active in our lives and what we were doing and, you know we were doing all these boring things and he was talking about our friends and about computers and other stuff.
> (I#1, p. 4)

There is no doubt that Ida saw this teacher as a model for the type of teacher she wanted to become.

During the teacher education program, Ida claimed to be little affected by what was taught in most of the classes. A couple of exceptions were the field experience and a particular professor she had in one of her classes. During the field experience she had the opportunity to observe many teachers and be able to first hand see what they are struggling with in a classroom setting. She was exposed to disciplinary problems and the challenge of managing many people at the same time, something she did not have to worry about as a social worker. Ida saw such experiences as essential to becoming a good teacher and thought that what she has seen in most of the university classes were not very relevant. In her view, the university classes were removed from the reality of classroom teaching and she would rather advocate some form of apprenticeship in the preparation of new teachers.

> Maybe perhaps experience would help, but I don't think theory helps.
> (I#3, p. 10)

One exception at the university was the learning theory professor. She claimed to have learned a lot from him. Just like her favorite high school teacher, Ida described this professor as an exceptional educator with an unusual talent of coming up with creative ways of presenting the material. He was also an excellent communicator. She claimed to have learned a lot from just watching him as a teacher, he was exceptional because unlike the other professors, he was modeling what he was talking about in his instruction.

> I think it is kind of ironic because he is modeling what he is talking about entirely, you don't necessarily know that he is doing that, but I am. (I#2, p. 13)

Although Ida acquired some new insight into the use of computer technology during the quarter, she was surprised how little she saw technology used in actual classrooms and in courses in the teacher education program. Most of the classrooms she visited during her field experiences had computers, but they were never used when she was present. One exception was a middle school teacher who used a grading program.

> Oh, nothing, I didn't see anything [during the field experience] except the overhead and the middle school teacher had her grades in a grade-book and the same in the high school I was at. (I#2, p. 15)

Because she never saw computers used in classroom settings she started to question whether this was a result of lack of skills or, in some cases lack of equipment. Whatever reason, she did not feel that any of the classes provided her with models for how to use computer technology in her future practice.

> It seems, from my experience now, and from my observations, and you know, I think it seems like people really don't know how to use it. You know, is that a function of money, or is it a function of time, or is that because of creativity, I don't know, because I am not educated enough in technology to make a judgment on that.
> (I#2, p. 15)

In addition, Ida had in her spare time during the quarter read a novel that painted a very critical picture of the new world of information technology. This author had claimed that the interaction between man and machine is artificial and that there might be a chance that elements of human interaction might be lost and that people would become increasingly isolated.

> I think of it in very positive ways, like unifying the world and that sort of things, and this person's argument was that it is taking us away from nature, and actually gives, there is something about it that kind of destructive really, that we are not really fully aware of. It is true I mean, we are constantly getting further away from nature, so, thinking about it in that way, I don't know I don't know what we should do.
> (I#2, p. 18-19)

Much like Henry, Ida felt that her initial beliefs about teaching and learning were never seriously challenged throughout the quarter. A reason for this could be that her pedagogical views were global in nature and she would site personal goals rather than content goals to define the purpose of her future professional career. Ida also shared the very diffuse, but optimistic, image of computers in teaching and learning that many of the candidates who were computer novices initially possessed. Despite the fact that she throughout the

quarter would become increasingly aware of various uses of computers, she would also become increasingly confused about how to use the technology in a classroom environment. The main reason for this could be traced to her general beliefs about technology and the society, and the absence of computers both in the university classes and in the classrooms she visited during her field experiences.

Eric, Gabriel, Henry and Ida all entered teacher education with little computer experience but with differing images of computers in education and beliefs about teaching and learning. All four of them would quickly acquire enough skills to operate the machines in the computer laboratory. While computer knowledge seemed to play a very limited role in the candidates developing pedagogical images of computers in the teaching of science, the candidates drew much more from their evolving general pedagogical beliefs in constructing models for how to use or not to use computers in the teaching of science.

While the six teachers in the study are very similar in their subject matter knowledge, the individual candidates, largely independent of their computer knowledge, possess distinctly different knowledge and beliefs about teaching secondary school science and the use of computers in the teaching of subject matter. The following chapter will explore in more detail the images of computers in the teaching of science that the candidates developed during the quarter and the sources of those images.

Chapter VI

DIFFERING IMAGES OF COMPUTERS IN THE TEACHING OF SCIENCE

Teacher candidates base their visions of classroom teaching on their perceptions of what it means to teach a particular subject matter (Clark & Peterson, 1986; Grossman, 1990; Nespor, 1987; Wineburg & Wilson, 1988). Although these images may be general and largely based on their own experiences as students at this point in their career (Feiman-Nemser, McDiarmid, Melnick, & Parker, 1989; Lortie, 1975), they define the candidates' thinking about how and what to teach. These visions, or in our case, conceptions of teaching science, combine the candidates' philosophies of teaching with their perceptions of the goals of teaching a particular subject matter to a specific age group and may or may not include the use of technology.

Although all of the candidates in this study entered their professional preparation expecting to use computer technology in their future teaching, their images of what role computers ought to play in the teaching of science were often vague and poorly articulated. Throughout the quarter some of the candidates developed new visions of how to use computers in their future teaching, while the conceptions of using technology stayed relatively unchanged for others. What follows is a discussion of the candidates'

developing images of computers in teaching, proceeded by a discussion of the possible sources of their developing images.

Using Computers in Education

The question of access to computers in schools has become an essential part of society's perceptions of what is needed to improve our schools (Cuban, 1993). Images of children working in front of computer screens have become the manifestation of a modern school. Unfortunately, the portraits often painted in political speeches as well as in articles in the popular media about the use of technology in K-12 education are often high in hopes but vague on specifics. This quote from President Clinton's address to the Democratic National Convention in 1996 exemplifies the educational expectations that are often tied to the introduction of modern technology into our classrooms.

> Now, what does that mean [that every classroom has computers hooked up to the Internet]? That means that we have a chance for the first time in the entire history of the United States - this has never been true before - in the history of the United States to see that the children in the most remote, rural schools, in the poorest urban classrooms have access to the same information at the same level of quality in the same time and the same way as the kids in the wealthiest, best schools - public or private - in America do. That will revolutionize education if we can do that. (Clinton, September 25, 1996)

Unable to draw on experiences from their own schooling when it came to the use of computers in the teaching of science, many of the candidates in this study

would frequently reflect similar hopeful, but often ambiguously defined beliefs about technology in education. With the exception of Henry and to some extent Beth, the candidates' initial image of computers in education was dominated by one filled with "drill and practice" programs and game activities. Although some of the candidates added alternative perspectives as the quarter progressed, the ideas of having students answer questions prompted by a program or play some sort of game (often perceived as wasteful of time or energy by the candidates) persisted as a dominant feature of many of the candidates' thinking about technology in K-12 classrooms.

One way of capturing the candidates' various images of computers in the teaching of science is to group them into six broad areas. These are: 1) writing, storage and calculation, 2) laboratory support purposes, 3) drill and practice, game like activities, 4) simulation and game programs, 5) multimedia/presentations, and, 6) media, information gathering and communication activities. Although the borders between the different categories are sometimes blurry, the first model encompass the most common use of computers, namely for word processing, to create data bases or perform calculations using a spread sheet. All of the candidates would consistently support this form of computer use. A reason for this could be that they saw the use of word processors and spread sheets as a natural part of writing and performing calculations. They never considered these uses an invasive

technology in the classroom, one that might have challenged the candidates' perceptions of what constituted a good learning environment.

