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SCIENTISTS ARE FROM MARS, EDUCATORS ARE FROM VENUS:
RELATIONSHIPS IN THE ECOSYSTEM OF SCIENCE TEACHER PREPARATION

By

Don Duggan-Haas

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Teacher Education

2000

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ABSTRACT

SCIENTISTS ARE FROM MARS, EDUCATORS ARE FROM VENUS: RELATIONSHIPS IN THE ECOSYSTEM OF SCIENCE TEACHER PREPARATION

By

Don Duggan-Haas

Great problems exist in science teaching from kindergarten through the college level (NRC, 1996; NSF, 1996). The problem may be attributed to the failure of teachers to integrate their own understanding of science content with appropriate pedagogy (Shulman, 1986, 1987). All teachers were trained by college faculty and therefore some of the blame for these problems rests on those faculty.

This dissertation presents three models for describing secondary science teacher preparation. Two Programs, Two Cultures adapts C.P. Snow's classic work (1959) to describe the work of a science teacher candidate as that of an individual who navigates between two discrete programs: one in college science and the second in teacher education. The second model, Scientists Are from Mars, Educators Are from Venus adapts the popular work of John Gray to describe the system of science teacher education as hobbled by the dysfunctional relationships among the major players and describes the teacher as progeny from this relationship. The third model, The Ecosystem of Science Teacher Preparation reveals some of the deeper complexities of science teacher education and posits that the traditional college science approach treats students as a monoculture when great diversity in fact exists.

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The three models are described in the context of a large Midwestern university's teacher education program as that program is construed for future biology teachers. Four undergraduate courses typically taken by future biology teachers were observed and described: an introductory biology course; an introductory teacher education course; an upper division course in biochemistry and a senior level science teaching methods course. Seven second semester seniors who were biological Science majors were interviewed. All seven students had taken all of the courses observed. An organization of scientists and educators working together to improve science teaching from kindergarten through graduate school is also described in a case study.

The three models described in the dissertation build upon one another and the third model, that of the ecosystem is recognized as both the most accurate portrayal and most complex and therefore most difficult to apply. The system of science teacher preparation is in many ways a system under stress and that stress will result in system evolution. Through better understanding Complex Adaptive Systems and applying that understanding to the system of science teacher education, individuals may be able to influence the nature of system evolution.

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ACKNOWLEDGMENTS

To thank all of the people who have helped shaped the thinking that resulted in this dissertation would generate a document longer than the dissertation itself. There are many individuals who contributed to my growth into the teacher, researcher and person I am today. Teaching works best when it includes modeling of desired learning. Had my parents not taught by example in the way that they did – to read, to work and to care for humanity, I would assuredly not be the man I am today.

Countless people have mentored me over the more than ten years I have taught. My first formal mentor teacher was Janice Bryant at Bloomfield High School and without her good example I may have lost my passion in the crushing work of my first teaching job. In my first job, I worked with Sam Shama, whose kindness kept me sane and who showed me that teaching is intellectual work. Since working with Sam, I have tried to follow his example of reaching out to new teachers and offering support where I could.

Where I taught the longest and learned the most about work in classrooms was Norwich High School in Norwich, New York. I now know how lucky I was to work with the people I did. In the science department, there were people who helped me to understand teaching especially Patti Giltner, Jim Wysor and Joe Stewart. Patti and Jim were experts at understanding their students. Joe was a department chair par excellence who was knowledgeable about the special considerations of science teaching more than any teacher I know. He understood the legal and safety issues, he was aware of coming reforms and he knew how to teach physics in a way that his students understood. Rich Bernstein is perhaps the best teacher I have known and his work along with Dave Paul in the NHS English Department is the best model I have ever seen for professional

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development. Rich and Dave both showed that the work of a teacher is the work of an intellectual and that is fortified by working together – a model not in common practice.

My work at Michigan State University has been guided by both the members of my formal committee and by members of the larger MSU science education and teacher education communities. Jim Gallagher, my advisor, was wise enough to recognize the correct amount of responsibility to give me and the guidance to help me grow these through experiences. Joyce Parker manages to move back and forth between the two cultures described in this dissertation as part of her daily routine and to do so successfully and diplomatically. David Labaree taught me how to read and write at the graduate level and often had me chuckling as I was learning. Doug Campbell gave me my first broad exposure to ethnography and his mentoring of groups of grad students through dissertation study groups is an invaluable service. Jim Miller is a bench scientist who is also an excellent teacher and has an understanding of the big picture that is essential to making meaningful changes in education. These are the members of my formal committee, but Ed Smith, Deb Smith and Andy Anderson were also effectively parts of my committee. My work together with Ed and Jim Miller allowed me to work with great, "big picture" thinkers. I was very lucky to work shoulder to shoulder with Andy Anderson in teaching future science teacher for two years. I regard all of these wonderful people as teachers, mentors and friends.

Saving the best for last, I thank my love, Katy for her patience and support throughout the long ordeal that is dissertation writing. Not only is she a wonderful woman, she is also an excellent science educator who keeps me grounded in the realities of schools. Thank you, Katy, for putting up with my irritating ways. The end is here!

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INTRODUCTION

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Relationships in the Ecology of Science Teacher Preparation

This dissertation sets out to tell a story of connectedness and disconnectedness. College science and teacher education are separated by a wide gulf, but at the same time that they are distantly separated they are closely connected. The connection is the future science teachers they both work to prepare.

Great problems exist in science education spanning at least from kindergarten through college (NRC, 1996; NSF, 1996; Schmidt, 1997). This study looks at the system that prepares science teachers for the secondary level. One way to frame the problems of science teaching at the 7-12 level is to begin by noting that future science teachers go through formal instruction in science content and in how to teach. The problem, stated baldly, is that the typical teacher fails to successfully integrate science content and pedagogical knowledge (Shulman, 1986, 1987). The causes underlying that problem are immensely complex but are rooted in the disconnect between the science content and pedagogy portions of science teacher preparation.

The catalyst for this dissertation was a series of interviews completed for the Salish I Research Project[1] asking new secondary science teachers to reflect on their teacher preparation programs. More specifically, the interview asked these teachers a series of questions about their college science courses and a parallel set of questions

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[1] The Salish Project was a three year study involving nine universities and their recent graduates in science education. Salish sought to identify linkages among teacher education programs, the way in which new teachers taught and the outcomes of their students. It is described briefly in Chapter 1 and the executive summary is available online at: <http://ed-web3.educ.msu.edu/cvsme/salish.htm>.

about their coursework within colleges or departments of education. The trend of responses in all nine Salish institutions was striking – in analyzing responses to questions about teacher education courses, I found that if I imagined what the opposite response might be, this is what was said about their science courses. This pattern is laid out more completely in Chapter 1. Initially, I had planned to frame this dissertation adapting C. P. Snow's *Two Cultures and the Scientific Revolution* as a framework, and indeed, I begin with such a framework.

Snow's description of the growing rift between the cultures of science and the humanities can be seen to correspond to the rift between science and teacher education on large university campuses. I found that Snow's framework helps to portray the sharp dichotomy that is science teacher preparation, but it is not a terribly rich way to investigate the relationship between the Two Cultures (college science and teacher education) and that relationship is the most interesting piece. The more I delved into science teacher preparation, the more I realized that Snow's framework was too simple to explain what I was seeing.[2]

A barroom conversation (a gossip session is perhaps a more telling label) about some friends whose marriage was ending led me to another framework. There were many reasons that these friends separated, but two struck me as particularly salient for my dissertation. First is a communication failure; the partners in the marriage were failing to communicate how they felt about what was happening in their relationship and the husband was largely clueless that the wife was moving closer and closer to divorce until she had effectively made up her mind. Second, the most simplistic view is that he

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was too much like his father and she was too much like her mother for the relationship to stand the test of time.

Both of these characteristics of a failed marriage are mirrored in the characteristics of science teacher preparation programs. There are two primary components to most such programs – content training housed in colleges and departments of science and pedagogical training housed in colleges and departments of education. The norm is poor communication between these departments, particularly in larger institutions. Science teachers, like most folks, have the desire to affiliate with a culture and with cultural norms. It seems teachers affiliate with content-centered teaching or with student-centered teaching as are the norms in their schools.

By content-centered, I mean that the focus of the classroom work is on the content, and students' needs are often ignored. By student-centered I mean something different from the way this is often described. Student-centered is often used interchangeably with terms like constructivist. Student-centered can mean hands-on, but without deep connection to content, or, in the extreme, it can mean kid-friendly with no real connection to content.[3] Few teachers affiliate with understanding-centered teaching, which places the *understanding* of material at the center of one's teaching (Anderson, 1996). Making the leap to the marriage metaphor, science teachers end up like the

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[2] I also came to agree with Snow's critics who say his description of science and the humanities is also too simple. See D. Graham Burnett's overview of criticism of Snow's Two Cultures, for one example. (Burnett, 1999)

[3] An example I have witnessed in my work with teacher candidates and their supervising teachers: a middle school teacher working with teacher candidates shut off the lights so that students in her social studies class could watch the impressive thunderstorm outside the classroom window. She provided incorrect information about the nature of thunderstorms as students watched.

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The divorce of pedagogy and content are central to this study. The unification of pedagogy and content through pedagogical content knowledge (PCK) is fundamental to good teaching (Shulman, 1986, 1987). This dissertation resonates with Shulman's belief that "TE [Teacher Education] programs would no longer be able to confine their activity to the content free domain of pedagogy and supervision" (1987, p. 20).

The identification of the marriage metaphor led me to read *Men Are from Mars, Women Are from Venus: A Practical Guide for Improving Communication and Getting What You Want in Your Relationships* by John Gray. I found his descriptions of the relationships between husbands and wives strikingly similar to what I saw happening between scientists and educators. Gray provides a framework that is useful for thinking about the relationships between scientists and educators and some thoughts on how to improve those relationships.

How is the relationship of scientists and educators like a dysfunctional marriage?

There are progeny involved – the science teachers who go through the divided or divorced program. The marriage is an arranged marriage of sorts. Neither the educators nor the scientists would necessarily choose the other as the ideal mate, but the evolving system of education first forced them together as normal schools grew into colleges and universities and as universities broadened their missions. As normal schools transformed into universities, science departments moved away from schools of education. As

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universities grew, they assumed roles of teacher preparation. As the size of these institutions grew, specialized professional communities also grew, and teacher education grew further and further away from scientists teaching "content"[4] courses.

Communication problems are central to both the relationship of scientists and educators and often in a failing or dysfunctional marriage. The placing of blame outside the individual is also common in both situations. This is sometimes justified, but generally unproductive if it is an end in itself.

Even when there is talk between scientists and educators, it is often misunderstood – see the writings of Hugh Gauche and Stephen Arch – scientists who have written critically about science education without understanding it (in my opinion). Arch says, "It just may be that counterrevolutionary, old-time lecture hall education is still with us after all these centuries because – although everyone agrees it is a terrible way for students to learn – it's still the best thing anyone has yet invented." (Arch, 1998) We too often talk past each other, or unjustly demean the work of the other. I believe Arch does that in the quote above – he demeans educational research by making the claim that lecture is the "best thing anyone has yet invented" for teaching college science. I have spoken unfairly of scientists who teach poorly by neglecting to take into account the constraints they face such as little or no pedagogical training and often having to teach classes of hundreds. Even though I have thought about it long and hard and understand better than most, I do not come particularly close to understanding the role of the scientists who share with me the responsibility of preparing new science teachers.

[4] I place content in quotation marks to highlight that such labels used to describe science classes wrongly imply that teacher education courses do not teach content.

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Feminist researchers also have much to say about scientists and educators. See for example, Sheila Tobias's and Angela Calabrese Barton's work (Barton, 1998; Tobias, 1990). Science is a traditionally male bastion. Education was one of the very first professions to welcome women.

The Ecology of Science Teacher Education

The dysfunctional relationship model is, like the Two Cultures model, incomplete. Both models fail to account for the larger context. The place of the schools and required fieldwork in those schools does not fit easily in either representation. Important issues like family and community are neglected. These issues do not fit into either model in any simple way, yet they play a fundamental role in the shaping of future teachers. The Salish I study showed that there was more variation in outcomes within each science teacher education program than there was among the nine institutions (Salish, 1997). This implies that we must go beyond, far beyond, science teacher education programs to understand the development of new teachers. Neither the Two Cultures model nor the Dysfunctional Relationship model can take that step well.

Both of these models are vast oversimplifications. This does not mean they are without utility. Karl Popper said, "Science may be described as the art of systematic over-simplification" (Andrews, 1993). Over-simplification of complex systems is often essential to making progress toward understanding those systems, but it also essential to remember that these are over-simplifications.

The third model I employ, that of the Ecosystem of Science Teacher Education, is the most complex and most accurate depiction of the system of science teacher education. This more accurate model is, naturally, substantially more complex. It is, therefore, the insufficient underst[illegible]

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most difficult to understand and least developed of the models. Cronbach (1988) reviewed James Gleick's *Chaos* (1987) *in Educational Researcher*, with an audience of educational researchers and other social scientists in mind. In that review, Cronbach notes that the ideas expressed in *Chaos* have important implications for educational research, but he predicts that use of these models will be necessarily metaphorical descriptions and not use the complex mathematical modeling involved in chaotic mathematics. I will not prove Cronbach wrong with this dissertation[5].

The genesis for this model is also more complex – at least four books helped form this thinking. In the order they came to my attention, they are ① Murray Gell-Mann's *The Quark and the Jaguar* (1994), (which introduced me to the idea of Complex Adaptive Systems). ② Robert Jervis's *System Effects* (1997) which more directly applied CASs to social systems. ③ Claudia Pahl-Wostl's *The Dynamic Nature of Ecosystems* (1995) gave me a deeper understanding of ecology. And ④ James C. Scott's *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed* (1998) which gave me insights to metaphoric use of ecological modeling. These books helped me better define a long held personal belief that my role as a science educator must be that of a generalist, in many ways more akin to a naturalist or ecologist than to a bench scientist. My goals as a science educator map onto the relational goals of the ecologist as described by Pahl-Wostl (p. 47). This is described in Chapter 7.

In most ecosystems, there are niches for both generalists and specialists. This is true in the ecosystem of science education as well. Over the past several decades in education and in the past several centuries in science, there has been movement to

[5] The term "ecological models" often refers to complicated computer models involving higher mathematics. These models mimic specific ecosystems. The model I use is purely metaphoric.

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increased specialization. This change has both costs and benefits. The most obvious benefit for science teacher preparation is the increasing understanding of individual aspects of science and education. The cost is the loss of ability to see significant connections and relationships between the two fields. One important example is described by Shulman in his conception of pedagogical content knowledge (Shulman, 1986, 1987) as mentioned earlier. In many ways to be described in this dissertation, we have lost sight of the big picture of science teacher preparation as we have moved into our own unique but worthwhile specialties.

In any complex system, properties emerge which cannot be predicted solely from the study of less complex levels within the system. While it is useful to study college science teaching and teacher education in and of themselves, this kind of study can never reveal the actual workings of the total system. The emergent properties of the combination of the parallel systems of science education and teacher education do not fulfill the goals of either program component, of either science or education.

Cutting three ways

When Leonardo DaVinci dissected cadavers, he found it necessary to dissect repeatedly, at least three times as organs are complex and cutting in certain directions only allowed him to understand certain aspects of an organ. It was necessary to cut each organ at least three ways. Each cut tells something different about what is dissected – likewise, it is necessary to view this complex adaptive system from multiple perspectives, using at least three different conceptual frameworks.

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The three models employed here are also akin to the different models of the atom used by chemists and physicists. Lewis dot structures are useful simplifications for understanding certain aspects of chemical reactions. They fail to reveal much of the true nature of chemical interactions, however. The Two Cultures framework is my Lewis dot structure – a vast, but still useful, simplification.

Atomic and molecular models that include electron orbitals are more complicated and difficult to understand than Lewis dot structures, but they paint a more realistic picture of how atoms interact. The relationship model derived from Gray's work parallels this next level. Models applying quantum-chemical understanding are more accurate and allow for predicting how more complex molecules interact. This work led to the 1998 Nobel Prize in Chemistry for John Pople and Walter Kohn. The Nobel Prize, of course, indicates that the complexity of such models is well beyond the realm of understanding of most individuals[6]. The same is true of the system of science teacher preparation. The first two models seek to decomplexify science teacher education in useful ways. The third model, the complex adaptive system, digs deeper and recomplexifies.

This dissertation will look into the practice of secondary science teacher preparation using three frameworks: Two Cultures (defined by Snow), the marriage relationship (defined by Gray and others) and the complex adaptive system (described by Gell Mann, Jervis, Pahl-Wostl, Scott and others). The frameworks for investigating the relationship are grounded in a philosophical framework of social constructivism.

[6] While it could be argued that the brilliance of a Nobel laureate is in the ability to make complex phenomenon understandable, it is rarely made truly understandable to the layperson.