The use of computers as laboratory support devices are closely related to the calculation and storage model. Laboratory experiments are an integral part of teaching science. In addition to keeping track of data and to write reports, computers allow students (and researchers) to perform more accurate measurements and observations. When connected to the right peripherals, computers can be used to, for example, record speed or time, as well as to enhance images in a microscope.

Drill and practice exercises can take the form of everything from pre-designed "learning experiences" to small question and answer programs. This type of computer use has in some instances aimed at creating individual learning environments for the students that are independent of a teacher. This strategy has long been the model for the field of educational technology and the instructional software industry (Heinich, 1984; Kerr, 1991).

A dramatic improvement in hardware and software capacity has over the last years lead to a rapid development of simulation programs that allows the user to explore areas that normally would not be possible. Examples of these programs include everything from "dissection programs" to software that allows the students to explore the works of nuclear power plants. Outside the school environment, such programs are used to test models of buildings and airplanes as well as to train physicians in how to perform a surgical operation.

Needless to say, some of this software is too expensive for schools, but less sophisticated versions, such as programs that allows students to simulate the dissection of a frog, are fairly common. One should notice that all of the candidates in this study, with the exception of Beth, had very little experience with simulation programs. Instead of viewing simulation programs as an opportunity for free exploration, they would rather look at them as more or less a drill and practice program containing graphics, much like the frog dissection program that most of them saw or heard about during their first technology class.

New computers have multimedia capabilities that combines those of TV/video, audio players, computer applications and over-head projectors. Teachers and students can with relative ease create presentations that include video clips, pictures, text, graphics and sound, and use this as way of underscoring points in a lecture or to clarify the information that is being conveyed to the class.

Finally, over the last five years there has been a rapid development of computer networks. Anyone who has access to the Internet can with relative ease communicate with people around the globe using electronic mail or access information about most topics by searching World Wide Web pages. For the science teacher this means that his or her students can in some instances communicate with scientists who are working on a particular project or daily follow ongoing experiments such as, for example, those on board the space

shuttle or at the Monterey Bay Aquarium. A consequence of this development is that the teacher and the textbook may not longer be the main source of information to the students. Instead of spending hours searching the library, students have the opportunity to find out more about a concept by searching the Internet for a few minutes. None of the candidates was very familiar with the Internet when entering into the program. This might explain why this feature of computers did not come up as a topic during the first interview. At the same time, the Internet, especially the portion labeled the World Wide Web, has exploded in size and versatility over the last year. During the time data was collected on the candidates, the Internet was still in the infancy as an easily accessible technology.

Changing Images of Computers in the Teaching of Science

For some of the candidates, especially those who had little previous experience with computers, the perceptions of computers in teaching science were limited by what they knew about the capacities of the machines. Even adept computer users such as, for example, Frieda, had a tendency to limit the scope of the possibilities that technology promised when it came to using it in a classroom setting as opposed to what she had experienced in non educational surroundings. Figure 3 (p. 153) provides an overview over the changes in the candidates' perceptions of computers in education during the quarter. It should be noticed that the overview does not represent a list of the students'

knowledge of computer use, but provide information about the type of activities that they could see themselves use computers for in the teaching of science before and after completing the technology course.

	Group I Experienced with Computers				Group II Computer Novices							
	Frieda		Beth		Eric		Gabriel		Henry		Ida	
Use	Be-fore	Af-ter	Be-fore	Af-ter	Be-fore	Af-ter	Be-fore	Af-ter	Be-fore	Af-ter	Be-fore	Af-ter
Writing/ Storage/ Calculation	X	X	X	X	X	X	X	X	X	X	X	X
Laboratory support		X	X	X		X		X	X	X		
Drill and Practice/ Game	X				X						X	
Simulations	X			X	X	X	X	X			X	
Media - Presentation	X	X	X	X	X	X	X					
Media - Information/ Communic.		X						X				

Figure 3: Images of technology in the teaching of science.

Figure 3 shows that three of the candidates, Frieda, Eric, and Henry would use computers for as many categories at the end of the quarter as they did when they entered their teacher preparation. Beth and Gabriel increased the number of tasks they would use computers for, while Ida would use computers for far less purposes at the end of the quarter than what she indicated at the beginning.

If we were content with counting the various images we might conclude that most of the candidates retained their perceptions of computers in their future teaching or had adopted additional images throughout the quarter. A far more detailed picture develops if we look how the number of tasks that the students would use computers for varied as the quarter progressed (See Figure 4, p. 155).

We can conclude from Figure 4 that Gabriel, Frieda and Eric developed a very critical stance towards the use of computers in the teaching of science in the middle of the quarter. Essentially they would for a period use computers only for writing reports and do calculations. Later they would develop new roles for how they could use the technology in their future classrooms, images that were significantly different from the one they had originally proposed (See Figure 3, p. 153).

Ida represented an exception to this trend, she would consistently find less room for technology in her future practice, essentially accepting the use of computers only for writing and calculation activities. Beth and Henry, on the other hand, never went through a period of rejecting the technology; they both retained their original views of how to use computers in science classrooms. Beth would even add a category to the images she brought to her professional preparation.

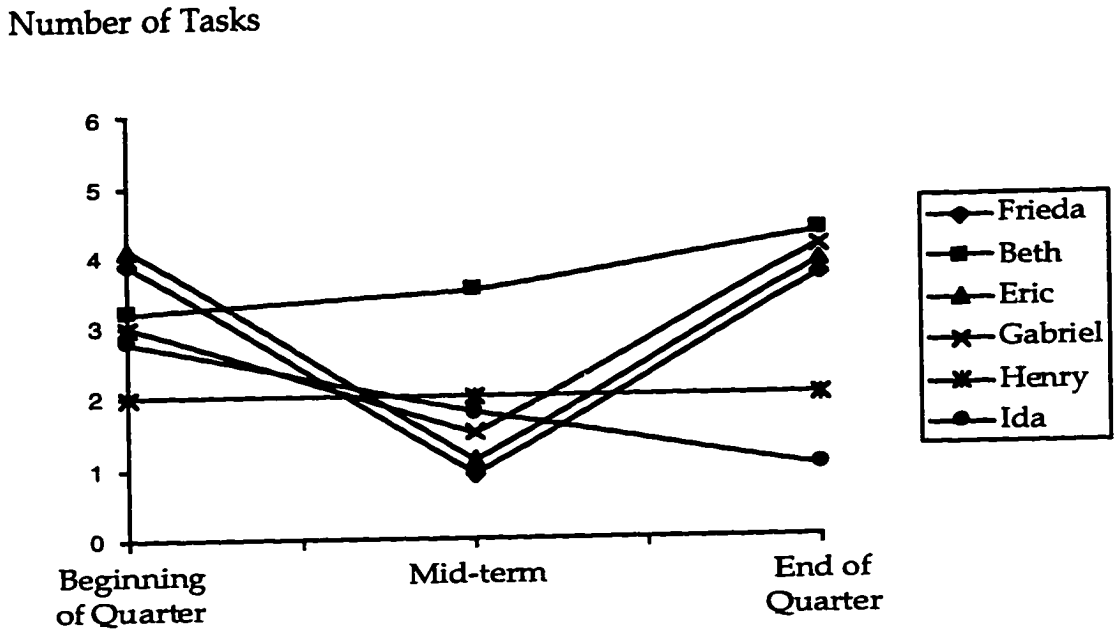

Figure 4: Number of tasks for which the candidates expected to use computers in the teaching of science.