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This dissertation makes the argument that deficits exist in teacher preparation because the interconnections of pedagogy and content necessary to develop strong and applicable pedagogical content knowledge are severed by the gulf between the culture of college science and teacher education, the dysfunctional relationship between those two cultures, and the dynamics of the larger system of science teacher preparation.

Research Questions:

To paint the picture of science teacher candidates' struggles with cultural dissonance the following questions are addressed.

1. What are the natures of college science and teacher education classroom cultures?
2. How do these two cultures compare and contrast with each other?
3. Is the difference between the classroom cultures of college science and teacher education a problem? If so, why and according to whom?
   a. Can these differences act as strengths? According to whom?
   b. How might problems of the dichotomy be minimized while benefits are maximized?

The Structure of the dissertation

Before giving an overall outline of the dissertation, I will note one apparent (but not actual) omission. In scanning the Table of Contents and the dissertation as a whole, it may appear there is no review of the literature. I chose not to make a literature review a stand-alone chapter because my use of the literature branched in multiple directions as I worked on the various problems associated with my research questions. The literature

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referenced in this dissertation is wide-ranging, some might say too wide-ranging. Before, during and after data collection, I read broadly. This ties to my conclusion that my role as a teacher educator is that of a generalist. There is a cost. By drawing from a variety of types of literature, it was not possible to go to the same depth I could have had I instead focused on a more obvious review of college science teaching, teacher education, teaching for understanding and pedagogical content knowledge. Benefits outweigh costs, however. I believe this dissertation portrays the system of science teacher education more holistically than most and offers insights into that system not possible in more narrowly focused research.

This broad focus ties not only to the literature referenced but also to the dissertation as a whole. Any of the three conceptual models described here could have stood alone as the conceptual framework for a dissertation. Any one of the data sources could have been the focus of a dissertation. Indeed, I began with a proposal using the first framework as *the* conceptual framework of the dissertation. As I collected my data and began to write about it (while still collecting more data) I found the Two Cultures framework interesting but lacking.

The relationship between the two cultures seized my attention, and I began to consider its importance. This led me to the second framework, which I eventually came to see in a similar light as the first: interesting, but lacking. Part of what led me to the third framework was my growing interest in, and reading about, environmental education, environmental issues, and systems thinking. I came to see more value in connecting these three models than writing a dissertation on a single one of them. I believe I have developed three conceptual models that are each useful in and of themselves but more useful when viewed collectively. I also believe the data collected analyzed along with the literature cited gives ample support to each model and lends credence to the conclusions derived from those models.

This dissertation is backgrounded by the idea that good teaching is rooted in the ideas of social constructivism. That is not to say that those who teach need to know the terminology used by educators to describe social constructivism, but that they must have at least an implicit understanding of learning as an interactive process and provide structures that facilitate the necessary kinds of interactions for students to learn the target material. In addition, to teach science effectively using a social constructivist model, deep understanding of science concepts is essential.

This kind of teaching has been described in several reform documents. The most relevant of those documents to this dissertation is NSF's *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology* (NSF, 1996). Lesser known, but also very relevant is OERI's *Issues of Curriculum Reform in Science, Mathematics, and Higher Order Thinking Across the Disciplines* (OERI, 1994). This includes a synthesis of literature on constructivism and defines constructivism as including the following:

1) Learning is dependent upon the prior conceptions that the learner brings to the experience.
2) The learner must construct his or her own meaning.
3) Learning is contextual.
4) Learning is dependent upon the shared understandings that learners negotiate with others.
5) Constructivist teaching involves understanding students' existing cognitive structures and providing appropriate learning activities to assist them.
6) Teaching can utilize one or more of several key strategies to facilitate conceptual change depending upon the congruence of the concepts with student understanding and conceptualization.

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7) The key elements of conceptual change can be addressed by specific teaching methods. "...To elicit and highlight the existence and nature of competing points of view" ((Pines & West, 1986), p. 595) cited p. 27.
8) Constructivism leads to new conceptions of what constitutes excellence in teaching and learning and in the roles of both teachers and students. Teacher changes from disseminator to facilitator (p. 28) "Students The role change from 'student-knowledge acceptor' in a transmission model of learning to that of 'student-knowledge constructor in the constructivist model of learning that requires students take an active role" (p. 31).
9) In constructivist teaching and learning, more emphasis is placed on learning-how-to-learn than on an accumulation of facts, creating a philosophy of content in which "LESS IS MORE." This understanding of (or bias toward) teaching and learning is the foundation upon which this dissertation is built.

Adapted from (OERI, 1994)

A related framework that informs this dissertation is an understanding of The Learning Cycle. This has been described in various ways, but I find the language used by Charles Anderson to be the most concise and comprehensible. His description is grounded in the work of Collins, Brown and Newman (Collins, Brown, & Newman, 1989) and defines the Learning Cycle as including the following steps: ① Establishing the problem; ② Modeling, how one works through the problem; ③ Coaching the learner; ④ Fading as the teacher removes him or herself from coaching; and ⑤ Reinforcement (Anderson, 1999).

Throughout the dissertation, I make references to my own changes in thinking and how one idea may have supplanted another. Changes in conceptual understanding occur as existing conceptions are drawn into question. The explicit sharing of my own conceptual change is intended not only to reveal my thinking process to the reader, but also to aid the reader in making their own conceptual change.

The first chapter lays out some of the initial understandings I had of the Two Cultures of science teacher education before I began this study. It is intended to establish the problem of the dissertation. I presented an earlier version of this chapter at the

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American Educational Research Association meeting in 1998 (Duggan-Haas, 1998). It is derived primarily from interview data from the Salish Project. It lays out some findings from the Salish Project, and describes that project briefly. Again, my work as a graduate assistant for that project was the genesis for this dissertation.

The second chapter describes the methodology used for the new data collection for this dissertation. It tells of how and why I went about collecting the data I collected. It answers questions about what classes I chose to focus on, who I chose to interview and not interview, and the descriptions of what it was that I did to collect and analyze data for this work.

The third chapter describes what I saw in my classroom observations. The fourth chapter describes what the college seniors who were about to become science teachers had to say about their teacher education program. Chapters three and four include both science and teacher education classes.

Chapter 5 looks at an approach that promises to reduce some of the problems rooted in the problematic relationship of college science and teacher education. It is a case study that begins to look at the actual relationships among scientists, mathematicians and science and math educators. Up to this point in the dissertation, the relationships are either suppositions or the relationships as seen by the students among their classes (not among their professors). Chapter 5 offers a glimpse of direct interactions between scientist and educators.

Chapter 6 reshapes the conceptual lens described in Chapter 1 to look at the relationship between college science classes and teacher education classes rather than identify the differences between them. The locus of analysis moves from the individual

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cultures to the relationship between those cultures. Chapter 7 expands and complexifies the ideas of Chapter 6 by identifying and describing the larger system of science teacher education. Here the locus moves again from a single relationship to a more systemic[7] view of multiple relationships. In both of these chapters, I move beyond the description that fits neatly into the Two Cultures framework and develop deeper explanations of the problems associated with the tensions between and among aspects of the program.

Chapter 8, the final chapter, explicates why the issues raised in this dissertation matter. It identifies reasons for hope and apprehension about the success of reforms targeting college science teaching and secondary science teacher preparation. It includes strategies that offer hope for small scale, localized change and why successful large-scale national change may continue to be profoundly difficult and excruciating slow.

The Tone of the Dissertation

This dissertation is written in an informal tone. This may put off certain readers, but I believe it will make the dissertation accessible to more people than it will drive away. It will also become clear to the reader that I hold the lecture method of instruction as a primary method in great contempt. It might even be fair to say that I am openly hostile to the lecture method. Some undoubtedly will see this as bias. Perhaps it is, but is bias grounded in substantial research. The lecture method does "work" for a minority of students, but it has never worked very well for most students at any level. While lecture has a role in classrooms, it is a limited role. Using lecture as the *primary* method of instruction is inappropriate at any level.

[7] I use systemic in the biologic sense, with parallels to ecosystems. This is importantly different from how

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The American Association for the Advancement of Science, The National Research Council and The National Science Foundation all have published important work that back this claim (AAAS, 1989, 1993; NRC, 1996; NSF, 1996). Indeed, NSF states their goal emphatically:

> **All students have access to supportive, excellent undergraduate education in science, mathematics, engineering and technology, and all students learn these subjects by direct experience with the methods and processes of inquiry.**
>
> America's undergraduates – ***all*** of them – must attain a higher level of competence in science, mathematics, engineering and technology.
> (NSF, 1996) p. ii (emphasis in original).

While some apparently believe that science classes "weed out" students who are not capable of doing science, it appears that the nature of teaching in science programs discourages people who are capable of doing the work but put off by the nature of the teaching (Seymour & Hewitt, 1997; Tobias, 1990). It seems likely that some of the discouraged, those who Seymour and Hewitt refer to as switchers, would make good teachers.

My openly hostile tone is clearly unorthodox for a dissertation. It is my hope that a somewhat unorthodox approach will have greater impact than the typical, more gentle (and I think less interesting) approach. If you are reading this as a scientist who teaches and you find this inflammatory, fine. All I ask is that you consider the data that you have about the effectiveness of your approach. Consider alternative hypotheses for test scores beyond good score = understanding; bad score = misunderstanding. I recognize there are constraints for the scientists who teach and address this in Chapter 6. I invite the scientists who teach to identify the constraints and work around them or work to change

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this term has been used elsewhere in education, including the NSF funded systemic initiative programs.

them. My approach makes no pretense that I am unbiased and acknowledges that all research has bias regardless of whether the researcher acknowledges the bias or not.

The reader should also remember that the study setting is *not* a typical science teacher education program. Midwestern University's Teacher Education Program is recognized nationally as exemplary. This reputation is grounded in the College of Education, not the College of Natural Science. The education courses are atypical for a large university and the science courses appear to be typical. My apparently critical take on the science courses contrasted with a comparatively favorable portrayal of the education courses is in line with what others have said about exemplary teacher education programs and typical university undergraduate science courses.

The teacher education program at Midwestern University has benefited from years of thoughtful redesign and the hard work of implementing that redesign. Nothing on a comparable scale has occurred in science at Midwestern so the reader should not expect as favorable a portrait. In spite of this, the teacher education program is far from perfect. As stated at the beginning of this overview, science teachers fail to meld their science and pedagogical knowledge into a coherent whole that is in the form which research indicates is appropriate. The onus of responsibility for helping teachers make this integration is on the education faculty. Herein lies the problem of science education at all levels: teachers typically fail to successfully integrate content understanding with pedagogical understanding so that all their students will come to understand science in a deep and meaningful way.

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CHAPTER 1

TWO PROGRAMS, TWO CULTURES: THE DICHOTOMY OF SCIENCE TEACHER PREPARATION

> "The test of a first-rate intelligence is the ability to hold two opposed ideas in the mind, at the same time, and still retain the ability to function."
>
> F. Scott Fitzgerald as quoted in Trilling 1945 essay reprinted in *The Liberal Imagination*

> Teachers differ from biologists, historians, writers, or educational researchers, not necessarily in the quality or quantity of their subject matter knowledge, but in how that knowledge is organized and used. For example, experienced science teachers' knowledge of science is structured from a teaching perspective and is used as a basis for helping students to understand specific concepts. A scientist's knowledge, on the other hand, is structured from a research perspective and is used as a basis for the construction of new knowledge in the field.
>
> Cochran, King, and DeRuiter (1991, p. 5)
>
> Second quote excerpted from Veal & MaKinster (1999)

This chapter establishes the problem for the dissertation and was generated through my work in the Salish I Research Project. It draws from data collected from science education graduates of nine universities. The primary Salish data source relevant to the dissertation was the New Teacher Preservice Program Interview. The interview protocol is included as Appendix B.

The data for this chapter was collected and analyzed before the work of the rest of the dissertation and it was a catalyst for the bulk dissertation work. In short, the work of the nature of ...

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this chapter establishes the problem of the dissertation. It reveals my earlier thinking about the nature of science teacher preparation[8].

Throughout the dissertation, I refer to classroom cultures and to academic cultures. I also refer to classroom climate. These terms are not synonymous. Culture refers to a broader context than climate. When I refer to climate, I am referring to what happens in a particular class under tutelage of a particular instructor, the prevailing conditions or set of attitudes in that classroom. A culture includes peoples acting in many different climates, though there are typically similarities running throughout the climates that are included within a culture. The culture is the totality of the socially transmitted behavior patterns, beliefs, institutions, and all other products of the relevant community. The climates in upper and lower division courses within a college may be quite different, but each course, and the climate of each classroom, contributes in a different way to shape the culture[9].

Background

As science teacher candidates move through their teacher preparation programs, they move between the meritocratic, masculine culture of their science classrooms and the democratic, feminine culture of their teacher education classrooms. Both cultures attempt to win the allegiance of the teacher candidate. Furthermore, the keepers of the culture of the college science classroom intentionally distance themselves from education in general and teacher preparation programs in particular. This chapter describes the

[8] As noted in the overview, I include mentions of changes in my understanding in hopes that this will guide the reader in their understanding.
[9] This relates to the linearity of teaching methods mentioned previously.

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rivalry between science and teacher education by describing and contrasting the nature of the two cultures that were defined by distilling the interviews of new teachers in the Salish I Project.

C. P. Snow's timeless work, *Two Cultures and the Scientific Revolution* (1959) inspired the framework I employ in this chapter. In *Two Cultures,* Snow described the growing rift between the academic cultures of science and of the humanities. Such a framework suits the cultures of the college science *classroom* and the college teacher education classroom. It is important that I stress neither of the cultures I refer to are the same, or even particularly similar too, the cultures that Snow wrote about. He addressed how academics work and speak with each other. I am addressing how academics work with and speak to their students.

In this chapter, I portray these two cultures through a series of three contrasts between the culture of the science classroom and that of the teacher education classroom: ① "Weeding out" vs. Nurturing; ② Meritocratic vs. Democratic; and ③ Masculine vs. Feminine. These three contrasts are obviously overlapping; the first two contrasts, in fact, combine to make the third. I will also draw conclusions on the impacts the dichotomy has on the preparation of science teachers and discuss differences in the levels of risk and ambiguity of the two classroom cultures. Before laying out the contrasts, I will give a very brief overview of my own background which may be useful in understanding this paper, followed by a brief introduction to each culture.

As a graduate student in teacher education I had worked on the Salish I Research Project researching the relationship between teacher education programs and the way new science teachers teach. Prior to entering graduate school, I taught high school Earth

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science and physics for eight years. I began my undergraduate work as a dual major in a 3-2 program in physics and engineering. Halfway through that program, I changed to a straight physics major with a minor in education. The descriptions and contrasts that follow use my background in teaching and teacher education as a lens to focus on college science teaching.

Here I have adapted C. P. Snow's framework of two cultures (Snow, 1959) to describe the largest portions of science teacher candidates' college classroom experiences. There are of course, more than two cultures. Field biologists speak and work very differently from theoretical physicists in their research, but what they do in the classrooms where they teach is remarkably similar to each other and remarkably different from what is going on in teacher education classrooms on the same campus. Teacher educators behave like teacher educators. Scientists who lecture act like scientists who lecture. Within each set of classrooms (that is, within each culture), "...without thinking about it, they respond alike. That is what culture means." (Snow, 1959, p.11)
In comparisons across several universities, striking similarities were found in the way science is taught. Two studies, each describing several universities' science programs, are referenced extensively. The Salish Project involved nine universities and their recent graduates in science education[10]. The second study referenced is Elaine Seymour's and Nancy Hewitt's study of why science, mathematics and engineering (S.M.E) undergraduate majors change majors at a higher rate than most other undergraduate majors.

[10] Some universities also included recent graduates in mathematics education.

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Seymour and Hewitt's book, *Talking About Leaving: Why Undergraduates Leave the Sciences,* chronicles their ethnographic study of 335 undergraduate students who switched from S.M.E programs as well as students who stayed in S.M.E programs at seven colleges and universities. The study design included slightly more switchers (54.6%) than non-switchers (45.4%) and women and minorities were intentionally over-represented in the sample. All participants scored 650 or higher on the mathematics portion of the SAT. The seven universities were chosen to represent a cross section of the types of universities teaching future mathematicians, scientists and engineers. Four public and three private universities were included, varying in size and in the nature of their students (Seymour & Hewitt, pp. 25 - 27). Again, the purpose of the study was to determine why S.M.E students change majors at higher rates than undergraduates in most other disciplines. In making this determination, Seymour & Hewitt describe the culture of the typical college science classroom and also factors counter to that culture that seem to encourage students to stay in the S.M.E pipeline.

I was only able to find one large-scale study that looked at the culture of teacher education classrooms -- the Salish I Research Project. The Salish Project was an exploratory study involving nine universities and their recent graduates in secondary science. Here, the project goal was to explore the nature of the links between teacher education programs, the way new science teachers teach and the outcomes of their students. This involved both teacher candidates and college faculty in both science and teacher education describing the coursework in their programs. An underlying assumption of the study was that both science and education faculty are teacher educators. Like Seymour and Hewitt's work, this study described the culture of the

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college science classroom. It also described the culture of the teacher education classroom. I worked on the Salish I Project for the two and a half years.[11]

In the Salish I Project all participants were volunteers. What might that mean? It seems reasonable to assume that volunteers for such a study would be more aligned with the culture of teaching. The culture of science is not known for its respect of either qualitative or educational research. If new teachers subscribe to the culture of science, they may wish to have no part of such a project. Certainly, by using volunteer subjects, the data do not reflect the total population of new science teachers in every aspect. I know, from experience as a research associate for the project, that those who dropped out of the study (at least at Midwestern University) were less likely to have valued their teacher education coursework. This is important to keep in mind as the reader evaluates the conclusions drawn in this chapter.

Describing the Two Cultures:

Both *Talking About Leaving,* and The Salish Project describe striking similarities in the teaching of science and the broader culture of college science programs across the universities in their respective samples. In college science classrooms, it is common place that students are lectured to, competition is fostered and collaboration is discouraged. Little support from faculty is available or encouraged (Seymour & Hewitt, 1997, Duggan-Haas, 1997). In teacher education, according to Salish findings, instructors generally attempt to foster a classroom community by requiring collaboration and discouraging competition. Students work in groups and are supported affectively by their

[11] The Executive Summary of the Salish Final Report, *Secondary Science and Mathematics Teacher Preparation Programs: Influences on New Teachers and Their Students,* is on the World Wide Web at <http://ed-web3.educ.msu.edu/cvsme/original_cvsme/salish.htm>.

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Table 1.1: Two Progr

professors. (Duggan-Haas, 1997; Salish, 1997) The dichotomy is very real here and those who are familiar with both cultures instantly recognize the contrast.

Table 1.1: Two Programs, Two Cultures

It is little surprise that students see little relationship between their science and Teacher Education course work. It seems that every instructional characteristic of one program is reversed in the other. Unless otherwise noted, quotations are taken from New Teacher Interviews of Midwestern University graduates.

Characteristic	Science	Teacher Education
Course Instruction	Lecture, "...mostly lecture. Not much labs, not great labs when we had them."	Group work/discussion, "I would say a little bit of everything besides lecture."
use of lecture	Frequent	Rare
use of cooperative learning	Rare	frequent
class-size	large	small
Program purpose/goals	Goals are well-defined and understood: content dissemination; to learn facts	Goals are poorly defined or understood. Many different goals are identified.
Textbook use	Common	uncommon
Instructional Resources	Textbook	Readings — collections of articles also occasional videos
Methods of assessment	objective tests, mostly multiple-choice	written work before the internship, written work along with teaching performance during the internship.
Teacher-Student relationships	"By far, the commonest words used to describe encounters with S.M.E. faculty are 'unapproachable,' 'cold,' unavailable,' 'aloof,' indifferent,' and 'intimidating.'" (Seymour & Hewitt, p. 141)	personal; "Excellent," was a term used by half the participants in the national sample to describe the faculty-student relationship in the Salish study.
Program components valued by new teachers	Research or research like experiences – In the original Salish study, two new teachers graduated from Midwestern U reported such experiences; one as a volunteer, the other at a different institution. In most cases, these experiences were outside the formal program.	The full-year internship; the sequence of courses in Teacher Education related to their subject matter. In all cases, these experiences were part of the formal program.
Partial Summary		
Classroom culture's relation to professional work	Undergraduate science courses do not generally reflect the work of scientists. Unfortunately, they may reflect the work of science teachers.	Undergraduate teacher education courses reflect what teachers should do (in the opinion of teacher education faculty) in their own classrooms.

(Adapted from Duggan-Haas, 1998)

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Table 1.1 shows a comparison of science classroom culture and teacher education culture that was created primarily from Salish data. Seymour & Hewitt support Salish's conclusions about the science classroom culture. Table 1.1 is derived from new teacher responses to questions on the New Teacher Interview. Teachers were asked a series of nine questions about their college science courses and then asked a series of nine questions parallel in structure regarding their teacher education courses.

On at least some level, both cultures "work." While it is true that more S.M.E. majors change their major than in other fields (a little more than 50%), we do not have a shortage of mathematicians, engineers or scientists, regardless of what some report in the popular press. In fact, there is a surplus of the most qualified members of these professions (Shamos, 1995, Seymour & Hewitt, 1997). Likewise, there is no real shortage of teachers (Shamos, 1995). However, as Linda Darling-Hammond notes, too many -- about half -- of middle school and high school science and mathematics teachers do not have degrees in the subjects they teach (Darling-Hammond, 1997). Of course, there have been volumes upon volumes written portraying the dire state of schools and teacher education in modern day America (see, for example, National Commission on Excellence in Education (1983), Lanier & Little (1986) or Hirsch (1996)). There have been some well thought out critical responses to these pieces (see, for example, Berliner & Biddle (1995) and Labaree (1996)).

On Science

The problems that Seymour and Hewitt describe and on which I concur are not seen as problems by all who teach science at the college level. The consequences of fixing these "problems" are difficult to predict. This analysis will lead to some informed knowledge of p

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speculation in this regard, however. When viewed from a perspective that is built upon some knowledge of pedagogy, it is very difficult to classify the current state of affairs as the way it ought to be. Several studies of tertiary science instruction have found fault. Smaller class sizes, and higher faculty-student interaction (monitoring, advising, counseling, involvement in faculty research) are methods that have shown to improve teaching and increase retention rates of students in science. These studies include the Office of Technological Assessment reports of 1988 and 1989 and Porter, 1990 (in Seymour & Hewitt, pp. 6 - 7, 1997).

The most common problems stated by S.M.E students in Seymour & Hewitt were:

- lack or loss of interest in the disciplines which comprise S.M.E. majors, which ranked first (43.2%) among the reasons for switching, and was mentioned as a concern by 59.6% of all switchers and by 35.5% of non-switchers
- a non-S.M.E. major is seen as offering a better education, or more interest, which ranked second (40.4%) among reasons for switching was mentioned as a concern by 58.5% of all switchers, and by 31.6% of non-switchers
- poor teaching by S.M.E. faculty which ranked third (36.1%) among the reasons for switching, was mentioned as a concern by 90.2% of all switchers, and by 73.7% of non-switchers

(Seymour & Hewitt, p. 145)

As reflected above, problems that motivated switching were generally also recognized by students who did not switch majors. Seymour & Hewitt refer to this as the "problem iceberg." The problem is shown in students leaving S.M.E majors, but it lurks under the surface for those who remain. Notice the near unanimous concern about poor teaching among the switchers and non-switchers alike. It seems likely that these are not separate problems, but rather tightly intertwined. Poor teaching is perhaps a cause of both the lack of interest identified as the most common cause and clearly related to the

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second most common cause - better education available in non-S.M.E. majors. These problems of pedagogy are an integral part of "weeding out" students.

THE CONTRASTS:

① "Weeding out" vs. Nurturing all the flowers, weeds or not:

> "They do the usual speech: 'Look to the right of you; look to the left of you. Forty percent of you won't be here next year.' I think that's the standard speech at every university." (Male Black engineering non-switcher)
>
> (Seymour & Hewitt, p. 123)

As we go about cultivating future science teachers, we begin by planting them amidst students with a wide variety of career goals. In their introductory science classes, they sit among others who wish to become doctors, engineers, scientists and more. Indeed, many who become teachers begin college with other career aspirations.[12] Immediately, the science department or college structure begins to "weed out" large numbers of these scientifically inclined undergraduates.

The phrase "weed out" is common place in the vernacular of college and university S.M.E. students throughout the U.S. It is, however, a poorly chosen term for the process it describes. Weeding is selective. Weeds are removed from gardens because they do not hold the same promise for production as the plants that were intentionally planted. In *Talking About Leaving: Why Undergraduates Leave the Sciences,* Seymour and Hewitt conclude that weeding out reduces numbers in the S.M.E garden, but it does so indiscriminately. The students who change majors, the "switchers," from S.M.E. are

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just as likely to be qualified and successful in their coursework as those who stay in S.M.E. The quote at the beginning of this section is reflective of stories told on many campuses. It matches well with what I was told in my first undergraduate physics lecture. It does not encourage students in S.M.E.; it uniformly and indiscriminately discourages.

This traditional opening line of the first science lecture has multiple explanations. It communicates the common belief that few individuals are, "born scientists." It contributes to the reduction in student numbers in the courses and programs which, on most campuses, could not be supported from freshman year through graduation if there was no attrition or minimal attrition. The speech reflects that the purpose of the course is not education, but rather selection (Seymour & Hewitt, p. 394). It begins the hazing portion of the indoctrination into the culture of science. It is, in effect, the signal that pledging the fraternity of science has begun. In some ways, this hazing is crueler than fraternity hazing in that it not only demoralizes; it also denies mutual support.

For those who survive the hazing portion of the indoctrination, life gets better. In upper level courses, group work is often encouraged. The luckiest (or most ambitious) of students work on research projects with faculty. Those who complete research are far less likely to be switchers. And they are far more likely to like and respect science faculty (Duggan-Haas, 1997; Seymour & Hewitt 1997, p. 147). Hazing is discussed further in sections ② and ③.

In contrast, students in teacher education are nurtured, at least until they student teach. While many people believe there are natural born teachers, if teacher educators believe this it is not overt in their teaching. As a general rule, instructors in teacher encourage

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education encourage, not discourage. Weeding out may occur (and perhaps should occur more) but it is not indiscriminate. People are not encouraged on the first day of course work to change their majors! Interview responses in the Salish Project indicated that students believed their professors in Teacher Education were approachable and those in science were unapproachable. (Again, see Table 1.1.) Students were also encouraged to form support networks with their fellow students by working together on much of what they do in class and, to a lesser degree, out of class.

This situation may be reversed in the world of work. New teachers generally have the same responsibilities on the first day of school as veteran teachers, with little support in handling those responsibilities. If the new graduate instead goes to work in industry, they are typically further trained and responsibilities are developed over time.

Selection is not a primary purpose of the coursework in Teacher Education. Coursework is intended to instruct, to educate, to prepare students for the world of work. Teacher education is vocational, unlike much of science and mathematics education.[13]

Poor teaching in science is rewarded on multiple levels. This is not to say, however, that science instructors intentionally (or universally) teach poorly. But it diminishes incentive to teach well. If a professor teaches poorly, fewer students will come to his or her course and more will drop the course, reducing the paperwork load. In the longer term, the loss of numbers in the program matches the structure of the program. This alignment is the result of program evolution. If students did not drop out in large numbers, resources for upper level courses and labs would be overwhelmed. Poor teaching is also considerably easier than good teaching. Through student interviews,

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[13] I have intentionally omitted engineering here, as engineering students are more likely to be involved in vocational training including actual work in industry as part of their bachelor's degree program.

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Seymour and Hewitt found that some science professors, on at least four of the seven campuses involved in their study, taught by reading directly from the text book as their *primary* method of instruction! (P. 154). This means that preparation for teaching is virtually non-existent for these professors.

The harsh nature of curved grades also contributes to weeding out. It is not unusual for a 50% exam score to be a C or even a B after grades are curved. Receiving a 50% grade can be a severe ego shock to students who were often among the best in their high school class[14]. The above raises several important questions. Is boring, uninspired teaching rewarded? Are poor assessments of understanding rewarded in ways not tied to their explicit purposes? Is the lack of teacher-student interaction rewarded by students dropping from science programs?

Seymour & Hewitt were unable to identify good indicators of what made one student more likely to switch out of S.M.E than another student. Switchers were about as likely to have good grades or poor grades as non-switchers were. Switchers were more likely to be critical of their science teaching and less likely to have developed ways of coping with the stresses of their science coursework. One method of coping more common among non-switchers is collaborative group work in the form of study groups.

The above implies that the students who switched were just as capable of "doing science" as those who stayed. It also implies that switchers are more concerned about quality teaching. Putting two and two together indicates that the process of weeding out discourages some of the best potential science teacher candidates from becoming teachers as an S.M.E. degree is generally required to teach science.

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[14] It is important to note that while curved grades were widely reported in Seymour and Hewitt's study, it did not appear to be common practice at Midwestern University.

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② Meritocracy vs. Democracy:

Though the weeding out process appears to be indiscriminate based on ability, this is not widely recognized within the college science classroom culture. An uncritical look at weeding out would lead to the conclusion that only the strong survive. It may be true that some of the strong survive, but some of the strong leave too. A more critical analysis might lead one to conclude that the brightest recognized a poor learning environment and intelligently sought a better education elsewhere. The culture of science is meritocratic in belief, but it is not so clear that it is meritocratic in practice.

Again, the process of weeding out is a hazing process. It forges a bond between those who survive it and it is their entrée into the culture. Weeding out serves to *indoctrinate* students into the culture of college science. It is far less clear that it helps to *educate* these same students about science. Hazing does not make one smarter or even more knowledgeable. Hazing induces a feeling of superiority. Ask any frat man which fraternity is the best on campus or any serviceman which branch of the armed forces is the best and you are most likely to hear that the organization to which he belongs is the best. Is the primary purpose of the weed out courses to educate science students or to select those who should continue? Both the means and ends in this process are suspect.

Students, switchers and non-switchers alike, complain of not understanding the material taught in the introductory courses. This material should be fundamental to understanding what happens in upper level courses. The true, deep understandings of the fundamental aspects of a science seem unlikely to be learned in the introductory courses. But surviving the weed out courses allows one to *feel* superior in intellect.

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Weeding out is counter to much of what is taught in teacher education classes today. It is commonplace in teacher education to speak of educating *all children*. In fact, it is the foremost goal of *The National Science Education Standards* (NRC, 1996). If teacher educators weed out many students, they not only fail to model this core belief, but act in direct opposition to it. I have said that weeding out in science courses tends to be indiscriminate. This appears true based on ability, but it is not true based on gender or skin color. White males dominate the culture of college science classrooms. Weeding out disproportionately effects men of color and all women (Seymour & Hewitt, p. 132). Conversely, teaching has long been the professional work most open to men of color and especially to women.

The culture of the college science classroom is an elitist, market model while the culture of the college teacher education classroom is an egalitarian, democratic model. Teacher's colleges are the people's colleges. They are accessible to a large portion of the populace, and what is accessible is much more than entry into the programs. Successful completion of the programs is genuinely attainable. The same could hardly be said of science programs. While entry into S.M.E programs is achievable, exit from it with a degree only comes in a minority of cases.

The discrepant goals of college science and teacher education are discussed in more depth in Chapter 6. This discussion uses Labaree's framework of conflicting educational goals (Labaree, 1997) to explain one aspect of the dysfunctional relationship between college science and teacher education.

Giving sharper, perhaps more legitimate, definition to the meritocracy of science are those individuals who seemed to intuitively grasp abstractions which other students

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could not seem to "get it" no matter how much effort was put forth. These individuals were described on all seven of the campuses in Seymour & Hewitt's study, but they did not come close to dominating the non-switchers in numbers. They did serve to frustrate their fellow students by making the meritocratic nature of science painfully obvious, however. The existence of these curve-wrecking individuals goes counter to the democratic norms of education instilled in most students before arriving at college. Failure in grade school is seen not as a result of lack of ability but rather a lack of effort. This belief is carried on into college (Seymour & Hewitt, pp. 101 - 102). And it is reinforced in colleges of education. After all, *all* children can learn (at least this is a dominant belief in those colleges of education)!

In the marketplace, grades in the two cultures have very different meanings. In the market driven, competitive world of science, grades matter. Grades are a commodity that buy admission to grad school (Labaree, 1997). Good grades may be awarded with future scholarships (this is true in teacher education, too but to a much lesser degree). In teacher education, on the other hand, it is common for students to be told that grades do not matter. And it's true, at least to some degree. The more valuable commodity in the education marketplace is the letter of recommendation. Without good letters of recommendation from collaborating teachers and field instructors, starting teachers are at tremendous disadvantage in their job searches, even if their grades are outstanding. This means that there is currency – meritocracy – in teacher education but it is somewhat less blatant.

The valued letters follow the trend of teacher education where assessment is generally far more qualitative throughout the program when compared to the science

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program. In the heated competition of science coursework conversely, the curve is king. (Again, this does not appear to be the case at Midwestern.) The curve must be beaten to stay in the game. Beating the curve may mean breaking 55% on an examination (and the examination is likely to be objective and probably multiple choice). It means being driven to do better than your classmates. Adjusting to percentage scores in the range associated with curved exams is often difficult for students to do. The need to do better than average is also often a difficult adjustment. The idea that collaboration is cheating is also a difficult shift in mindset from high school where cooperative learning is becoming more and more commonplace.