Another compelling characteristic of the candidates' developing perception of the use of computers during this quarter was how many of the candidates adopted new images that replaced or supplemented the images they had brought to the teacher education program. Frieda, Eric, and Gabriel all entered their professional preparation thinking of computers in education as tutorial devices that could take on the role of a teacher, a machine that could introduce scientific concepts to the students and provide the appropriate questions related to what they would be working on. At the end of the quarter they would rather emphasize the important role that computers can play as tools in support of laboratory exercises or as a vehicle that would allow the

students to access more and better information about topics they would be working (See Figure 3, p. 153). For example, Frieda imagined herself upon entering the teacher education program using computers for writing, "drill and practice", simulations and multi media (e.g. presentation support) activities in her future teaching. At midterm, she would reject most forms of computer technology in her classroom, but would towards the end find room for new uses in areas such as to support laboratory experiments and to gather information searching the Internet. Notice that she abandoned "drill and practice" and simulation programs as a viable use of computers in teaching and learning science. Instead she adopted two tool oriented approaches as way of using technology to support her teaching.

For the type of activities they retained, such as the use of simulation programs in Eric and Gabriel's cases, they envisioned these used differently than what they had initially described. Instead of seeing these programs as deliverers of the curriculum, they would use them as an introduction to a topic or as one way of underscoring a point that otherwise could be difficult to describe. In the same way Beth would add the use of simulations to her image of computers in the teaching of science.

> They can work with it [the program] and maybe the next session discuss it with each other.
> (G#2, p. 21)

In conclusion, the six candidates' developing images of computers in the teaching of science had contrasts and similarities that need to be explained

further. For example, Beth, Henry and Ida's changing images are not only different from the those of the other three, there were also striking contrasts among how Beth, Ida and Henry in terms of how they were thinking about technology in teaching and learning. I will propose four hypotheses as a way of directing the discussion of possible differences and the sources for these across cases. The first of these looks at the role students' prior computer knowledge might have played in influencing their images of computers in education, the second looks at the role of the technology course-work, the third hypothesis deals with the field experience, and finally, the fourth with the students' perceptions of science pedagogy.

Hypotheses 1: The candidates' changing images were influenced by their prior computer knowledge.

In my initial conceptual framework for this study, I assumed that computer experience, the ability to use the machines for multiple purposes, represented an essential factor in teacher candidates' developing images of computers in the teaching of science (See Figure 1, p. 31). It would soon become evident that it was difficult to find a clear link between the candidates' prior experience with computer technology and their initial image of how to use them in a classroom setting. For example, both Frieda and Eric expected initially to use computers for a variety of purposes, although Eric had never seen or tried many of the uses that he proposed. Even Gabriel and Ida, who

were the candidates with the least knowledge of computers, suggested upon the entry into the program several areas for which they would use the technology.

It is also difficult to find a relationship between the candidates' prior computer knowledge and their changing perceptions of the role of computers in the teaching of science as the quarter progressed. One possible explanation for the minimal role prior computer knowledge seemed to have played could be traced to the fact that the students who had worked very little on computers, quickly became familiar with the basic operation of the machines (maybe a result of vastly improved operating systems) and were soon able to explore many of the features and programs in the same manner as the experienced computer users. Another reason might be connected to the focus of this study which did not ask whether the candidates actually could technically do the things they described, but emphasized broad images and possible uses in the teaching of a particular subject matter. The images they described could therefore be based on possibilities they had heard or read about, and not necessarily something they had observed or tried out on a computer. One notable exception to this trend was Beth who had considerable computer knowledge and seemed to consistently see the possibilities for using a variety of computer activities in her future teaching.

There was, on the other hand, a qualitative difference between the skilled computer users and the computer novices with regard to the depth and insight in which they were able to describe the use of computers to support, for

example, laboratory activities or presentations. Frieda and Beth provided far more elaborate portraits of what they envisioned computers used for than the others. Frequently those two would refer to how they had used technology in their previous work when talking about what would be appropriate in a classroom. The other participants would more often refer to something they had heard about or read about or seen on TV when proposing possible uses.

Hypotheses 2: The candidates' changing computer images were influenced by the technology course-work.

The content of the technology course-work can be used to explain why so many of the candidates changed or added new images of how they would use technology in their future teaching. All of the candidates reported to have gained something, mostly the ability to operate new aspects of computers that they were previously unfamiliar with from these classes. For example, this was how Frieda and Henry summarized what they had acquired from the technology sessions:

> I am more fluent on the Internet, I can look for stuff and get information.
> (F#3, p. 24)

> There are many new gadgets that I have seen.
> (H#3, p. 19)

These evaluations of the technology course-work are consistent with the goals that the technology instructor set for the class. In her view, the purpose of the

class was to ensure that the students would leave the technology classes with an ability to use a "variety of technologies in a variety of ways" (TT#1, p. 10). Most of the classes were therefore spent working on different types of hardware and software, functions that were not necessarily linked to a certain area pertinent to the teaching of science.

The participation in the technology course-work cannot, on the other hand explain why Henry and Ida did not add any new images of computers, or in Ida's case, reject most computer uses in the teaching of science. A possible reason for Henry's consistency could be that he was often observed working on his own things, usually the Internet, during the technology sessions. He justified his lack of interest by claiming that it was redundant to spend time learning computer programs while in the teacher education program. Instead he wanted to wait until he had received a teaching position, and then focus on the programs he would encounter there:

> When I get to a classroom I will be able to see what programs they have and learn how to use those well, so I am not really interested in the programs that are here.
> H#2, p. 11

That candidates choose to focus on only a few of the areas they are introduced to in teacher education is consistent with what Hollingworth's (1989) description of how teacher candidates tend to focus on only a few areas of the vast amount of topics they encounter during their professional preparation. She claimed that because the candidates are introduced to so many

complex ideas during their course-work and their field experience, they will choose to focus only on those they view as most important. The fact that the technology course was non-graded and taught by a teacher assistant rather than a professor, might have contributed to Henry's perception of the importance of the class and his choice not to put to much effort into it.

Ida's development is, on the other hand, more difficult to explain. Although she was introduced to new ways of using computers, she would become increasingly critical of their use in classroom situations. Her case represented, together with several aspects of the evolution that took place among the other candidates, developments that cannot alone be explained by their participation in the technology course-work. Another example; none of the classes covered the use of laboratory support devices, but still three of the students, Frieda, Eric, and Gabriel would add this as a desirable use of computers in a science classroom. This is especially remarkable in Eric and Gabriel's cases who had very little computer experience before they entered their professional preparation. Also, one can not look at the participation in the technology course-work to find explanations as to why some of the candidates would reject many of the uses of computers they had initially suggested, especially since some of these applications were those that received the most attention in the technology classes. For example, a lot of class time was spent on how to use presentation software and the Internet, very few added these categories to their images of how to use computers in their future

teaching (one less would use presentation software, whereas two candidates added the use of the Internet as a desirable use).

Hypotheses 3: The candidates' changing computer images were influenced by impressions from the field experiences.

The field experience has often been referred to as the most formative part of a teacher's professional preparation (Lortie 1975; Lanier, 1985; McDiarmid, 1990). During this time the students have the opportunity to observe models of teaching and try their hands at the practice in front of real students. Many teachers have emphasized the importance of having opportunities to watch computers used in classrooms as an essential addition to technology classes in the process of learning to use computers for instructional purposes (Handler, 1993). But all models are not the same, and there is no guarantee that the candidates will observe exemplary teaching while visiting classrooms. Indeed, in some cases the field experience may be counter productive, reinforcing already established misconceptions about teaching and learning (Feiman-Nemser & Buchman, 1985; Grossman & Richert, 1988).