The competitive nature of science classes is illuminated well and some potential consequences are hinted at in the following quote from a male Hispanic engineering switcher:

> "The first two years here, all you think about is hoping you do better than everybody else -- actually, you hope that everybody else fails... It's bad. It breeds competitiveness and singles out certain kinds of people to succeed, as opposed to other more gentle types of people -- *people* people. (Seymour & Hewitt, p. 120)

Again, we see that the requirements of science programs that derive from the competitive culture may be chasing away some of the best science teacher candidates. The characteristics of assessment in science -- that it is individualistic and highly competitive -- are starkly different from assessment in teacher education. In teacher education, group projects are common. Assessed activities are generally term papers and written projects. Rarely are they objective tests (Salish, 1997). Collaborative group work is not only encouraged, but it is often an integral part of in-class work and not unusual for homework assignments. Curving grades is non-existent or virtually non-existent.

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The culture of college science classrooms encourages the solitary endeavor and you must be strong, perhaps even manly, to carry out the endeavor. Science is seen as hard and only those with great ability, with merit, can be successful. Teacher education courses, on the other hand, are rarely seen as difficult (at least by those outside the culture). The collaborative work going on within them reflects a belief that "we're all in this together." George Bernard Shaw's oft repeated words, "He who can, does. He who cannot, teaches" (Andrews, 1993), reflect the perception of teaching held by many. *Anyone* can teach. Teaching is commonplace. Science is prestigious. Even within education, teaching is often degraded, and degraded for not being scientific enough. See the scientistic teacher bashing of Lanier and Little, for example (1986).

Not surprisingly, teaching as a career choice is frowned upon within the culture of science. Many of the non-switchers in Seymour & Hewitt's study who planned to teach kept it from their science professors because of widely held beliefs that professors defined such ambition as deviant from the culture and that science professors withdraw from students who openly express an interest in teaching (p. 200). Disapproval comes not only from professors, but also from peers and parents. Detractors note that teaching requires additional preparation to make less money and have less prestige.

Students of color were the only S.M.E seniors who reported encouragement from science faculty or professional advisors to teach (p. 201). The most cynical part of me sees this as subtle racism -- preserving the white male domain of real science by shooing those perceived as "undesirables" into the lesser field of teaching. More optimistically, I am hopeful that it is the result of a recognized need for more positive minority role models in contact with children.

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Twenty percent of the 335 students in Seymour & Hewitt's sample considered teaching as a career. Eight percent were actively pursuing teaching credential or planned to do so. The stamina of this eight-percent is impressive in the face of the opposition of their science professors. Of course, they have been made stronger by surviving the hazing process. How many more would be pursuing teaching careers if it were not for the opposition of these professors?

Some of the twenty percent may eventually find their way into classrooms as teachers and others may develop an interest in teaching after working in industry. If they enter teaching through the back door, through alternative certification programs, they may embrace the teaching model for science that they know best, their college science coursework. Salish data indicates that when alternative programs offer support to teachers only after they are placed in the field as employed teachers, the teachers tend to teach didactically. Seymour & Hewitt indicate that teachers in alternative programs without support often have severe problems with classroom management and often do not last long in the classroom.

The future workplaces of S.M.E. majors, for both teachers and non-teachers alike, stands in interesting contrast to the cultures of their college classrooms. Scientists, mathematicians and engineers, when they reach the world of work, are likely to move from the competitive, solitary work of their undergraduate experience to working on design or research teams. They are now placed in situations where they are rewarded for collaborating when they were punished for doing so as undergraduates. The teams they form, of course, may be highly competitive with other teams, but in order to be successful, they need to collaborate well together within each team. And teachers?

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Teachers go from collaborating with their classmates to the solitary life of a teacher, functioning as the sole adult, the sole professional, behind the door of their classroom. Hopefully, they facilitate the collaboration of their own students, but it is fairly unlikely that they work with other adults in teams the way their counterparts in the "real world" of science, engineering and mathematics. Some middle school teachers, fortunately, do work in meaningful teams. Unfortunately, some work in teams that are teams in name only.

As teacher candidates begin the transition from student to teacher in earnest, they too go through a hazing process – student teaching. This common, nearly universal indoctrination process has been the initiation into the teaching field for over one hundred years, since normal schools offered teaching experience in the affiliated practice schools. And for over a hundred years, critics have been puzzling and grousing about the slow rate of change in K-12 education. Here's a news flash: student teaching is a major obstacle to systemic school reform.

The selection process for mentor teachers is incredibly variable. In some districts, administrators decide what teachers can have a student teacher. Sometimes this is done with an eye on who can best aid in the preparation of a new teacher; sometimes with an eye to what teacher needs help in the classroom. Even in good teacher education programs, the bureaucracy of schools can foil the best intentions of program designers. Of course, it can be argued that teachers can learn a lot about teaching well in virtually any kind of classroom – in troubled classrooms, they simply learn what not to do. This may be true, but it is also fundamentally flawed pedagogically. If the learning cycle is the way in which people learn, then future teachers deserve good models of quality among Wideen, Ma

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teaching. Wideen, Mayer-Smith and Moon in their meta-analysis of learning to teach research found that generally the student teaching experience fails to yield the desired outcomes (Wideen, Mayer-Smith, & Moon, 1998).

③ Male vs. Female:

From the preceding contrasts, it is not hard to see that the culture of the college science can be described as a male culture while the culture of the teacher education classroom can be described as female. It is not terribly shocking, either. It is not unusual for students to complete a science or engineering degree program without having contact with a single female professor in their program. Teacher education was among the earliest departments to have female faculty and science (other than biology) is among the last. Science is a fraternity with hazing -- the weeding out process -- that at first glance appears to be discriminatory based on ability to *do* science. S.M.E. majors are more likely to change their major than majors in other fields, but women and people of color who are S.M.E. majors are even more likely to change their major than are white males.

Like in the broader culture of science, one viewpoint is recognized as being the correct one in the culture of the college science classroom (Harding, 1991). The objective tests are perhaps the most powerful indicator of this. In teaching, however, multiple perspectives are acceptable, even desirable. Nurturing, mutual support and collaboration are valued, not individualism and competition. The profession of teaching was the first to be feminized -- over a hundred years ago. It is also the first profession to include people of color on a large scale. Teaching is inclusive while science is exclusive.

The culture of college science is often hostile to the culture of teacher education while the culture of teacher education is often envious of the culture of science. This group is shown by th

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hostility is shown by the active dissuasion by science faculty of their students away from teaching, as Seymour and Hewitt describe. The envy is evident in writing like that of Lanier and Little (1986). Science teaching has been seen as a craft, not a science. This contributes to its "female" quality. Efforts to make it more scientific, especially at the elementary level have been met with great opposition.

This section is the shortest of the three in this chapter because it synthesizes what precedes it. To repeat the above within this context is unnecessary. The rift between the cultures is deep, wide, and independent of the taxonomy used for classification for all intents and purposes.

Risk and Ambiguity

When new teachers were asked in the Salish New Teacher Interview to describe course objectives those in Teacher Education were described and classified using an entirely different vocabulary from the objectives described for science courses. While there were six overarching categories of responses about objectives in science, there were 16 in Teacher Education (see Table 2). This is not a result of using a finer toothed comb to sift through the Teacher Education objectives. The responses in regards to Teacher Education objectives were far more diverse. When new teachers were asked about the objectives of their science classes, the majority included factual knowledge and almost half included lab skills. Other objectives were not stated at nearly these percentages. For Teacher Education, no response code received as much as 25%. The objectives in teacher education are less defined to the new teachers. I interviewed ten of these individuals for the Salish project and seven more for the dissertation study and they often are at a loss as to stat

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were at a loss as to stating objectives for teacher education, but they had no real problem identifying objectives for their science courses. This difference again speaks to the existence of two cultures. In science courses, the objectives are clearly recognizable. In teacher education the objectives are muddled by their numbers. It is impossible to focus on a dozen (or dozens of) targets simultaneously.

Table 1.2 is based on responses in the New Teacher Interview to the following questions, "How would you describe your typical science course?" and, "How would you describe your typical teacher education course?" For both questions, interviewers were expected to probe for "types of objective, e.g., certain knowledge, specific skills, attitudes towards science." For the question relating to teacher education courses, the probe was also to include attitude toward teaching secondary school students (Salish, 1997b). The sample consists of 70 new teachers from eight universities (one site lost its tapes and transcripts).

Some of the goals of teacher education courses described by the new teachers could be categorized as factual content knowledge (e.g., human development or psychology of teaching and learning) or skills (e.g., classroom management), however, there is more interdependency among the goals stated in teacher education. Many of the goals identified for teacher education can be described as developing certain attitudes (e.g., those addressing teaching as a profession). This was not the case for science classes. new teachers tended to identify more than one goal for both sets of courses.

The learning goals of science courses are both clear and rigorous. In teacher education, the goals appear to be neither clear nor rigorous. While it seems clear that rigor is a virtue, it is less clear that clarity of objectives is a virtue. The new teachers who readily ident

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could not readily identify the objectives of their teacher education courses did not seem proud of this ambiguity in their preparation. However, Walter Doyle (1986) makes a persuasive argument that workable solutions in the professional workplace are rarely unambiguous and that it is problematic that professional preparation (i.e. college coursework) is unambiguous. Doyle argues that rigorous courses tend to focus on memorization and not understanding - they are high risk with low ambiguity, while less challenging courses often focus on opinion rather than understanding. Neither portion of the program, science nor teacher education, seems to be likely to bring about understanding, but for quite different reasons. Science courses seem to fit Doyle's model of courses that are unambiguous and challenging, while teacher education courses are more likely to be ambiguous and easy.

These different approaches might seem to be complementary - one section of the science teachers' preparation is challenging and unambiguous and the other is ambiguous and unchallenging. This mixture does not, however, make for professional preparation that appropriately balances risk and ambiguity. That balance needs to occur within each class, not among several of them.

Through these differences in risk and ambiguity, these two portions of teacher education programs certify unprepared individuals. The science portion of the program is recognized as selective based upon ability, but Seymour and Hewitt demonstrate that may not be so. The education portion has long been recognized as being too inclusive and non-discriminatory based on ability.

Goals for science courses	% responding
1. Content Knowledge	
factual	72
conceptual	19
application	22
other	7
2. Skills	
laboratory	49
algorithm & formula use	0
problem solving	12
other	4
3. Nature of Science	1
4. Science, Technology & Society	3
5. Interest/prepare students	
for upper courses	
for graduate school	0
other	13
6. Enjoyment of science	12
7. Other	16
	6

Goals for Teacher Education Courses	% responding
1. Teacher as researcher	1
2. Teacher as reflective practitioner	3
3. Teaching as a profession	19
by sharing teaching experience	7
by discussing content relevant to teaching	29
professional organizations	0
professional issues	3
other	0
4. Human development	1
5. Psychology of teaching and learning	7
6. Testing, measurement, evaluation and assessment	6
7. Philosophy of teaching	
develop research-based rationale	14
understand various models of	10
teaching	13
constructivist philosophy	7
other	
8. Management of learning environments	
where secondary students are active learners	26
classroom management and	21
discipline issues	3
other	23
9. Instructional design	3
10. Nature of science	4
11. Instructional technology	
12. Managing instructional	19
resources	1
13. STS	
14. Social foundations of education	1
15. Development of writing skills	0
16. Process skills of science	3
17. Other	30

Table 1.2. Goals of Courses Identified by New Teachers. Totals are well in access of 100% as most new teachers identified more than one goal, particularly in teacher education courses.

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Conclusion

The distinction between the culture of college science and the culture of teacher education is not a false dichotomy. The differences are very real and have very real consequences. These cultures are not simply different from one another, but also in opposition to one another. They are cultures at odds. The exact nature of the consequences of the dichotomy in which science teacher candidates are prepared for teaching is difficult to measure, but not difficult to deduce.

Science teacher candidates are integral players in both cultures, yet teacher education does little to address the dichotomy. Students move between these cultures in conflict with little help from teacher education and often with active opposition from science faculty. Failure to address the difference almost certainly allows promising science teacher candidates to seek and find other careers and shapes the teaching of candidates who complete the credentialing process in ways counter to what is best for their future students.

This chapter raises more questions than it answers. It describes the dichotomy that is science teacher preparation, but it does not address what that dichotomy means for the teachers prepared. What difference does the difference make? How can we and should we bridge the cultural divide?

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Chapter 2

HOW COLLEGE SCIENCE AND TEACHER EDUCATION WERE INVESTIGATED

The first chapter established the problem for why the classroom climates and cultures in college science and teacher education courses are worth investigating. In this chapter, I lay the groundwork for how the investigation took place. Chapter 2 describes what specifically is investigated, when it was investigated, who were subjects in the study and how the questions raised in Chapter 1 were addressed.

Why Biology Teacher Candidates?

Internal variation within each culture is assuredly great and painting any complex system as a sharp dichotomy is obviously a simplification and the education of science teacher is no different. However, this simplification is useful. To minimize, though certainly not eliminate, problems of over simplification, one science discipline, biology, received closer attention than other disciplines in this study. Biology is the most common major of future science teachers both at Midwestern University and around the country. Thus, investigating the experiences of biology teachers' preparation promises a story relatable to the experiences of more science teachers than investigating any other science discipline.

Chapter 1 opens possibilities for collecting a wide range of data types and sources. New data collection was designed strategically to be both manageable and still useful for investigating the problem. While Salish does indicate striking similarities in aining across biolog

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teaching across biology, chemistry and physics, data collection in science classes in this study was limited to two biology classes -- an introductory course for majors and an upper division course also for majors.

Limiting observations to biology courses is intended to avoid over-generalizations (and to make the data set manageable). The situation, both for biology majors and for science teacher candidates at Midwestern University are unique. The sample of classes is small and this was done at a single institution. Connections are made to existing research to illustrate how this research fits into existing bodies of knowledge.

Biology was selected for several reasons:

1. The largest portion of secondary science teacher candidates both at Midwestern University and around the country are biology majors, so these classes have the most relevance to the most teachers, teacher educators and teacher candidates.
2. My science background is perhaps weakest in biology[15], which allows me to assume a role closer to that of student than in any of the other science disciplines. This has the additional potential benefit of better preparing me to work with biology teacher candidates.

[15] I completed a field botany course as part of my masters' degree program, but other than that I have had no biology coursework since my sophomore year of high school in 1978-79. I have had no formal coursework dealing with evolution, genetics or human physiology in a very long time. Obviously, this could also be viewed as a weakness, especially since I am unable to draw a parallel for observing in education classrooms. One could argue that I come with a lot of experience as an observer in classrooms and only one of them was a high school biology classroom and this places me in a context similar to a college freshman biology major, but this is too much of a leap! I have learned a fair amount of biology in less formal ways. None the less, my limited biology experience better allows me to make the familiar strange.

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3. Earth science/geology does not seem to fit the sharp dichotomy shown by chemistry, physics and biology (See Table 1.1). Courses in Earth science, according to Salish data and my own anecdotal experience, are more likely to attend to "real world" applications and involve students in engaging fieldwork as undergraduates. Therefore, this discipline does not fit the first two frameworks applied in this dissertation.
4. Chemistry and physics programs each produce a small percentage of teachers, so analysis here would be both more difficult and relevant to a significantly smaller number of future teachers.

What Classes?

After reviewing course requirements for teacher certification in biology (see Appendix A), and discussing courses with faculty involved in science teacher preparation, two science courses and two teacher education courses were selected for observation. For each pairing of courses, one was a lower division course and one was an upper division course. In both science and teacher education, the upper division course had the lower division course as prerequisite. Enrollment information and official course descriptions for all courses are shown in Figure 2.1.

Department	Course #	# enrolled	Max. Size	Course Name	Course Description
Biological Sciences	BS111	391	550	Cells and Molecules	Cell structure and function; macromolecular synthesis; energy metabolism; molecular aspects of development; principles of genetics.
Biochemistry	BCH401*	181	285	Basic Biochemistry	Structure and function of major biomolecules, metabolism, and regulation. Examples emphasize the mammalian organism.
Teacher Education	TE250	32	32	Human Diversity, Power and Opportunity in Social Institutions	Comparative study of schools and other social institutions. Social construction and maintenance of diversity and inequality. Political, social and economic consequences for individuals and groups.
Teacher Education	TE401	34 & 18	35†	Teaching Subject-Matter to Diverse Learners	Examining teaching as enabling diverse learners to inquire into and construct subject-specific meanings. Adapting subject matter to learner diversity. Exploring multiple ways diverse learners make sense of the curriculum.

Table 2.1. Information regarding target courses for observation taken from Midwestern University's on-line course catalog.

* BCH401 lectures are videotaped and VHS videotapes are made available in the main library's audiovisual library. The lectures are also broadcast on Midwestern University Cable TV at scheduled times.

† This number is deceiving. Due to unexpectedly high student enrollment, a second and a third section of the secondary science 401 were added. There were three sections each with a maximum size of 35 students, with an actual enrollment in each subsection of just under 20. These three sections met together on occasion, in some ways making an effective class size of 60. There were three instructors.