None of the candidates in this study observed the use of computers in science classrooms (or in any of the university classes except for the technology course-work) during the two field experiences they participated in during the quarter. This might explain why Frieda, Eric and Gabriel had so few illusions about the use of computers in education around midterm when they had just

finished their second field experience. It can also be one way of explaining why Ida rejected her initial suggestions for how to use computers in her future classroom. Several of the candidates found the absence of computers confusing, not sure about where to place the use of technology in the picture they had of themselves as future teachers. Ida expressed this most clearly when she concluded that, based on what she had seen in the teacher education course-work and during the field experience, it seemed like "people [teachers and university faculty] really don't know how to use it" (I#2, p. 15).

The cooperating teachers provided several explanations as to why they were not using computers in their teaching. All of the cooperating teachers had access to a computer in their classroom or they could make reservations for a computer laboratory and take the students there. The cooperating teachers explained that they found the arrangements cumbersome since the one computer usually available to them in their classrooms was not sufficient for a class of 25-30 students or they had to make reservations several weeks ahead in order to get into the computer laboratories. In addition, some of the teachers' images of computers were of "learning machines" where the students typed in answers to questions provided by a program, and they were unsure about the value of such experiences. One of the teachers, who had been observed by both Eric and Gabriel, described his view as follows:

> Computers are not available, we have a couple of computer labs here but they are always scheduled. I can't predict two months in advance what day I

> would need the computers for this lesson, by the time I know exactly what days I need, it has already been booked. So the availability of the computers is not where it should be yet. The other thing is, the kids are so computerized in so many other classes and in their home lives, you know, any one passively sitting in front of a TV is computerized, really. I want them to go back and do something with their hands, like write something or read something or act out something or demonstrate something, I want them to do things, and the computers are very good at something, but I am not convinced that that's the only way to go, so I minimize my technology.
> (CT1#1, p. 21)

In other words, the candidates observed not a single teacher in the field that could help them develop models for how to use computers in the teaching of science.

Although one can use the field experiences to explain why so many of the candidates at times saw very few functions for which they would use computers in their future teaching, it does not explain why they late in the quarter added new images, or why Beth and Henry never went through a period of conflict with regard to their perception of technology in their future practice. It is therefore necessary to look at some of the other developments that the students went through, such as their perceptions of subject matter and pedagogy, and investigate how these might have affected the candidates thinking about computers and teaching and learning.

Hypotheses 4: The candidates' changing computer images were influenced by their developing perceptions of science and pedagogy.

With the exception of Henry and to some extent Ida, all of the students entered the teacher education program viewing science as a collection of facts. Good teachers, they thought, would find ways to present these concepts in a manner that the students could easily understand and they would use various laboratory activities to accompany the presentations or introductions in order for the students to observe the phenomena they would be studying. In their view, the teacher plays a central role in the classroom as the provider of information and organizer of activities that can open the eyes of his or her students so they can see and remember what, for example, gravity or pollination is.

As the quarter progressed, all of the students but Henry, would, in some cases dramatically, change their views of what it means to teach science and the role the teacher ought to play in a classroom. Broadly one can describe this transformation as one from viewing science as laws and concepts that should be memorized to seeing science as an area of exploration, emphasizing what Schwab (1978) identified as the syntactical structure of a field of study. This development was consistent with what the science methods teacher wanted to see in the candidates. Here is how he described his students and the purpose of his class:

> We spend a significant amount of time examining, if you will, the philosophy of science. What science is all about, try and get it out, extend out and enlarge their points of views. A lot of them come [to the teacher education program], because of the way they have been taught science, believing that science is a collection of facts, principles to memorize and labs to verify them, that is what they have been told, that is how they have learned about it.
> (UF#3, p. 2)

In a similar way all of the candidates, with the exception of Henry, went from looking at teaching as a teacher centered activity to a more learner centered approach to classroom instruction. The development in the candidates' beliefs about subject matter and teaching and learning were closely tied to the readings and discussions they participated in the science methods class and the learning theory class. Both of these classes had as their aim to challenge the candidates' existing beliefs in order for them to develop their own identities as teachers and their images of what it means to teach science.

When the candidates were asked to rank the teacher education experiences that had influenced them the most with regard to teaching and learning, Ida, Eric and Gabriel ranked the learning theory class as the most important followed by the science methods class. Beth ranked the science methods class ahead of the learning theory class. Frieda, who developed a close relationship with her first cooperating teacher, and Henry ranked the field experience as the most influential followed by the science methods class and the learning theory class. Notably, none of the candidates judged the

technology sessions as having influenced their thoughts about teaching and learning. Typically, several of the candidates claimed to have changed completely their perceptions about what constitutes good pedagogy.

Many of the candidates went through a period of what Grossman (1991) described as "overcorrection" (p. 350). Confronted with extreme examples of new theories and practices through their readings and discussions in the learning theory class or the science methods course (in Frieda's case, talking to the cooperating teacher from her first field experience) the candidates were for a period of time stripped of the ability to justify the beliefs that were largely based on their own experiences as students. Both the learning theory professors and the science methods professor claimed that they deliberately overcorrected for traditional practices in their teaching by, in the case of the learning theory professors, require readings that focused on a wide variety of pedagogical views, including behavioral and constructivist approaches. Towards the end of the quarter, as the candidates started to drift back to the methods they for so long had observed during their own schooling, they retained elements of what they had encountered in the classes during the quarter as they developed new identities as science teachers.

Although the learning theory class and the science methods class did not cover topics that dealt with computer technology directly, they both affected the candidates' images of computers in education. A typical example of this was the reading of B. F. Skinner's (1954) article "The science of learning and the

art of teaching" where the author introduces his version of a learning machine. The candidates would often refer to Skinner's learning machine when talking about computers in the teaching of science, expressing a fear that by introducing computers into the classrooms, the students would be left in front of a screen solving problems provided by a program. Gabriel expressed it like this:

> They are just sitting there just like with the old, you know, Skinner and his black box.
> (G#2, p. 21)

Figure 5 (p. 170-171) illustrates the relationship between the number of tasks the candidates envisioned themselves using computers for in a science classroom and their developing views of teaching and learning. As the candidates became increasingly learner centered in their views of teaching and learning, they found less room for computer technology. This development is interesting since most research on computers in classroom settings have found that the use of technology strongly supports a student-centered approach (Kerr, 1991). One reason why the candidates did not immediately see the use of computers as something that would support such an approach could be the fact that they continued to see computers as tutorial devices far into the quarter and they did not see examples of technology in student-centered classrooms that could contradict such a view. Only at the very end of the quarter did some of the candidates start looking at computers as tools or support devices, and, as

they began to drift back towards their original models of teaching and learning, they would once more find room for computers.

The notable exceptions to this development are Ida, Beth and Henry. Ida was much slower to embrace the new ideas she encountered in her classes and never started to drift back to her original pedagogical beliefs (which were much more undefined than the other candidates) during the quarter. She was never introduced to a student-centered approach to technology as she adopted an increasingly constructivist pedagogy. This might explain why she throughout the quarter became increasingly critical of the use of computers in science. An alternative explanation can be traced to the fact that Ida reported to have read literature (not part of the teacher education program) that was critical of an overly technological future.