These classes were chosen because nearly every future biology teacher completes all four of them, and I was looking for ways to cut across the program in both time (sophomore vs. senior) and space (science vs. teacher education).[16] More than 20 of the

[16] Biochemistry is within a set of three courses (BCH 401, Basic Biochemistry; ZOL 350 Histology; and ZOL 482 Cytochemistry) of which future biology teachers must take two. The majority took Biochemistry. Among the 32 (?) Biological Science seniors in TE 401, at least 14 had already completed Basic Biochemistry. Two had either taken Biochemistry I & II (BCH 461 & 462) by the time they were in TE 401 or were taking it concurrently. Biochemistry I & II are for majors in either Biochemistry or Human Biology. One senior took BCH 401 concurrently, and at least 3 took the course in the spring following TE 401. A few more had taken a biochemistry class at another institution before coming to Midwestern University.

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32(?) future biology teachers had taken a biochemistry class and most had taken or would take BCH401. All who were at Midwestern University throughout their program had taken BS111, which includes six of the seven who were interviewed. All of these seniors had taken both TE250 and TE401.

What Is the Nature of the Data?

There are three separate but related data sets referred to in this dissertation. The genesis of this research was the Salish I Research Project, and data from that project is the first used in the analysis. While the Salish database includes a wealth of individuals' perceptions about various aspects of teacher education programs, of each of the two cultures, this data set had a significant hole – there were no direct observations in college classrooms. So, for the second data set, I collected new data in college classrooms and interviewed students who were in those classrooms with me in part to see how their answers in 1999 compared to answers a few years prior (in 1995 and 1996) when there were no classroom observations. The initial interviews done with students in 1999 followed the Salish protocol (See Appendix B). A group interview was completed near the end of the spring semester that grew out of my observations and follow up questions from the first set of interviews.

The third data set comes from a project that has facilitated communication and collaboration among scientists, mathematicians and math and science educators. I served as a graduate assistant for this organization since its inception in 1997 through the summer of 1999. While all of the work of this group informs my dissertation work, certain aspects are more directly related and interesting than others are. An important

facet of this loosely coupled organization is the brown bag lunch group that preceded the more formal structure of the administratively supported organization. The brown bag lunches (BBLs) continue and I have been an active participant in these meetings. However, it could be misleading to think of my role as that of participant observer in the ethnographic sense. The inclusion of this group in my study was not part of the original proposal and I never took extensive field notes while sitting in these meetings. I did however take more generic notes and these notes were distributed electronically as the minutes of the BBLs. A few of the meetings were also tape recorded. Some of the goings on in the BBLs are described in Chapter 6.

Notably missing from the dissertation study are substantial interviews with the instructors for the courses observed and analyzed. The purpose of this study is to investigate the curriculum experienced by the future teachers in the study. In 1974, Goodlad described five curriculum stages; ideal, formal, perceived, operational and experienced. His study showed that what instructors believed they were teaching, the perceived curriculum, often differed substantially from what the students experienced (Goodlad, 1974). This conclusion was also confirmed by Salish – what teachers said they did in their classes was not a good predictor of what they actually displayed in videotapes of their teaching (unless they actually said they taught didactically). Most teachers in the study described their teaching in ways Salish researchers labeled as conceptual or constructivist, but their actual practice tended to be didactic (Salish, 1997). In short, teachers tend to pedagogically exaggerate what they do in their classrooms. For the purposes of this dissertation, it was far more important to observe and document how

instructors actually taught than to accept without question their self-reports about their teaching.[17]

Salish Data

In the New Teacher Preservice Program Interviews in the Salish I Research Project, program graduates were asked two series of parallel questions about their science and education classes. In the interview, new teachers were asked to describe typical classes of each type and to describe what parts of each sector of the program were most important in their development as teachers. Again, the interview protocol is included as Appendix B. These interviews, done as part of the Salish I Project in 1995 and 1996, are the starting point of my dissertation. They, like the newly completed interviews, were analyzed using HyperRESEARCH Software as described in the final report of the Salish I Study[18] (Salish, 1997). The responses to that interview for the Salish Project are summarized in Table 1.1.

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[17] Without interview data, I do not have, nor do I claim to have, evidence that these faculty teach in ways inconsistent with their beliefs. Again, what they *do* is what matters to their students. What they think they do is not central to the purposes of this dissertation.

[18] The software used for the dissertation was HyperRESEARCH 2.0. This was a later version than that used in Salish and offered substantial advantage. Transcriptions were initially done by an undergraduate and I found that he took short cuts – cutting out my voice where he recognized the question. This made for confusing reading, especially where follow up questions were asked. The new version of HR allows direct coding from audio. After converting the tapes to digital format using Felt Tip Software's Sound Studio (**Kwok**, 1999), I was able to code directly from the audio. Transcription was not completely bypassed. I completed the original transcriber's work when dealing with sections of the interview that I thought might be included in the dissertation. Direct coding, when technological problems are absent is both quicker and allows the coder to bring up the spoken word of the participants in an instant. While things like emphasis and pauses can be indicated in a transcript, something is clearly lost when the voices of participants are transcribed into the printed word. Naturally, things are gained as well (this is why some text was transcribed). This also has important implications for using STAM, as the same can be done with video.

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Additionally, data more specific to my study was collected. This includes interviewing seven seniors using Salish's New Teacher Preservice Program Interview Protocol. These interviews were completed in February and March of their senior year. A subset (three) of this group was involved in a group discussion in April (attempts were made to gather all seven, but those attempts failed).

Classroom Visits:

Over the summer, I contacted each faculty member for the four classes and secured their permission to observe. These conversations were, in three of the four classes, the closest I came to a formal interview with the faculty involved. I have known Karen Jones since 1994, and we worked together in various ways, so contact with her was far more frequent. I was also more obviously involved in her class than in the other three for a variety of reasons. Most important of those reasons was that TE401 was where I made contact with the students and enrollment in this class was criteria for selecting students to interview. Also important is that I was far more conspicuously involved in the education classes than in the science classes. The education classes involved more conspicuous engagement for everyone in the room – I perhaps would have been even more conspicuous if I had sat on the sidelines and taken notes as I did to blend in to the science classes.

All classes were visited in at least three of their first five sessions, with the intent of gaining understanding about how classroom climate is established and the nature of classroom climate

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the classroom climate.[19] Observations also took place around the times of major assessments. Again, BS111 is a prerequisite for BCH401, so students would take these sequentially (though not consecutively), not concurrently.

Each class was visited for roughly eight hours of instruction. The science classes were 50 minutes in length, with BS111 meeting three times a week plus lab (which was not required for all students) and BCH401 meeting four times a week (as noted above). TE250 met twice weekly for an hour and a half and TE401 met twice a week for an hour and fifty minutes, plus four hours in middle or high school classrooms for field work. Content Area Literacy (CAL) was part of the TE401 course that was taught by other instructors (described below). CAL met one late afternoon per week for the first half of the semester. I visited the CAL section twice making my total observations in TE401 somewhat more than the average for the other classes. As a consequence of different scheduling structures, science courses were visited more frequently but for shorter duration.

It would perhaps be misleading to label my research as participant-observation. When I was in class, I did act in ways similar to that of students enrolled in the classes, but it was not practical for me to meet the expectations of these students on a day to day basis. The courses represent either 16 or 17 semester credit hours (depending on whether or not I enrolled in the lab for BS111). Dr. McNair told students in the first week of class that they should anticipate spending 15 to 20 hours a week outside of class time if they wish to be successful in Basic Biochemistry. I was a participant-observer in the class, but

[19] It was not possible to attend every class session in the first week as BS 111 and BCH 401 were both 8:00 a.m. classes, with BS 111 on Monday, Wednesday and Friday and BCH 401 on Monday, Tuesday, Thursday and Friday.

I did not act as a student.

I hold no illusions that I would have come to know the material quicker than the average student in the class would have. In fact, it is quite likely that I would have struggled more as I had not taken most of the prerequisite courses and those that I had taken were taken in the early 1980s. In both the Biosci class and Biochemistry, the professors stressed the importance of memorization – something that has never been a strong suit of mine. I am also less able to engage in prescribed learning styles, i.e., memorization, than I once was. The reading and other associated work with the other courses was not insignificant, either.

The unique situation of BCH401 observations deserves more than a footnote. This class allows students to "attend" the class in a variety of ways. Students may go to the large lecture hall listed on their schedules and watch the professor projected on a large screen in the front of the auditorium. The projection is a live broadcast from the university's communication arts building a half-mile away. Students may also sit in the studio during the broadcast and see the professor live in front of them. Students can choose to watch live broadcasts on one of the university's cable channels. The class is rebroadcast at 4:00 p.m. This service is available on campus, and in the towns and cities in the immediate area. Videotapes are also available in the library's media room[20] after 7:00 p.m. I "attended" BCH401 class in all the possible ways.

The structure of TE401 is also unique – the course enrollment was approximately twice the anticipated enrollment. Initially, two instructors (both faculty) were assigned to co-teach the course. The large size led to the hiring of a GA and the division of the

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course into subsections. One of the two faculty member's teaching time was bought out by grant work, which led to the hiring of a retired teacher to cover this piece of his teaching load. The subsections of TE401 typically met as independent but coordinated sections. This means that the instructors planned together and gave the same assignments. On occasions, the three subsections would meet together. This means that on most days, the class size was around 20, but there were times that the class size was 60. My observations were all in the same subsection, Karen Jones's, though I visited all three sections in pursuit of study participants.

As noted above, there was also a separate Content Area Literacy portion of the TE401 class. This met once a week for half the semester, at 4:30 on either Wednesday or Thursday afternoon. There were two sections on each day, each taught by graduate assistants. I attended two of these sessions, one near the beginning of the semester and the other was the final class at mid-semester. Students in agriscience education joined the science students.

In visiting each class, I took extensive field notes, tape recorded each class and participated in ways similar to that of the students. This participation meant that in science classes, I sat quietly and took lots of notes. In teacher education classes, there were always times that my voice was heard (like most or all of the students in the classes), either in small groups, or in whole class discussions or both.

In science classes, I tended to sit toward the back of the room, subconsciously, I think, slipping back into my undergraduate ways and trying to some degree to blend into the anonymous crowd. In teacher education classes, anonymity was not possible. I was introduced in the first session of each of these two classes, and, as I noted above, the lassroom dynamic

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Syllabi, texts, coursepacks and any materials distributed during an observation were collected and reviewed. Significant portions of each syllabus are included in the following chapter that describes the classes. Also included in that chapter are brief descriptions of the texts, coursepacks and other materials used in each class. The genres of texts used in the education classes were markedly different from those used in science classes and are compared in what follows.

Interviews and Group Discussion:

Seniors were contacted through my visits to their TE401 class. Initially, Karen introduced me and I said a few words about what classes observing, without going into detail of why I was doing the study. A month into the semester, I went to each of the three subsections and asked students who had taken or were taking biochemistry to indicate on a sheet passed around what course was taken; when the course was taken; and who the instructor was. It was clear that I had a large enough group of students who had taken or were taking the course at Midwestern University, that transfer students were not necessary for my study.

After collecting this information and sorting through it, I found that there were seven students who had taken BCH401 with the instructor teaching the section I was currently observing. I approached each of the seven students and they all agreed to be interviewed and to take part in a group discussion about their science and teacher education courses the following semester. Not all actually participated in the group discussion, though a

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The group discussion began with each senior drawing a concept map or other representation of the relationship between their teacher education and science courses and then there was a general discussion around that notion. I did have some specific questions that arose from the earlier interviews and from my observations in the four classes, but the conversation was generally free-flowing and addressed many issues directly and tangentially related to my research questions. At times, Joseph led the conversation more than I did. The student-drawn representations are reproduced schematically in the Chapter 4.

The Seniors:

All seven of the future biology teachers who were interviewed had taken TE250 and BS111. They were all in the same cohort in their teacher education classes and all took TE401 in the fall before the interviews. All of them had also taken BCH401 with the same instructor, James McNair, though not all at the same time. Only one had taken the course concurrently with TE401. See Chapter 4 for further information on the seniors.

Conventions used in class and interview excerpts

I found the style used in Deb Trumbull's *The New Science Teacher* as useful conventions for including participant voices. When including what was said either in class or in interviews:

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"I modify their spoken language to remove repetition, such as fragments that begin a thought that is expressed more fully in the next sentence. I remove qualifiers when they are used habitually... terms such as "kind of" or "sort of." I also remove and catch phrases... such as "you know" or "it's like." Indicating larger chunks of omitted material required judgment, since the standard conventions were designed to indicate changes in printed texts. As anyone who has transcribed speech knows, we often do not talk in sentences, so as the transcriber I imposed sentences to make the transcripts readable. I use three ellipses in the middle of a sentence to indicate omitted phrases. I use four ellipses to show that I have omitted a larger blocks of transcript, at least one full sentence. I used dashes to indicate the [speaker's] pauses for thinking. When I add words to make the meaning more clear, I put the words in brackets."

(Trumbull, 1999) p. xix

These changes are minor and always indicated as described (with dashes, brackets or ellipses). I am not a good enough writer to write in as many different voices as are portrayed in this dissertation. Table 2.2 shows a brief example of verbatim transcript alongside the text I included in Chapter 4 using the practices described above.

Verbatim Interview Transcript:	**Text in Table 4.1:**
Bill: It's pretty much non-interactive lecture. Like lecture like the instructor stands up in front of the class and imparts the information to the class.	Bill: "It's pretty much non-interactive lecture. ...The instructor stands up in front of the class and imparts the information to the class."

Table 2.2 Transcript excerpts showing conventions used when quoting individuals

Like in Trumbull's work, I include long passages in the participants' own words, both from what was said in classrooms and from what was said in their interviews. This is intended to lend credence to my interpretations of what they said and to allow the reader to make their own interpretation. It is also essential for rich descriptions of the classroom setting that follow in the next chapter.

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Chapter 3

A VIEW INTO SCIENCE TEACHER PREPARATION

This chapter focuses on the first of my research questions, "What are the natures of college science and teacher education classroom cultures?" That question is addressed through reporting my observations in the four science and teacher education classes I visited. A chapter that reports senior students' descriptions of and responses to these classes follows this chapter.

Future biology teachers are Biological Science majors[21]. Other undergraduate majors in biology here choose a sub-discipline like Biochemistry, Human Biology or Zoology. These other more specialized biological science majors target those who wish to pursue medical school or other advanced degrees. The requirements are listed in the appendix.

I begin by describing two science classes, one taken typically by sophomore science majors (BS111, Cells and Molecules), the second (BCH401, Basic Biochemistry) taken by upper division students in a variety of biological science majors. The first course is not a formal prerequisite for the second, but BS111 is required for Biological Science majors and they would take the lower level course earlier in their college career. All biology teacher candidates take Cells and Molecules[22]. Basic Biochemistry is taken by a sizable majority of biology teacher candidates. The description of two teacher education courses follows, beginning again with a course typically taken by sophomores

[21] Some are dual majors. Among the seniors in the study sample, two have a second major in zoology.
[22] This does not include transfer students or those within the DaVinci School (described in the following footnote).

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(TE250, Human Diversity: Power and Opportunity in Social Institutions) and the second taken by seniors (TE401, Teaching Subject Matter to Diverse Learners). The first class is one of the prerequisites for the second.

The reader will see that these descriptions map onto the cultures described in the first chapter reasonably well, but that the reality is not such a sharp dichotomy. This chapter offers detailed descriptions of four classes that were chosen to be somewhat representative of future biology teachers' experiences in college classrooms. Notably missing is a small upper division science course. The reason that such a course is not included is that these future teachers did not typically take such courses. Only two of the seven seniors interviewed reported having taken a college science course smaller than sixty students. Even for those who had taken these small courses, they were the exception rather than the rule.

The descriptions of the two science classes are fairly similar to each other and quite different than the descriptions of the education classes. One might note that the education class descriptions are longer and conclude that I give an unbalanced representation. I argue that the natures of the classes require descriptions that are both quantitatively and qualitatively different. The science classes were uniform from day to day and throughout each class period. In both science classes, the professors lectured everyday excluding exam days and students were passive. Questioning or any other student actions besides note taking were rare. This allowed shorter descriptions of the science classes. The education classes required more description because the reality was more diverse -- student voices were central and the activity varied throughout the class period and semester.

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These descriptions map on well to the three conceptual models employed in this dissertation. As the reader moves through the chapter, s/he should be attentive to the three models: ① Two Cultures; ② The Dysfunctional Marriage of College Science and Teacher Education; and ③ The Ecosystem of Science Teacher Preparation. Particular attention should be paid to the contrast of uniformity in science with diversity in education.

I struggled with how to structure this chapter to make it most accessible to the readers. I had difficulty in determining how to address issues of space and time. I opted to sort first by space then by time. That is, science classes are described first then teacher education classes are described. Students begin their science coursework prior to their teacher education coursework, and finish their science requirements prior to their student teaching internship. In science and in teacher education, the sophomore level class is described first followed by the upper division course. I considered beginning with descriptions of sophomore year classes followed by descriptions of courses taken primarily by seniors.

I believe the structure I chose allows for readability of the chapter, but the reader should keep in mind that the structure of the chapter is quite different from the structure of the teacher candidates' experiences. The reader must be attentive to the fact that teacher candidates moved between science and teacher education classes on a daily basis starting in either their sophomore or junior year. A typical first semester senior biology teacher candidate's schedule is below in Figure 3.1.

Time	Monday	Tuesday	Wednesday	Thursday	Friday
8:00 a.m.	TE401 work in schools	Science Laboratory for the Secondary Schools NSC401ⓢ*	TE401 work in schools	Science Laboratory for the Secondary Schools NSC401ⓢ*	
9:00 a.m.					
10:00 a.m.					
11:00 a.m.	CEM383ⓢ P. Chem		CEM383ⓢ P. Chem		CEM383ⓢ P. Chem
Noon					
1:00 p.m.	ZOL445ⓢⓢ Evolution		ZOL445ⓢⓢ Evolution	TE401	ZOL445ⓢⓢ Evolution
2:00 p.m.					
3:00 p.m.	CEM383ⓢ P. Chem				
4:00 p.m.					
5:00 p.m.			TE401 CAL*		
6:00 p.m.					

Figure 3.1 A typical senior biology teacher candidate's schedule.
ⓢ*CEM383*: *Introduction to Physical Chemistry I.* This 3 credit hour chemistry course had a 200 student lecture section on Mondays, Wednesdays and Fridays. This student had recitation on Monday afternoons.
ⓢⓢ*ZOL445*: *Evolution.* This 3 credit hour zoology department course had a 140 student lecture section on Mondays and Wednesdays. This student had recitation on Friday.
ⓢ**NSC401*: *Science Laboratories for Secondary Schools.* This College of Natural Science course is required for Biological Science majors (a.k.a. biology teacher candidates). It is described briefly at the end this chapter.
**CAL*: *Content Area Literacy.* This subsection of TE401 meets for only half the semester.

The typical schedule is derived from schedules of biological science seniors in TE401 in the previous year. Of the 16 students surveyed, 15 took *NSC401: Science*

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Laboratories for Secondary Schools, concurrently with TE401, ten took *ZOL445: Evolution,* and eight took *CEM383: Introduction to Physical Chemistry I.* Only one took *BCH401: Basic Biochemistry* concurrently with TE401[23]. Seven of the seniors took this set of courses, with one of those seven also taking a mathematics class. Recitation sections varied, so this only matches the exact schedule of two students. This pair worked together in the same K-12 classroom for TE401 practicum.

For all four classes described, considerable time is spent describing the first classes at the beginning of the semester. In reviewing the notes and tapes of these opening classes at the end of the term, I found that the first sessions of each class set the tone for the term. This was not quite as evident in BCH401, in part because I missed the first class (as I could not be in two places at once) and in part because information about the first class indicated that it did not set the tone for the course in the same way as the other class's first days did. Consequently a slightly later (and quite interesting) class is described in more detail. In the other classes, less time is spent on description beyond that first day as the culture for each class was well established early on. To foreshadow the tones set in each classroom setting, science classes could quickly be described as teacher-centered, with students spending each fifty minute class period writing pages of notes and teacher education classes could be described as student

[23] Had I discovered this information prior to beginning my study, the design likely would have been altered. While this is true – I would have done observations in NSC401 as well – it is not a significant problem for many reasons. The existence of the four credit NSC401 *and* a four course, 17 credit hour subject specific sequence in teaching methods make Midwestern University extraordinarily unusual. Information about this course is included in the study, but not observational data. While it is also true that the typical student did not take BCH401 in the fall of their senior year, the typical student did take the course in another semester.

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Science Classes:

Biological Sciences 111: Cells and Molecules

Catalog Information:

Credits: Total Credits: 3 *Lecture/Recitation/Discussion Hours: 3*
Prerequisite: CEM 141 or CEM 151 (General Chemistry).
Not open to students with credit in: DVS 145[24]
Description: Cell structure and function; macromolecular synthesis; energy metabolism; molecular aspects of development; principles of genetics.

Schedule Information:

Maximum enrollment: 550
Number enrolled: 391
Class meeting times: 8:00 a.m. – 8:50 a.m., Monday, Wednesday, Friday
Location: B108 Gilmour Hall
Instructors: Jon Peters (for the first half of the semester)
Phil Opanashuk (for the second half of the semester)

The Instructors:

Jon Peters appeared young for someone with a Ph.D. that was awarded in 1970. He is white with dark hair and he is neither thin nor heavy. He often wears plaid, short sleeved button down shirts. Prior to our meeting about my observations in his class, we had been in meetings together but had never talked more than to perhaps exchange a few

[24] DVS is the abbreviation for the DaVinci School – an integrated science program within the College of Natural Science. In this school within a school, students are in smaller classes and there is some thematic instruction. DaVinci describes itself as, "an undergraduate residential program for students pursuing broad, science-based fields of study. " Students in the program initially are housed in the same residence hall, "...where the School's classrooms, laboratories, and offices (both faculty and administrative) are located. Because of its residential nature, DaVinci offers the intimate setting and the individual attention of a small college along with the resources and opportunities of a major research university." One senior interviewed, Darcy, was a student in the DaVinci School.

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words. He does care about the success of his students and told me in our first meeting that he wants to improve his teaching, but that he has no interest in, "that touchy-feely education stuff." In that same initial conversation, we spoke of the difference between knowing and understanding. He argued for the need to know before the need to understand. It became clear to me that we did not see eye-to-eye and I dropped the matter for diplomatic reasons. I got the feeling that the less I said the better for my ability to successfully meet the needs of my study. Jon's background is in microbiology and he studies RNA, a key piece of the content in BS111.

In the second half of the semester Phil Opanashuk teaches the course. The majority of my observations were under the instruction of Dr. Peters, and, for the sake of brevity my description will focus on Peters.

The room:

The room was a large auditorium, with 22 rows of seats. See Figure 3.2. A photograph of the room is included in Chapter 7 as Figure 7.4b. The online course schedule states that the room has a capacity of 622. The color scheme of the room matched the school colors -- blue plastic seats with wood-grain Formica fold out tablet arms, and off-white Formica flooring in the aisles, with blue accents. In the front of the room were two overhead projectors pointed toward the huge screen that dominated the front wall -- approximately 28 feet long. Tables at the front, center and back allowed wheelchair access. A green chalkboard on wheels was off to one side. In short, this room was a typical large lecture hall, with recent renovations that made it sterile rather than dingy.

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It was a room that could have contained the footprint of my modest graduate student home a few times over. The living space in that two-bedroom home was just over 800 square feet. The square footage of this room was approximately five times that large, but here the furniture could not be rearranged. The ceiling of the room was not quite as high as the roof of that one and a half story Cape Cod home.

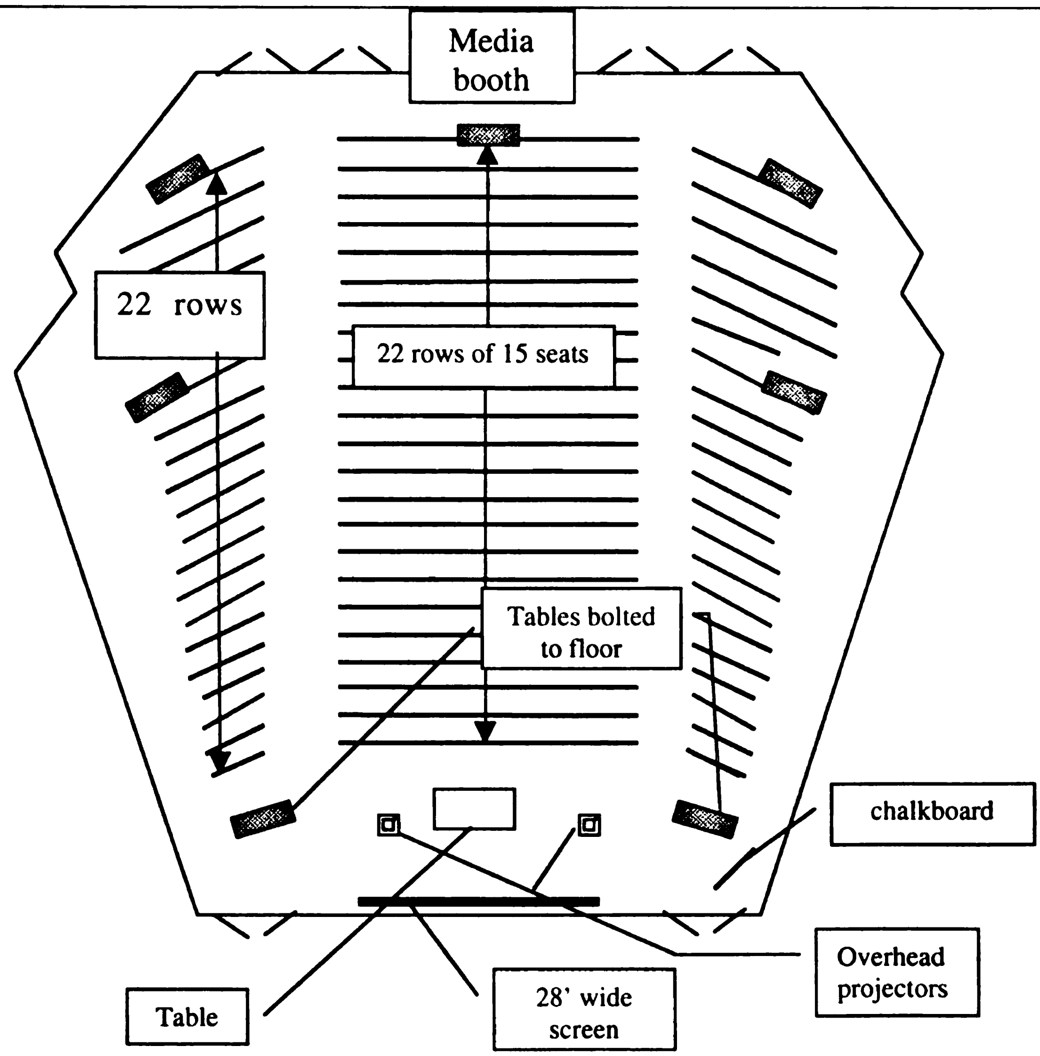

Figure 3.2. B108 Gilmour Hall:
Classroom for BS111. The drawing is not to scale. A photograph is included in Figure 7.4 in Chapter 7.

The room is a fine example of what environmental educator David Orr refers to as, "architecture as crystallized pedagogy" (Orr, 1999). The chairs were bolted to the floor. The floor gr

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floor. The floor gradually sloped to the front so that the professor stood in an area about four feet below the doors at the back of the room. The room is designed for and encourages, almost mandates, lecture.

The first week of BS111...

The bustle of the beginning of the school year on a large college campus is an exciting time. The sidewalks and bikeways are full of students trekking off to class. In the first week of the semester, as I made my way among the four classes I was to visit occasionally through the semester, I witnessed two minor bike accidents and several more near accidents. The crowds on the sidewalks would greatly diminish over the next few weeks.

As a thirty-five-year-old, I was stepping into my first large lecture hall science class since finishing my master's degree ten years before. In that program, I had only one class in a lecture hall. That was a geology course that I was taking to attain permanent teacher certification in Earth science. My explicit purpose in attending this day's introductory undergraduate biology course was quite different. I was there to learn about the nature of the class, and the academic culture that the class represents.

On that first day, the huge room looked nearly full when I arrived ten minutes before the 8:00 a.m. start of class. On my way into the classroom, I was handed a recruitment flier for a note-taking service. I took one and headed into the auditorium. Many students continued to enter after I found myself a seat three quarters of the way to the back and to the left. While there were students seated in every row throughout the addendum, a clo

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auditorium, a closer glance showed available seats for well over a hundred more – the auditorium does seat over 600.

Looking around the room, I was reminded that there is no such thing as a typical college student. While most around me were clearly in their late teens and early twenties, there was a smattering of "kids-my-age" in the room. Of that vast majority who were of the traditional college student age, most, but by no means all were white and looked, in one way or another, American. Some, mostly men, had the appearance of a hangover that I often sported as an undergrad -- unshaven, apparently unshowered and distinctly bleary-eyed, a few even wearing sunglasses in the class. Of the approximately 400 students around me though, the obviously hung-over numbered perhaps a dozen, perhaps 20.

Most students looked clean and fresh (at the beginning of class), many in T-shirts, many a bit more dressy. Most students wore shorts. Baseball caps were common, many worn backwards. I did notice a couple of pierced noses and one woman with magenta hair. These individuals were noticeable because they were different from the crowd in the room – again, there did not seem to be a "typical" student. In spite of being planted in uniform rows, the class was hardly a monoculture.

The gender split was about equal. Perhaps one in ten was Black, again with a near equal gender split. Three or four men reminded me of Asian and Pacific Islanders I have known. They were men of color wearing white, button-down shirts.

The syllabus had been available before I arrived and all copies were gone. The professor announced that the TA was to arrive shortly with more copies. If the TA failed to arrive, the syllabi would be available, and he gave the location where they could be paced up. Or they

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picked up. Or they could be picked up in class Wednesday. As he began to write on the overhead, I squinted and put on my newly prescribed glasses that I came to need for sitting in the back of classrooms to observe student teaching interns. Attention focused on Dr. Peters.

At a few minutes after 8:00 a.m., the TA arrived. Dr. Peters introduced her and a throng of students made their way to the front of the room to pick up copies. I joined the stream, forgetting that I had picked one up from the professor in our meeting the previous week about my observations. The process of a few hundred students picking up their syllabi takes a few minutes. I had met the TA through work on a project to improve instruction in a non-majors' biology class. In the flurry of activity, she does not acknowledge that she recognizes me.

Dr. Peters introduced himself, saying that he was in microbiology. He did introduce himself as Dr. Peters, using his formal title. This contrasts with the informality used by instructors in Teacher Education classes. He noted that his office number and office hours are in the syllabus and that he would be a little late for office hours that day, as he would likely be in this classroom for a little while after class.

Dr. Peters asked if there were any freshmen in the class. About a dozen hands went up and he followed up by asking, "Why are you taking this course?" Chemistry is a prerequisite, so they were told they did not belong. Most of the freshmen were seated closer to the front than I, so I could not see any response and there was no verbal response. These students remained throughout the class. Reading the words he spoke may make them sound harsher than they were. While asking such a question does not [illegible] welcoming

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"If you have questions that you don't want to ask me because I look like I'm an ogre, and you don't want to talk to me, you can send me an e-mail and I'll try to get back to you… I will get back to you within 24 hours." He noted that the same info is available for Dr. Opanashuk and the teaching assistant. He described some of her responsibilities, which included taping class and getting several copies to the library's media center.

Some general logistical information was shared – e-mail would be used extensively. Some tips for success were also shared.

> "Most important… is that you *do* come to lecture. I know you've been preached to before. I don't like to preach… A live lecture is much different than if you're listening to the lecture on tape; buying notes from those people that sell them outback, which you've already gotten little pamphlets about… I don't condone that at all. I think it's an infringement on my rights, however, I have no legal way that I can stop the course from being scribed. I *do* think by being here you get a lot more out of the lecture. The way I emphasize things, the way I point to things, the things I write on the overhead are all part of the learning experience. So I do believe if you come to lecture you get a lot more out of it."

Dr. Peters went on to say again that he doesn't like notes being sold and that the department has studied association of attendance and grades. Students who come to lecture fairly regularly get a half grade higher. He had mentioned this association when he and I met the week before. I wondered when he had first mentioned it if the relationship was causal. My wonder resurfaced as he repeated the data.

There were to be weekly review sessions on Thursday afternoons, typically lasting an hour to an hour and a half. Students were encouraged to come to these sessions and ask questions and to ask questions in class as well.

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This was something that I would see repeatedly in this class and in BCH401 in the coming weeks and months. "No question is a dumb question... If you don't understand something, don't be afraid to ask a question. I will never make fun of anyone for asking questions or in anyway embarrass you." Here he was speaking primarily of review sessions, though he, Dr. McNair (the biochemistry professor) and Dr. Opanashuk would all make frequent and largely unanswered pleas for questions during class time.

He mentioned the difficulty of scheduling review sessions and noted that the Thursday afternoon time, while it did conflict with some labs and dinnertime was about the best time possible. All of the logistical information was included in the syllabus. Part of the syllabus, "STRATEGIES FOR SUCCESS IN BS111," is included in Appendix D.

Throughout the class thus far (the first fifteen minutes) students had continued to wander in, although the rate had dropped off.

Dr. Peters continued his monologue, moving on to issues that tie into the current reforms (and many old reforms) in science education.

> "The information in BioSci 111 is the foundation for many advanced level classes. I know that many of you are premed and pre-vet students, and pre-graduate school students. A lot of you are going to need this material... In fact, whether you are going to be a professional student later on, or whether you are going to be out working in the work force, the *material* we give you in this class is important for you to become an informed citizen... There will be many things... that you'll have to vote on, and you should be able to vote, not based on opinion, but based on some scientific fact and some knowledge."