> This person's [the author of one of the books] argument was that it [the technology] is taking us away from nature, there is something about it that is destructive really, something that we are not fully aware of.
> (I#2, p. 18)

Henry and Beth, like the others, saw it as important that the students would learn and understand the laws and theories that constitute the basis for scientific exploration. Beth did, like most of the others, go through a period where she would overcorrect her initial beliefs about teaching and learning. But, unlike, for example, Frieda and Eric, she did not totally abandon her initial beliefs, she was always questioning the theories and practices she was

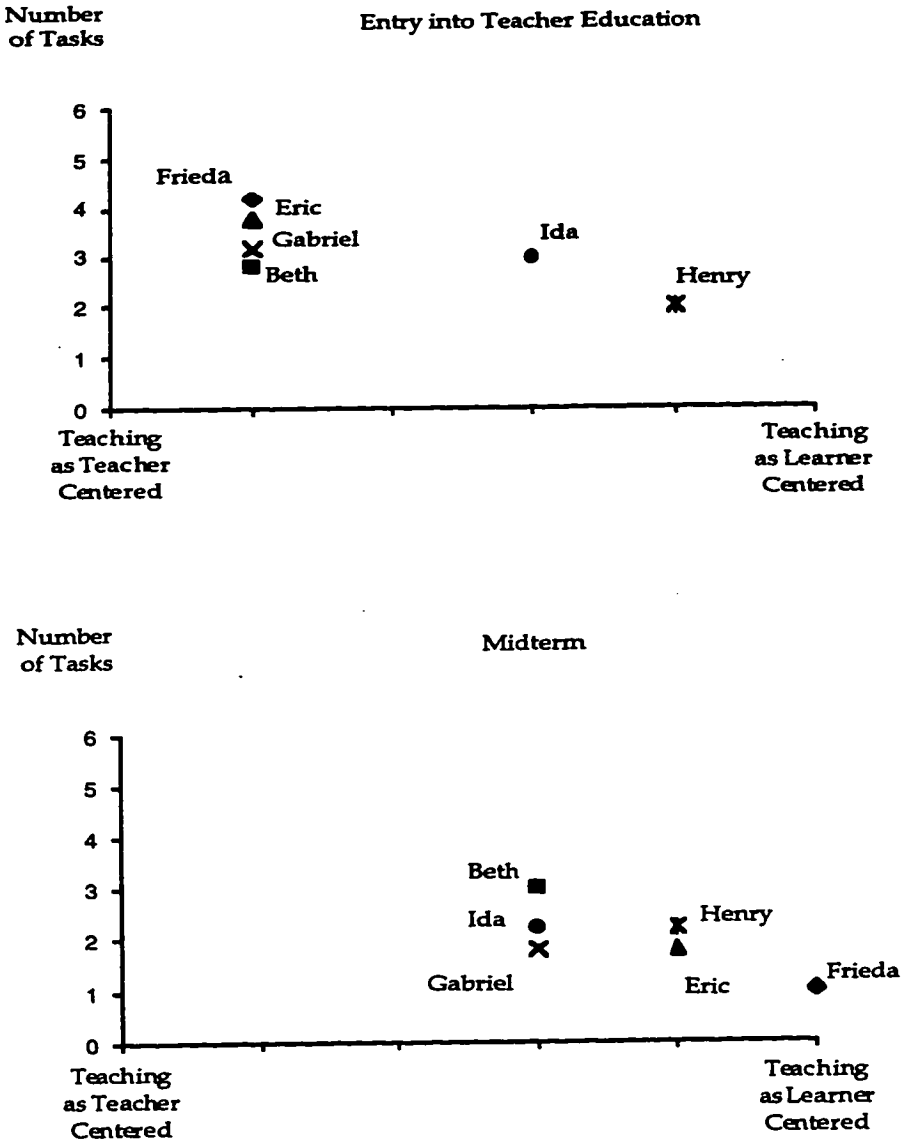

Figure 5: Number of tasks for which to use computers related to the candidates' pedagogical beliefs[3] throughout the quarter.

[3] Based on interpretation of interview data. For example, when Frieda stated in the final interview that she would in some cases tell her students about certain concepts rather than using a constructivist approach, I would interpret this as an indication of a more teacher centered approach to teaching.

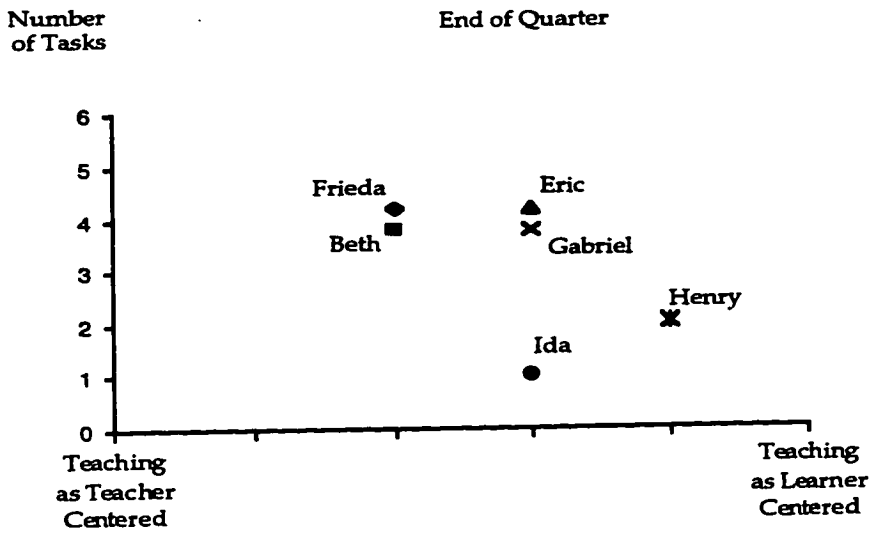

Figure 5: Continued.

confronted with in her classes. This might explain why she never developed the same critical stance towards computers as the others who went through substantial changes in their views of teaching and learning. Another explanation might be found in the fact that she had used computers for many purposes, including practical tasks and simulations in the chemistry laboratory she worked, and had probably the best developed view of what computers cando of all of the candidates. It might therefore have been easy for her to adopt new images of computers as her pedagogical beliefs changed.

Henry, on the other hand, went through very few changes both with regard to his view of pedagogy and his view of computers in teaching and learning. Looking closely at Henry, we see a person who from the beginning

of the program viewed teaching as a far more learner centered activity than any of the other candidates. Already in the first interview, Henry would emphasize allowing the students to develop their own hypotheses and then explore possible solutions to these. He labeled this method "the guided inquiry method" and traced it to the physics classes he had taken to prepare himself for entry into the teacher education program.

> In college, the physics classes I took, 407,408, 409, I really liked the courses where students were working using guided inquiry, on developing their own ideas and then coming up with the right answer, and then talking about it in the class. I think I might like that in my classroom, using a lot of hands on experiences.
> (H#1, p. 2)

Instead of being challenged by the teacher education course-work, Henry felt that the articles and the discussions confirmed the beliefs he brought to his professional preparation.

> I think a lot of the articles, the things they said were basically, or the things I picked out of them anyway, were things that seemed to agree with how I felt.
> (H#3, p. 2)

The same can be said about his image of computers in education. He had seen computers in his pre-teacher education college classes connected to measuring devices used to measure time and speed. Besides word processing, this was the only things he had seen desktop computers used for. Although the candidates were introduced to a variety of computer hardware and software during the technology sessions, they never encountered ways of using these that

challenged pre-existing images. It was therefore easy for Henry to retain the perceptions he already possessed, and, combined with a low level of participation in the technology classes, this can explain why he never added new functions for which he wanted to use computers in his future teaching.

Conclusions

The candidates entered their professional preparation with multiple images of computers in their future teaching. Experienced computer users as well as novice computer users had initially high expectations with regard to using this type of technology in their future science classes. Since most of the candidates had minimal experience with computers in classroom settings, one must assume that the source of many of these images could be traced to the exposure that computer technology has received in the popular media over the last few years.

With the exception of Henry and Beth, the candidates' initial view of computers in education was one of a tutorial machine that could run programs introducing students to scientific concepts in an effective manner. In general this was the image that prevailed among the candidates throughout the quarter. An example of this was how they viewed simulation programs. Most simulation programs are very interactive, open-ended and self-directed. The candidates, who early on were introduced to a crude frog dissection program that was labeled as a simulation, were unable to develop a more sophisticated

view of this particular use of computers. It was striking how isolated the technology course-work was in relation to the rest of the teacher education program, and how the candidates had to refer to a single introduction to a topic as they attempted to develop models for how to use technology in classroom settings. This point is particularly important since we know how important it is to provide multiple models for the students. In many ways the example with the simulation programs reflects the lack of focus in the teacher education course-work on the misconceptions about computers that the candidates brought to their professional preparation.

As the candidates adopted new, more learner-centered, understandings of pedagogy, they would reject the use of technology that they perceived as tutorial. Instead they would add features of computers that clearly were tool oriented such as attaching measuring devices to the machines in order to be able to perform more accurate experiments in a laboratory setting. When the candidates started to drift back to their original views of teaching and learning at the end of the quarter, they would again accept some of the images of computer use that they just a few weeks earlier had rejected. From this perspective, the learning theory class and the science methods class had a far greater influence on the candidates images of computers in classrooms than the technology course-work.

There were a couple of interesting exceptions, Beth and Henry. Henry had upon entering teacher education adopted a strong belief in student centered

classrooms and he was therefore far less affected by the, in some cases controversial, pedagogical perspectives he was introduced to in his classes. Throughout the quarter he retained his images of computers in science, namely as tools that are used to support laboratory exercises. Beth, on the other hand, went through a period of change in her views of science and teaching and learning. But unlike the others who would reject the use of computers as they adopted pedagogical beliefs that were increasingly student oriented, she would consistently find room for the use of computers. Since Beth was a very experienced computer user, she might be an example of how prior computer knowledge can help students in their adoption of such technology as they develop their identities as teachers.

If teacher candidates enter their professional preparation with strong beliefs about computers in education, with images that often contain misconceptions about computers and their use, and if the teacher education course-work is unable to challenge and help the candidates develop these views, then the findings from this study have important implications for teacher education and further research on prospective candidates' adaptation of computers into their teaching. I will in the next chapter explore possible implications and outline directions for future studies of these phenomena.

Chapter VII

IMPLICATIONS

What kind of conclusions can we draw from this study of six preservice science teachers and the professional program which they chose to attend? It is not within the realm of this study to generalize to all candidates entering a teacher education institution or all teacher education programs. We cannot claim that Frieda, Beth, Eric, Gabriel, Henry and Ida represent the population of prospective teachers or that this particular program portrays other schools of education as well. However, by looking at characteristics of the candidates' images of computers in education and attempt to describe how a particular teacher education experience influenced their conceptions of using technology to teach a particular subject matter, the study can contribute to a developing body of research on how teacher learn to teach with technology in particular, and how they develop an understanding of how to teach a particular subject matter in general. The study also poses implications for research and practice in the area of teacher education course-work, especially within the technology portion of teacher education programs.

I understand that by outlining several interpretations of the data, I might have tested the reader's understanding of validity. How could I allow a design that supported several possible solutions? Actually, I see the different

interpretations as the beginning of a debate by providing arguments that formulates alternative ways to view accumulated findings. As Wilson and Wineburg (1993) expressed it:

> Validity, to paraphrase Cronbach, is not a property of instruments but a property of arguments. Each scenario, or argument, views our data differently and comes to different decisions based on this view. Each plays devil's advocate by raising questions, questioning assumptions, and making us rethink things we prize so dearly that we often forget they are hopes and aspirations, not documented truths. (p. 762)

It is from this perspective one should look at the findings I presented in the previous chapters. Of course, I could have developed one scenario based on the data available. But no matter how convincing this picture might be, it would still represent only one out of many based on a particular view of technology and pedagogy. The purpose of proposing several ways of attaching significance to the same data is to provide opportunities for discussion, to bring to the forefront the fact that learning to teach is a complex endeavor where we have to make choices between competing theories and convictions.

Based on the hypotheses I outlined in chapter six, I will in what follows attempt to outline a few possible implications for practice and research when it comes to preparing new teachers in the use of computers as pedagogical tools.

Images of Computers in Teaching and Learning

Despite the fact that a large portion of present teacher candidates have never seen the use of user friendly desk top computers during their own schooling, they have high expectations with regard to using such devices in their own future position as educators (Liao, 1993). This study suggest that candidates enter teacher education with clear (but perhaps limited) images of what computers can do in classroom settings. Most often these images characterize computers as tutorial devices, machines that can take on the process of teaching students and thus challenging the traditional role of the teacher. In some cases this view of computers in education can be traced to the candidates' lack of computer knowledge, but experienced computer users as well as novices possessed this image of the machines and the various tasks they could be used for.

These images became particularly evident when I looked at features such as the Internet and the use of simulations. These forms of computer use are especially interesting since the Internet and simulations are features that usually fit the view of a student centered classroom. Despite the time that was spent on these technologies in the technology classes, the candidates continued to see these as very controlled environments that would limit rather than encourage their future students' ability to explore scientific concepts.

Many teacher education programs put considerable time and effort into enabling the students to overcome misconceptions about subject matter and

pedagogy, beliefs that they have developed over a lifetime of observing in classrooms. This study indicates that it might be necessary to take a close look at the images of computers in education that teacher candidates bring to their professional preparation and find ways to address these in the same way as we address the candidates' pedagogical and subject matter beliefs. If the misconceptions are not spoken to in any form during their teacher education experience, there is a great chance that the candidates will continue to have a very limited view of computers in teaching, or in some cases reject their presence because they perceive that the technology does not offer support for a particular view of what constitutes teaching and learning.

The ability of a teacher education program to enable the candidates to develop images of computers as instruments that can support varied teaching in different ways, and not merely to support presentations or as word processors, could represent an important step in helping the candidates overcome the misconceptions they bring to the program. Only by allowing the candidates to see the possibilities that computer technology represents can we expect to experience some of the educational gains that has been so eagerly anticipated in the wake of the enormous investments in technology that has taken place in K-12 education.

The Focus of the Technology Course-Work

Like many teacher education technology classes the focus of the course that these candidates participated in was on how to operate computers and certain types of software. Although a certain level of computer knowledge is necessary in order to operate the machines, this study indicates that the candidates relatively quickly acquired the skills that allowed them to explore software and certain peripherals attached to the computers. Even Gabriel, who had minimal experience with computers when he entered the program was able to search the World Wide Web using Netscape the first day of class. One can expect that in the future an increasing number of candidates will enter teacher education with computer skills, and we can also anticipate that the trend towards increasingly user friendly software will continue. It is therefore natural to question the need for concentrating the focus on the basic operation of devices during the technology course-work.

Also, this study indicated that the candidates found the technology course-work of little significance, especially when it came to developing their identities as teachers, but also when it came to developing images of computers in education. The candidates saw topics such as how to use Hypercard and how to create "home pages" using Hyper Text Markup Language, as unattached to learning to teach science. While the candidates were struggling to develop identities as science teachers, the technology course-work had a tendency to emphasize general technology, and these classes were therefore marginalized

in the plethora of ideas and impressions that the candidates pondered in the other classes and during the field experiences.