He returned to the importance of review sessions and quickly moved on to a few words about the lab, which was not required for all students. The lab was required for Biological Science majors (a.k.a. future biology teachers) but it was not required for all majors that required BS111. A few students also took the class to meet the university's general science requir

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general science requirement. Dr. Peters then covered basic logistical information related to exams – including that half of the class would take them in another room that had not yet been determined. He also noted that example exams were included in the syllabus, one of his and one of Dr. Opanashuk's. There were plenty of old exams to look at out in the world. If students chose to look at these, they should be sure to look at a variety of exams. Students should be aware that the two instructors would give different kinds of exams. Exams would be machine graded, he noted.

He continued to talk about logistical issues. Grades were final and there was no extra credit. Likewise, there were no makeup exams and he covered more explicit information about this from the syllabus. He spent a few minutes on this topic, driving home the importance of the point. This section of the syllabus is included in the next section of this chapter, in Figure 3.4a.

Peters pointed out that the grading scale was listed. The class was not curved for several reasons. Curves encourage competition, which encourages cheating. He noted that all students are starting with a 4.0[25], and if everyone deserved it, everyone would be cheerfully awarded 4.0s.

He said a few words about the textbook (Campbell, 1996) and described it (jokingly) as heavy, and an "excellent, excellent textbook." He noted that it has a nice glossary and useful study questions, many of which were easier than exam questions. The text is described briefly below.

"I have no further instruction on basic course information. Are there any questions?" He waited through approximately two seconds of silence and moved on.

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"Ok. I will tell you, you should all read Chapters 2, 3 and 4 of the textbook. They are not going to be lectured on at all." These chapters addressed chemical concepts and those concepts should have been a familiar to students from General Chemistry, a prerequisite to this course. He again said that he doesn't want to preach and told students to read the list of Do's and Don'ts in the syllabus (included as Figure 3.4c in the syllabus section below). Although he had just said he was finished describing course information, he returned to this description.

He began a story and paused for the tape to be flipped by the TA. The story was prefaced by his saying, "One of the criticisms you'll hear is that I go too fast," and that it related to a friend of his daughter's who had taken the class. The tape was flipped and the story was abandoned.

He went on to say not only to come to class, but also to pay attention, to not sleep and to not read the paper. I noted that, a few rows over, a male student was sleeping. Sleeping students were something that I would see on each of my visits to this class[26]. He did say that if you were going to come to class and not pay attention to do whatever you do quietly. This described exactly what appeared to be going on around me. Most students appeared to be paying attention. Notebooks were virtually all open, notes were being jotted in them occasionally, and most eyes were focused on Dr. Peters at the front of the room. Later in the class period and throughout the semester, students wrote notes at a much faster pace, when testable material was the topic of lecture. Those who were

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[25] At Midwestern University, grades are on a four-point scale. Letter or percentage grades are rarely referred to. A 4.0 is an A, a 3.0 is a B, a 2.0 is a C, a 1.0 is a D and 0.0 is an F. Final course grades are always divisible by 0.5, unless the course is pass/fail.

[26] Sleeping students are not unique to science classes. While I never saw students sleeping in the education classes I observed for this study, I have seen them asleep in the classes I taught!

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doing other things were doing so inconspicuously. The sleeping student I observed was not snoring or sprawled out, just sleeping quietly with his head on his shoulder.

Peters continued to offer advice on how to be successful in the class, "You can't cram 11 hours of lecture into a few hours studying and expect to do well on the exam." He suggested an hour of study a day and added that for each hour in class, students should spend about three hours out of class in related studying. He spent a considerable amount of time on this. This point was also stressed in biochemistry, though the number of hours suggested there was higher.

The following quotation immediately followed the above segment on spending enough time studying. The first two paragraphs are a verbatim, uninterrupted section of Dr. Peter's monologue. I have included it as an extended piece of text as I find the concepts expressed quite interesting and I find the lack of transition between what I regard as quite different ideas also to be interesting. Not only are the central ideas and the abrupt transition between them interesting, but so is the allusion to the management school. He also foreshadows the argument I make in Chapter 7: to understand the whole of science teacher education, you must understand the pieces, including science classes.

> "This is not a weed-out course. I mean, this is a big course, everybody thinks is a weed-out so we can flunk you out; so you can go to the management school or whatever. That is not at all the intention of this class. It's never been designed that way. It's never been thought of that way. I don't even like to think of it that way, but it does come up.
>
> It is important material that you should know and I absolutely *love* the material I am going to tell you about. Cells to me, the individual cell, is the most exciting thing to learn in biology. It's fun to learn about human physiology, how the heart works, how the muscles work, how the brain works and all that, but if you don't understand how one cell works, *by itself*, all the intricate things that it does, you don't really appreciate the whole picture."
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> "...I hope I can give you that same kind of enthusiasm and curiosity. I *hope* that at the end of this course, you know some facts that

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help you in future courses, but I hope that also you're asking questions. Why? How does a cell do this? Why does a cell do that? How does this molecule interact with another? *Have curiosity.* Ask the question, '*Why?*' Often we don't know the answers, but at least we're gathering information to make strides forward. This is really an exciting time to be taking a course like this, because of all the really exciting things that are happening in the sciences. [inaudible]

So, this is not a weed-out course. It's meant to get you enthused about cells and, eventually this will lead you into how things work, how living organisms, work."

Peter's passion for the material and his statement of that juxtaposed with the statement that BS111 was not a weed-out course seized my attention. Does the professor's passion for the content taught decide whether or not a course is a weed-out course? Who gets to make the decision as to whether a course is a weed-out course? If the professor's views differ from the students' perceptions, do the professor's views particularly matter?

Dr. Peters next encouraged students to form study groups. This is a topic that was visited occasionally and strongly encouraged by both Dr. Peters and Dr. McNair in biochemistry. My interviews with seniors indicate that this advice was not well-heeded by most of the teacher candidates in my study. The advice is sound – he recommends groups of, "three or four or five," and to get together once a week and go over the information in the lectures, to ask each other questions, and he noted, "...an easy way to learn something is if you actually have to teach it to somebody else." He was in the midst of the only episode I saw in his class that would fit into a teacher education class. He went on to say, "Ask each other questions. If the person who gave the answer can't explain, then they don't understand it either. (Pause) Working together to master the material is fine, and I really encourage you to do that."

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Now, more than halfway through class he moved on from logistical information to the science of the class. His mode of delivery changed – the overhead came more directly into play as he said, "Ok, so what is the reason you take this class? Why do we really think you should know this material? First of all, cells are the fundamental unit of life." He wrote this on the overhead and students stirred. They too, began to write, almost 400 of them, simultaneously. The sleeping student wakened and began to jot in his open notebook.

The reader might pause here and imagine or recall what this looked like – students moved from being inactive to active simultaneously (though not terribly active). They changed postures and started doing something besides watching and listening. Some might argue many of them stopped listening and started writing.

For the remaining 10 minutes or so of class, it began to approach a typical class. Dr. Peters wrote text on the overhead and the students apparently copied it into their notebooks. On this day though, most of the words were recognizable to non-scientists who read the paper everyday, and he made more references to the news and "real world examples." The amount of text on this first day was also far less than in a typical ten-minute segment of classes to follow. As he wrote, he spoke:

> "So, cells are the fundamental unit of life and molecules, are the fundamental structural component, which make up cells. And the principle molecules that you are going to learn about, proteins, nucleic acids, carbohydrates and lipids. These are the four fundamental molecules that we're going to study and try to *understand* how in the correct spatial arrangement, and properly regulated, these molecules, make up a cell, the simplest unit of life, the simplest unit of reproduction. (Pause). The question is *'why?'* Why do you have to learn this material?"

In the time that he has said this, he has also written most of it on the overhead, and the students around me have dutifully written it down as well. He did not write out that he said. In re

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all that he said. In re-listening to the audiotape, I noted that his voice pattern changed when he wrote. As he wrote, he spoke the words slower and more deliberately. By the end of class, the huge projection screen covering much of the front wall had the following largely in capitalized block print:

> molecules structural component
> PROTEINS
> NUCLEIC ACIDS
> CARBOHYDRATES
> LIPIDS
>
> In the last several minutes of class, he added:
>
> RECOMBINANT DNA TECHNOLOGY
>
> And, finally:
>
> 3 x 10^9 base pairs in our DNA

Figure 3.3 The text written by Dr. Peters on the overhead projector near the end of the first class in BS111.

He talks again more generally about goals – students should become self-learners, and then talks extensively about some of the advances in biology and biotechnology.

Dr. Peters talked about bio-insecticides, FLAVR-SAVR tomatoes, bacteria used to clean toxic spills, bacteria that can act as a plant anti-freeze to reduce frost damage to crops, noted that, "Dolly [the sheep] is the big thing," and went into some depth about cloning, mentioning a moratorium on human cloning. He talked about the human genome project and wrote the note about base pairs of DNA on the overhead. In describing these advances, he occasionally used illustrative analogies like, if all the base pairs in the human genome were represented by text, it would take over a thousand books the size of the

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the size of the [1300 page] class text to list them all. He continued his descriptive list with issues including tissue growth and organ transplant technology, life on Mars, the possibility that there is a gene for violent behavior, and a few comments on moral and ethical questions that arise as a result of the new technologies. One example of moral and ethical considerations is genetic testing for insurance companies. He raises these questions without answering them. Making clear, for at least the third time, that science does not provide all the answers for the questions it raises. Peters also noted that what is happening in biotechnology today was science fiction until fairly recently.

Most of the examples were more than casually mentioned. A few minutes after a passing comment on how cows are now bigger and producing more milk, he said the following about Bovine Growth Hormone (BGH):

> "Should we eat ice cream that comes from cows that were given growth hormone? A lot of people would say no. Ben & Jerry's Ice Cream says we will not use milk from cows that are given growth hormone. They've made some sort of a stance that that's not good. Well, is it harmful? Is it not harmful? How do you know? Well, you don't know until you have some of the relevant information to try to understand some of these things.
>
> A question that all of you will face as young adults is, well, what about AIDS?"

He then continued on to say about as much about AIDS as he said about BGH, and as he had said about many of the other examples above. After talking about AIDS, he again said that this class provides the foundation for understanding these issues. The clock was winding down now, 8:49 a.m. by my watch, 8:47 by the clock on the wall and he said,

> "So, all of these things that are so wonderful to think about, the recombinant DNA technology advances, also *bring* with them ethical and moral questions we do have to eventually address. OK, so one last thing before we leave – and I will say, I will ask you *please* not to do exactly what you are doing now. At a few minutes before the end of the hour, books start slamming. I can see the clock I still have a few minutes left,

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> please wait – If you have questions about biology, please write these down; bring them Wednesday or Friday and I'll try and answer them as they relate over the semester."

At 8:49 a.m., students were on their way. The room cleared quickly of its nearly 400 occupants. A few lingered to touch base with Dr. Peters and the TA. Each had a single file line as students waited to talk to them. By 8:53 a.m, the room was nearly empty. Those who remained included Dr. Peters, the TA, the students talking with them, and me. There were also a few students who apparently remained in this classroom for their 9:00 a.m. class. Two of these students were reading the campus newspaper. I left.

The BS111 syllabus

The syllabus itself was four pages long, with a little more than two pages of general information, (some excerpts are in Figure 3.4a, below) and a little more than one page for the lecture schedule (included below as Figure 3.4b). Also included in the syllabus packet was a list of **DOs** and **DON'Ts** (Figure 3.4c). The syllabus packet also included sample exams from the previous year; one from each instructor's portion of the course.

The syllabus itself began with contact information and office locations for the two instructors and for the lecture TA. A paragraph-long course description was also included (see Figure 3.4a). This description expanded on the description available from the course catalog. Class times, exam dates and the location within the library for listening to audiotapes of the class were all included on the front page.

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DESCRIPTION OF THE COURSE: BS111 will cover sub-cellular and cellular biological processes. Topics include the structure, function and synthesis of macromolecules. The cellular generation and use of energy will be examined. In the second half of the course the elements of the replication, transmission and expression of genetic information in the cell's life cycle will be covered. Examples of these processes will be taken from organisms ranging from viruses, bacteria, plants and animals. Theories and experimental methods used to understand cells and molecules will be presented.

EXAMS AND GRADING

GRADES WILL BE FINAL – NO EXTRA CREDIT GIVEN!

Exams in Biological Science courses vary by instructor. Therefore, previous exams may not be reliable guides for study. One Sample exam from Drs. Peters and Opanashuk are included in this syllabus.[27] The course objectives provide the best indication of test content. Exams will be objective and machine-gradable.

NO questions will be answered during exams. If you feel a question is ambiguous, a blank page will be provided after the exam to explain your concern with a question. This explanation should be turned in to the instructor or lecture TA at the end of the exam, with your name and student number clearly indicated. The reason for this policy is to avoid heterogeneous answers to question that might result given the large number of proctors that will be involved.

GRADING SCALE: Final course grade will be assigned according to the total points received (out of 500 possible) as shown on the following scale:

% of Total Possible Points	Grade for Course
83 - 100	4.0
77 – 82	3.5
71 – 76	3.0
65 –70	2.5
59 – 64	2.0
53 – 58	1.5
47 – 52	1.0
0 – 46	0.0

You must present a picture ID to hand in your completed exam. Proctors will check you out of the exam, and note your attendance on a check-off sheet.

E-MAIL: We will use an e-mail mailing list to announce various items to the entire BS111 class. You can also use the response option of the e-mail system to ask each of us questions relating to lecture material. We will respond either individually or to the entire class.

READINGS AND LECTURES: While the lectures will be related to the readings, they will not be exactly the same. The differences will be both of emphasis and content. Exams will be derived both from the reading s and from the lecture itself.

Figure 3.4a: Excerpts from the BS111 Cells and Molecules Syllabus.

[27] The typos in this sentence are reproduced from the syllabus. There is one sample exam from each instructor.

At the bottom of the front page, in underlined boldfaced capitalized print, the syllabus read, "**GRADES WILL BE FINAL – NO EXTRA CREDIT GIVEN!**" This was under the heading of **EXAMS AND GRADING,** but the underlining made the subtext more pronounced than the heading. This section continued onto the second page where more specifics about the exams were described.

The syllabus explained that there would be no make up examinations, though students in special circumstances (e.g., illness) may be eligible for a waiver. Students were required to notify the department prior to missing the exam in order to have a possibility of a waiver. No waivers were possible for the final exam, however if a student had either another exam scheduled at the same time or two others on the same calendar day, they may have been eligible to take the exam at an alternate time. "The rule DOES NOT APPLY if you have three exams scheduled in a 24-hour period (e.g., one exam on Monday night and two exams on Tuesday.)"

The syllabus responded to the special problems of the very large class that it covered. While some of the rules relating to exams may seem dogmatic or didactic, they are pragmatic. James Scott uses scientific forestry as a parable for understanding state efforts to improve the human condition. The managed forest is a "geometric, uniform forest … intended to facilitate management and extraction." (Scott, 1998 (p. 18)) The more uniform and geometric a forest is, the more it can be managed and the larger it can be. The same is true of university classes. Uniformity also allows for the transmission of the maximum amount of content. The lecture schedule (Figure 3.4b) along with the 20 chapters of the textbook that accompany those lectures indicate the expectation of the "covering" of a great deal of content.

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LECTUE [sic] SCHEDULE				
Lecture	**Date**	**Day**	**Topic**	**Text Chapter**
1	8/31	M	Course mechanics/overview	Review 2/3/4
2	9/02	W	Protein structure	5
3	9/04	F	Carbohydrate/lipid/nucleic acid structure	5
	9/07	**M**	**Labor Day**	
4	9/09	W	Cell Structure	7
5	9/11	F	Cytoplasmic Organelles	7
6	9/14	M	Nuclear structure	7
7	9/16	W	Membranes	8
8	9/18	F	Transport	8
9	9/21	M	Energy: enzymes	6
10	9/23	W	Energy: catalysis	6
11	9/25	F	Glycolysis I	9
	9/28	**M**	**EXAM 1 (lectures 1-10)**	
12	9/30	W	Glycolysis II	9
13	10/2	F	Glycolysis III	9
14	10/5	M	Photosynthesis I	10
15	10/7	W	Photosynthesis II	10
16	10/9	F	Photosynthesis III	10
17	10/12	M	Cell cycle/Chromosome structure	11
18	10/14	W	Mitosis	11
19	10/16	F	Meiosis	12
20	10/19	M	DNA replication	15
21	10/21	W	DNA replication	15
22	10/23	F	Mendelian Genetics I	13
	10/26	**M**	**EXAM II (lectures 11-21)**	
23	10/28	W	Mendelian Genetics II	13/14
24	10/30	F	Mendelian Genetics III	13/14
25	11/02	M	Human Genetics I	14
26	11/04	W	Mutations I	14
27	11/06	F	Mutation II	14
28	11/09	M	Genetic Code	14/15
29	11/11	W	Transcription/translation I	16
30	11/13	F	Transcription/translation II	16
31	11/16	M	Gene Function I	16/17
32	11/18	W	Gene Function II	16/17
	11/20	**F**	**EXAM III (lectures 22-32)**	
33	11/23	M	Gene Structure	18
34	11/25	W	Gene regulation I	17/18
	11/27	**F**	**Thanksgiving Holiday**	
35	11/30	M	Gene regulation II	17/18
36	12/02	W	Gene regulation III	17/18
37	12/04	F	Recombinant DNA I	19
38	12/07	M	Recombinant DNA II	19
39	12/09	W	Human Genetics II	19
40	12/11	F	Development/Review	43
	12/18	**F**	**FINAL EXAM 7:45 – 9:45** **(100 points lectures 33-40; 75 points on lectures 1-32)**	

Figure 3.4b: Lecture schedule from BS111 syllabus

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The lecture schedule also indicated that the professors changed the order of presentation (ever so slightly) from the order in the text, and in several points, treated two chapters together. In the first lecture, Dr. Peters spoke of some big ideas related to cell biology, but the introductory chapter of the text, which goes into these ideas in more detail, was not assigned reading.