There are several actions that can be taken to prevent the problem of technology course-work remaining unattached to the rest of the teacher education program. One possibility is of course to integrate the technology portion into the methods classes. This would require that the methods professors are able to develop visions of, and demonstrate in their classes, the use of computers in education that can support a variety of instructional strategies. The downside of such an approach is that it would put new, and in many cases unfamiliar and strenuous demands, on the professors who teach these classes since they would have to be adept at using a technology that is developing faster than most of us are able to keep up with in addition to the tasks they have become accustomed to over the years. There is therefore a chance that the technology can become marginalized in the methods courses because it changes so rapidly and the requirement of time and effort that needs to go into the preparation of such classes. Of course, as a new cadre of technology proficient methods professors enter the universities, there is a great chance that these problems will become less prominent.

Another action that teacher education institutions might want to consider is to carefully coordinate the technology course-work with the other classes that the candidates are required to take. This study indicated that the candidates' developing perceptions of subject matter and pedagogy strongly

influenced the type of tools they would use in a classroom situation. As the candidates adopted variations of student centered teaching as an appropriate model for teaching science, they increasingly found it difficult to find room for computer technology, a tool they viewed as controlling and not allowing the students to explore a particular topic. If the course-work had been carefully coordinated there might have been a possibility that the ideas presented in other classes and the during the field experience could have supported the development of images of using, for example, simulation programs, that could support the candidates' pedagogical beliefs. In such an environment the technology instructor would have the opportunity to address the misconceptions about the use of computers in teaching and learning directly and develop student centered classes that could support the pedagogical approaches encouraged in the rest of the teacher education program. The technology course that were the focus of this study did not provide such models, instead it was largely a teacher directed class where the instructor told the candidates how to operate certain types of hardware and software.

Another startling finding in this study is how little emphasis was put on technology in the rest of the teacher education course-work and during the field experience. It may seem like an impossible mission for the technology class to be able to install a vision for the use of technology in teaching when the use of computers were non existing in the other, and from the candidates' point of view, more important courses in the program. In order to provide models for

the use of technology that are meaningful to the students, it will be necessary that such tools are visible in the pedagogical practice of the university faculty. Only then will the candidates have the opportunity to experience multiple models of computers in education and ponder on ways in which they can use such tools in their own instructional practice.

The same argument can be used with regard to the field experience. It was appalling how little technology that was used in the schools that the candidates visited, especially since some of these schools had a reputation of being technology centers. Most often the field experience is the most formative part of teachers professional preparation. It is therefore particularly important that prospective teachers have the opportunity to see the use of technology modeled as they work with their cooperating teachers. In conclusion, in order to provide a technology preparation that that can challenge the candidates' thinking about such tools we will need to ensure that technology is widely used in the throughout the teacher education program, including the university course-work and during the field experience. Without such a commitment to the use of technology there is a great possibility that it will continue to be a tool that by the candidates is viewed as nice, but not very important, to the teaching practice.

What We Need to Know

This study suggests that research on how teacher candidates adopt computer technology as pedagogical tools needs to go beyond self-report data and interviews to more systematic analysis of the nature of the images of computers in teaching and learning that preservice teachers bring to their professional preparation and the effects of the teacher education course-work on these images. There is a growing literature on the effect of teacher education (Grossman, 1990) , especially when it comes to the significance of student teaching. We also know quite well the images of teaching and learning that students bring to their professional preparation (Feiman-Nemser, McDiarmid, Melnick, & Parker, 1989). What we know less about are the images of computers in the teaching of a particular subject matter that candidates bring to their teacher education experience and how these are influenced by the teacher education course-work.

Building on the assumption that the link between a particular curriculum content and pedagogy is idiosyncratic, it is important that the use of computers in teaching be studied in relation to candidates' subject matter background (especially candidates who aim to become secondary teachers) and their pedagogical beliefs. One need therefore to identify images across discipline majors in order to paint a more complete picture of secondary teacher candidates' developing perceptions of computers as instructional tools. In other words, do, for example, prospective social studies teachers possess

different images of computers in teaching and learning than science teachers? If so, what are those images and how are they influenced by the teacher education experience?

One implication from this study is that other course-work than the technology classes substantially influenced the candidates perceptions of computers in the teaching of science. Although Feiman-Nemser and her associates at the National Center for Research on Teacher Education have investigated how the teacher education course-work have influenced candidates' beliefs about the subject matters of writing and mathematics, little attention has been paid to how the non technological course-work influence the prospective teachers' perspectives of using computers as a pedagogical tools to teach a particular subject matter. Further studies are needed to determine the role of the technology course-work in relation to the more established classes and field experiences that we require teacher candidates to complete.

Finally, by looking at a small segment of a teacher education program we risk overlooking important experiences that influence the candidates' understanding of technology in teaching and learning. This point is especially salient when we look at how the non-technology classes influenced the candidates' images of what to use computers for in their future classrooms. In order to determine the combined effect of a teacher education experience, one need investigate how teacher candidates' perceptions of computers in education

change from their entry into a professional program to the point when they establish themselves as practicing teachers.

Conclusions

Case studies of a variety of teacher education programs can help provide the analysis necessary to build a richer conceptualization of the teacher education curriculum, in this case, particularly the technology portion of the course-work, and its influence on prospective teachers' developing identities as educators. As Wilson and Wineburg (1993) suggested, such studies can also provide arguments that allows us to rethink what is important in the preparation of teachers. Among others, this study challenges the notion that teachers can be prepared to use technology in their future teaching in courses solely emphasizing the operation of the machines, classes that are often detached from the rest of the teacher education course-work. The cases of Frieda, Beth, Eric, Gabriel, Henry and Ida suggest that learning to use computers to support teaching and learning is a complicated process, an enterprise that is affected by the candidates' images of technology as well as their understanding of subject matter and pedagogy.

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APPENDIX A: INTERVIEW PROTOCOLS (CANDIDATES)

Interview #1:

1. Can you tell me what lead you to become a teacher? (Probe for why and intellectual background.)
2. If you were to begin your teaching career tomorrow, what would your (ideal) classroom look like? (Activities, relationship with students)
3. You have seen many teachers throughout your schooling. What characterized your favorite teacher's classroom? (Why did he/she like it? What made it good?)
4. Did you have any teachers you did not like, what did his/her classroom look like? (Why?)
5. Can you tell me about your background in science? What areas did you concentrate on?
6. What are your strong areas in science?
7. What are your weak areas?
8. What does it mean to teach science in high school?
9. What would you want to cover? Why?
10. What do you associate with technology?
11. What kind of technologies are you familiar with? (Especially as it relates to computer technology)
12. Can you tell me about your background in technology (formal training, experience)?

13. Do you feel comfortable using computer technologies? What do you find difficult? What do you find easy?
14. The use of computer technologies has become increasingly popular in K-12 classroom. What do you think it means to teach with technology?
15. If someone is good at teaching with computer technology, what does his/her classroom look like?
16. Have you ever seen computer technologies used in schools? If so, how were they used?
17. Is there any type of computer technology that you think is particularly appropriate in teaching science in K-12 settings ? If so, why? What about other subject areas?
18. Can you think of any examples of inappropriate use of computer technology in teaching science in K-12 settings? If so, why? What about other subject areas?
19. What might make it difficult to use computer technology in education?

Interview #2:

1. What does in your opinion characterize a good teacher? Why are these important?
2. What are the characteristics of a good learning environment? Why are these important? What would such a classroom look like? (Activities)
3. What does it in your opinion mean to learn something? What does a classroom look like that support such learning? (Activities, content)
4. You have just finished your second field experience, could you tell me a little bit about where you were and what you have seen? (Any technology?)
5. Did you see any examples of good teaching? If so, what did this classroom look like? Why was it good?
6. Did you see any examples of questionable teaching? Why was it poor?
7. Here are some labels with the title of all the classes, including your field experience, you are taking so far in the teacher education program. Could you identify the courses that have influenced your thinking about teaching and learning? (Ask the candidate to rank the experiences). How did these courses influence your thinking about teaching and learning? (Talk about each course, starting with the most influential). What do you perceive as the goal of these courses?
8. Here are some labels with the title of all the classes, including your field experience, you are taking so far in the teacher education program. Could you identify the courses that have influenced your thinking about computer technology in the teaching of science? (Ask the candidate to rank the experiences). How did these courses influence your thinking

about computer technology in the teaching of science? What would you use computer technology for in your classroom? (Talk about each course, starting with the most influential).

9. If you were to identify other experiences that have influenced your thoughts about how to teach with technology, which experiences would you then choose? How did they influence your thinking about teaching with technology?

10. What did you see during your field experience with regard to the use of technology? What are the weaknesses of the usage you observed? What are the strengths of the usage you observed? (Probe for why this was good or not so good)

Interview #3:

1. Now that you have been introduced to some of the theoretical aspects of teaching and learning, what would you consider your teaching philosophy? What will your (ideal) classroom look like? (Probe for activities, the teacher's role).
2. What do you want your students to walk away with after a year with you as their teacher? (Probe for curricular and pedagogical goals).
3. What kinds of skills and knowledge do you think a new teacher need to have in order to be successful as a teacher?
4. Is there any type of computer technology that you think is particularly appropriate in teaching science in K-12 settings ? If so, why? What about other subject areas?
5. Can you think of any examples of inappropriate use of computer technology in teaching science in K-12 settings? If so, why? What about other subject areas?
6. I like to introduce you to a few classroom situations and hear your responses to these. All of these situations include the use of computer technology in the teaching of science. Scenario 1: Imagine a high school setting where students are using simulation programs. The students are working on individual workstations and the program allows the students to ask questions about the procedures that are simulated. When they have completed the simulation, the program provides the students

with a short test. What is your response to this type of teaching? (Why was it good/poor?) What role does the technology play in this type of teaching? (Any particular content for which this approach would be useful?)

7. Scenario 2: Imagine a classroom where students are working on astronomy. They work in small groups of three to four students, and each group has chosen one particular area that they are interested in. The class of thirty students share five computers and they use the internet to receive information about their particular topic. Because there is limited access to computers, the teacher has set up a list that gives each group equal time on the Internet. While one group of students are searching the Internet, the others are trying to prepare for their search or are making posters for the presentation of their findings. What is your response to this type of teaching? (Why was it good/poor?) What role does the technology play in this type of teaching? (Any particular content for which this approach would be useful?)

8. Scenario 3: In this scenario we meet a teacher who uses the only computer he has in the classroom to describe points he has about electrolysis. The presentation includes pictures and diagrams that illustrates the process. After the presentation the students work on questions regarding electrolysis that can be found in their textbook.

Next week the teacher plan for the students to perform experiments with electrolysis in the laboratory. What is your response to this type of teaching? (Why was it good/poor?) What role does the technology play in this type of teaching? (Any particular content for which this approach would be useful?)

9. Scenario 4: Imagine a class that uses computers to make summary of their findings. The students work in small groups and are doing experiments with falling objects. A computer program is used to measure and calculate the relationship between matter and acceleration, and the students produce diagrams and graphs on the computer that they intend to use when they present their findings to the rest of the class. What is your response to this type of teaching? (Why was it good/poor?) What role does the technology play in this type of teaching? (Any particular content for which this approach would be useful?)

10. If you look back at this first quarter of your professional training, what have you learned with regard to the use of computer technology that you did not know before you started?

11. Do you see this knowledge as relevant to the teaching of science? If so, how? Why?

12. At this point, what would you have liked to know about technology that you think might have been relevant to your future as a teacher? Why are these important?

APPENDIX B: INTERVIEW PROTOCOL (FACULTY AND TEACHERS)

Questions for interviews with university faculty and mentor teachers:

1. First a little bit about your background. Could you tell me about your educational background until present?
2. Tell me a little about your present work, what classes are you teaching? How long have you worked in this position?
3. What does it in your opinion mean to learn something? What kind of activities do you use in your teaching to support this notion of learning?
4. If you should describe yourself as a teacher, what kind of a teacher would you say you are? (Teaching philosophy? How do you like to organize your classroom? Activities? How do you relate to students?)
5. What do you want your students to walk away with after they have completed a course with you?
6. If you were to summarize what skills and knowledge teachers need in order to teach successfully in K-12 classrooms? What would you emphasize? Why?
7. What are your views on how to best prepare teachers for the classrooms? Why would you emphasize those particular aspects?
8. Do you ever use computer technology in your classroom? If so, what do you use it for? Why do you use it?
9. What future do you see for computer technology in education (the teaching of science), can you envision a classroom where technology is more frequently used than what is presently common? What would such a classroom look like?

10. How does this use of computer technology fit into your image of good teaching and learning?

Questions for interview with technology instructor:

1. First a little bit about your background. Could you tell me about your educational background until present?
2. Tell me a little about your present work, what classes are you teaching? How long have you worked in this position?
3. What does it in your opinion mean to learn something? What kind of activities do you use in your teaching to support this notion of learning?
4. If you should describe yourself as a teacher, what kind of a teacher would you say you are? (Teaching philosophy? How do you like to organize your classroom? Activities? How do you relate to students?)
5. What do you want your students to walk away with after they have completed a course with you?
6. If you were to summarize what skills and knowledge teachers need in order to teach successfully in K-12 classrooms? What would you emphasize? Why?
7. What do you see as appropriate use of technology in the teaching of science? Why?
8. Have you ever seen good use of computer technology in K-12 settings? Why was it good?
9. Have you ever seen poor use of computer technology in K-12 settings? Why was it poor?
10. What are your goals for the technology sessions? What kind of activities are you emphasizing? What kind of technologies? Why are you focusing on these technologies?

11. What would your ideal technology preparation for preservice teachers look like? How does this vision correspond to what you are doing now?

APPENDIX C: CODING CATEGORIES

Technology:

CK	Computer knowledge as applied to the ability of operating hardware and software.
BCE	Images about the use of computer technology in K-12 teaching (especially as it relates to pedagogy).

Source of technology knowledge/beliefs:

SCE	Experience (non experience) with technology in schools as a student.
SCTC	Experience (non experience) with technology during TEP course work.
SCFE	Experience (non experience) with technology during TEP field experience.
SCCC	Experience with technology during TEP technology course work.
SCOS	Other sources (training, work etc.).

Pedagogy:

BPTL	Pedagogical beliefs (learning theory).
BPLE	Beliefs about learning environment (student - teacher relationship, etc.).
BPS	Beliefs about subject matter (science).
BPTK	Beliefs about teacher knowledge (what teachers ought to know).

Sources of pedagogical beliefs:

SPE	Pedagogical experience in schools as a student.
SPTC	TEP course work.
SPFE	Field experience.
SPOS	Other sources (work, etc.).

Vita

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