The sheet "**STRATEGIES FOR SUCCESS IN BS111**" (Figure 3.4c) included with the syllabus also stressed the "BIG PICTURE," and referred to the students' need to understand the material for their role as citizens, regardless of their majors. These emphases are clearly in line with science education reform documents (AAAS, 1989, 1993; NRC, 1996; NSF, 1996). However, while understanding the "big picture" would likely enhance chances of success on assessments, this understanding does not seem to be necessary for success. Most exam questions were fact based and could be mastered through memorization of discrete information. See the section on assessment. Furthermore, explicit mention of connections within the content of the course and between course content and the world outside of the classroom largely disappeared after the first day of the class. This is not to say that content relevant to the students' experience was not presented; only that the professor ceased in pointing out that relevance.

The 48% attendance figure is repeated in the 1999 syllabus, but the 5.5 hours of studying is not. The '5.5 hours' in the 1999 version of strategies for success is replaced simply with 'hours'. Class appeared more full than 48% on my visits, but I regrettably never made my own count.

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Figure 3.

STRATEGIES FOR SUCCESS IN BS111

The course content of BS111 may be totally new, vaguely familiar of a more in-depth analysis of similar material from your secondary education. Regardless, there are several strategies that we feel you can employ to master and retain the material, relieve stress and, actually benefit you and your education objectives (these hints may work for other course). The following **DOs** and **DON'Ts** are intended as helpful hints – clearly not all are helpful to all students.

DOs

1. **DO** attend *ALL* lectures.
2. **DO** take notes on lecture material (obviously these areas will be emphasized on exams).
3. **DO** read *ALL* assigned reading material – either before or after the lecture(s) has been given.
4. **DO** take notes from assigned reading – either add to lecture notes or use to clarify lecture notes.
5. **DO** review lecture notes/assigned reading frequently – a general rule of thumb is that 1 hour of lecture requires 3 hours of outside review, preparation.
    a. Remember, at our discretion, we may give unannounced quizzes which will count in determination of you final grade.
6. **DO** attend weekly review sessions – come prepared to ask questions, especially on areas that are confusing, complex, or you just don't understand.
7. **DO** form study groups
    a. Find 3-5 friends or classmates in BS111 and meet weekly to review/discuss material.
    b. Ask each other questions – the BEST way to learn any material is if you have to TEACH the material. If you can't answer a question clearly, then you DON'T know the material.
8. **DO** listen to lecture tapes in the Audio Library for lectures that are unclear, confusing or complex – this is especially important if you miss a lecture.
9. **DO** meet with the Ombudsperson to clarify material.
10. **DO** meet with your lab TA to clarify material.
11. **DO** review your answers (both correct and incorrect) for ALL exams.
    a. This is extremely important – by determining the type(s) of question you answer incorrectly, you can modify your study habits to overcome deficiencies (examples: if you miss many FACT questions you need to spend more time on strategies to remember FACTS).
12. **DO** integrate material from various lectures to develop your understanding and appreciation of the *BIG PICTURE.*

DON'Ts

1. **DON'T** miss lectures (and DON'T sleep, read the Midwestern NEWS or talk in lectures – last year class attendance averaged only 48% of the students).
2. **DON'T** get behind (a large amount of material is covered in the semester).
3. **DON'T** memorize answers to old exams – we do change the questions/answers.
4. **DON'T** memorize lectures independent of each other (**DO** try to determine how one lecture/concept integrates with other lecture/concepts).
    a. The old axiom (5 minutes of concentrated worry = 1 hour of study) is **NOT** true – nothing substitutes for studying – last year's students reported studying only 5.5 hours per week.
5. **DON'T** cheat – either on exams or for the lab (copying someone else's report is plagiarism and will be punished).
6. **DON'T** blame us, the instructors, for giving you a poor or unacceptable grade – you EARN the grade!

BS111 is not a weed-out course for Natural Science majors. We want you to become fascinated with biology in general and how cells work in particular. We are still learning and continually amazed at the strategies cells use to LIVE and we want you to share our amazement and capture our enthusiasm. Most importantly, we believe that the material presented in BS111 is vital to your future, regardless of career choice. To be an informed consumer, voter, citizen in modern society, you must understand basic biology. BS111 is part of that *basic biology.*

Figure 3.4c: Strategies for success in BS111 from the BS111 Syllabus.
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It was stated both in the syllabus and in the opening lecture that BS111 was not a weed-out course. Students indicated otherwise in their interviews. (See the next chapter.) This raises the question of who decides what courses are weed-out courses? In my first college level science course, I was told to look at the two people to the left and to look at the two people to the right. Of those five, we were told, only one would graduate with a degree in science. The professors in my observations at Midwestern University did not make such statements. Students did not mention seeing this in their classes (unlike students in Seymour and Hewitt's study of college science (Seymour & Hewitt, 1997)). Does that mean these were not weed-out courses?

The remainder of the syllabus handout consists of prior exams – one each from Peters and Opanashuk. Exams are discussed in the section of this chapter on assessments.

For the fall 1999 offering of the course, the syllabus was almost entirely identical. The exams included were updated to the previous year, a few typos were corrected and the lecture schedule was changed very slightly. The first 16 lectures all had the same titles. "Cell signaling " was added as lecture 17; mitosis and meiosis were combined from two lectures to one; recombinant DNA was collapsed from two lectures to one and; development was expanded from one lecture to two.

The same instructors taught the course in both the fall of 1998 and the fall of 1999. This was true for the introductory courses in both biology and teacher education, but not true for either of the senior level courses. Dr. McNair had taught the biochemistry course for a number of years. The TE401 course is part of a two-year course sequence taught by the same faculty so the faculty teaching the course rotates every year, a

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every year, allowing professors to work with a group of students over a two-year period. The reason I mention how the following year differed (or did not differ) from the year of my observations is that evolution of the system will be discussed in Chapter 7.

The BS111 Text

Campbell, Neil A. (1996) Biology 4th Edition, Benjamin/Cummings Publishers, Menlo Park, CA.

The text is a massive tome of fifty chapters and almost 1300 pages. However, the course is not intended to address the entire text. The syllabus identifies the 19 chapters addressed in lecture – chapters 2 through 19 (pages 25 – 395) plus chapter 43 (pages 963 – 992). In other words, the course covers roughly a third of the text.

The text is broken into eight units: The Chemistry of Life; The Cell; the Gene; Mechanisms of Evolution; The Evolutionary History of Biological Diversity; Plants: Form and Function; Animals: Form and Function; and Ecology. This structure, the book's size and the overwhelming amount of vocabulary make it fairly traditional though it does have some interesting features. The first three units were the focus of the course. The book has rich color diagrams and photographs. Each of the units begins with a two to three page interview of a prominent scientist in the field. Interviews (all done by the author) include E.O. Wilson, David Satcher, John Maynard Smith and Margaret Davis.

A typical day in BS111

While BS111 was both bigger and in a different science discipline[28] than any courses I had taken as an undergraduate physics major or any I had taken as a master's

[28] This is not quite true. I did take one biology course in my master's program – a field botany course. My advisor (a biologist) said that I had to take it as my certification would include both Earth and general

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candidate in Earth science education, it was still remarkably similar to many of those classes. The class was huge – almost 400 students in a single session. It was very teacher-centered and content-intensive. The professor talked and provided information via the overhead projector for the entire fifty-minute class.

The typical class followed the pattern established in the last several minutes of the first class, though the vocabulary was typically far more technical. I usually filled about four pages of notebook paper with tightly written notes that resembled too closely the notes I would have taken if I were a student. I wrote down virtually everything that was written on the overhead. My notes differed from class notes in that they also included times at which things were said and plentiful side notes. These side notes include things like, "The guy sitting ahead of me and to the left is sleeping comfortably," and, "Says you don't have to memorize – I'm just showing you so you can see the units." He often did not include units in problems throughout the course – I always added them as a result of my physics teacher background.

Most students wrote nearly constantly, presumably recording primarily what was projected on the screen in the front of the classroom. On several occasions students began writing in unison when the professor began notes on test material after describing review sessions or other non-testable material. Several times on different days I was surprised to hear simultaneous page turning as students took notes, even forty minutes into the class. In the first class, students did not ask questions though the professor did explicitly encourage the asking of questions. In later classes, occasional questions did emerge. The majority were clarifications, i.e., "What is that word?" or, "Can you move

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science and I hadn't taken a biology course since 10th grade. Field botany is significantly different from the typical courses by undergraduate biology majors here due to its applied field focus and small size.

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that back on the screen?" in reference to something written on the overhead. On rare occasions, definitions were requested, for example, "What is catabolism?"

Occasionally, Dr. Peters would ask questions of the class, i.e. "Looking at Figure 6.7 in the text, is the reaction, endergonic or exergonic?" Several students meekly responded, "endergonic." I never heard Peters ask questions that had an answer of more than two words. These questions were asked less frequently than once per class.

Several times early in the term, students were encouraged to join study groups and Peters facilitated the forming of groups through his secretary. Students were instructed to email or call and let her know if interested. On September 18, a little more than a week before the first test, she had emails from about 40 students and Peters recommended that more students contact her.

College students tended to do the kinds of things that college students occasionally do: sleeping in class, roller-blading into class twenty minutes late, or reading the newspaper during class (none of this was common, but it all did happen).

Another way in which typical classes differed from the first class was in the use of prepared transparencies. In the first class everything projected on the screen was hand-written by Dr. Peters during the class. In later classes, transparencies of colored diagrams were used regularly. The most common source for these diagrams was the course text, though other sources were used as well. Peters also drew simple diagrams on the overhead during class regularly.

The most important difference between the first class and the typical class was the disappearance of connections to biology in the popular press and explicit connections to the students' li

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the students' lives outside of BS111. Peters made several interesting connections in that first day. He only rarely made them after that.

Dr. Peters did make the occasional joke or tell a funny story. On the second day of class when he introduced the Central Dogma (stated succinctly on the test as: "DNA ➡ RNA ➡ protein") he said that he had once asked on a test to explain the Central Dogma in three words and someone wrote, "Don't eat coyote." Whether either of these is what could reasonably labeled as an explanation is another matter.

While I typically found the presentation of material less than engaging, I appreciated aspects of the lectures. On September 18, Peters asked an intriguing question (intriguing to me, at least): "Why are all cells about the same size? That is, why are they all small?" He answered the question himself. They are small, at least in part because this allows diffusion to occur more quickly. On September 21 he made an interesting statement in talking about osmosis. First, he asked, "The movement of water across a membrane is called what?" "Osmosis," was mumbled back by a smattering of students. Then Peters said, "We don't really know how osmosis works. I often give the impression that there's nothing left to discover. Not true."

Attendance dropped as the semester progressed. According to the Fall 1999 syllabus, attendance averaged only 48%. This is the same statistic as in the 1998 syllabus, but the average number of hours studying was changed. On my visits, the room always appeared to have more than half the class there, though I did not count. Perhaps the preaching that he so detested was effective. The room never appeared to have less than half the number of students who were there on the first day, although late the semester it approached this. There was a noticeable drop in attendance after the first test.

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I never observed groups of students lingering to talk with each other, however small groups of students would sometimes linger after class talking with either the instructor or the TA. Occasionally the chalkboard at the front of the room would be used in these conversations. The after class conversations were always brief, at least in part because another class started in the room at 9:00 a.m. The huge room emptied far quicker than the smaller rooms used for the education classes. Only on exam days did students talk in the hall after class in substantial numbers.

Assessment in BS111

On testing days, the class was split with last names beginning with A-Q in the C108 Gilmour Hall, and the rest heading to a lecture room down the hall. Students silently filed in and at a few minutes after 8:00, Dr. Peters gave directions and tests were distributed. Scantron answer sheets were distributed at the door as students entered. Testing began by 8:05 a.m. and the first students were finished and out the door by 8:27 a.m., shortly after the last late arrival. IDs were checked exams were turned in.

Exams were multiple choice and true false. Some sample items are shown in Figure 3.5. In this class, all students who earned 4.0 as final grades had completed identical examinations in nearly identical ways – that is, they answered most questions (at least 83% of them) with the one correct answer from the set of possible answers given.

The questions, while all objective, did vary somewhat both in structure and in kinds of objectives targeted. Some required straight memorization, as is the case with rATP, the Central Dogma and the set of questions on diffusion and transport. Others required calculation. Perhaps most importantly of the 51 exam questions on the first

11.Which of the following statements about rATP is CORRECT?

1.ATP serves as the main energy shuttle inside cells
2.ATP drives some endergonic reactions by a phosphorylated intermediate
3.The regeneration of ATP from ADP and phosphate is an endergonic reaction
4.Hydrolysis of ATP releases the phosphate group
5.All of the above are correct (*)

12.The "central dogma" is which of the following?

1.protein → RNA → DNA
2.DNA → protein → RNA
3.RNA → DNA → protein
4.DNA → RNA → protein (*)
5.protein → DNA → RNA

26.The G for an enzyme catalyzed reaction is -20kcal/ mol. If the amount of reactant is doubled, the G is:

1.-10kcal/mol
2.-20kcal/mol (*)
3.-40kcal/mol
4.+20kcal/mol

For questions 27-30, select the BEST answer from the following:

1.Simple diffusion
2.Facilitated diffusion
3.Active transport
4.All of the above
5.None of the above

27. Rate is directly proportional to concentration difference (1)
28. Movement against a concentration gradient (3)
29. Movement across a biological membrane (4)
30. Osmosis (1)

EXTRA CREDIT

51.You isolate a new chemical that inhibits DNA replication in isolated mitochondria but does NOT inhibit DNA replication in isolated nuclei. However, when the chemical is added to intact human liver cells, it does NOT inhibit mitochondrial DNA replication. Which reasons below is/are likely to account for this observation?

1.Human liver cells do not contain mitochondria
2.The chemical can not be transported into intact liver cells
3.The mitochondria DNA mutates to nuclear DNA
4.Lysosomes degrade the chemical before it can enter the mitochondria
5.2 and 4 are both possible explanations (*)

Figure 3.5 Sample items from Exam #1 in BS111.
Correct answers are indicated with either a (*) or the number of the correct answer.

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exam, only the extra credit question even approached the real-world connections that Peters stressed in the first lesson, and it does so less directly than the examples mentioned in that first lecture. The extra credit question did seem to require higher level thinking than the regular exam questions.

Summary Comments:

BS111 was an intensive, facts-based and lecture-based course. There are glimpses of connections to applications and occasionally there is attention to the notion that science is an evolving body of knowledge and that things remain to be discovered. Students were treated as passive receivers of knowledge within the classroom, but they were also encouraged to be more actively engaged in their own learning outside of class, most obviously by being encouraged to form study groups. They were also verbally encouraged to ask questions during class, but aspects of the class structure prevented students from asking questions in spite of the professors' pleas. Part of that structure was the class's mammoth size. Another important part was an absence of wait time for questions to be asked or answered.

Peters' own data showed that most students did not come to class regularly and that they did not prepare for class in ways that he believed were adequate. He verbally encouraged his students to be more than passive learners, but he provided no in class opportunities to do so and knew that the average student was not studying out of class at the level he desired. This seems like a sure-fire method to maintain the disappointing status quo.

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The class was occasionally punctuated by humor. Dr. Peters came across as a nice man who wanted his students to learn about the cell, a passion of his. His stated desire for students to work in study groups where they taught each other indicated that he had some repressed appreciation of what he referred to as "touchy-feely education" stuff. It is not in anyway radically different from the college science classes described elsewhere (Salish, 1997; Seymour & Hewitt, 1997; Tobias, 1990). There are some minor differences however. Peters stated emphatically that his class was not a weed-out class (although at least some of his students disagreed). It was a far better class than some described by Seymour and Hewitt (and I experienced as an undergrad) classes where students were told to look to the right and left and be aware that only one would survive as science majors. Peters' grades were not curved to eliminate or diminish negative aspects of competition.

Students were treated uniformly the same. The work of students with the best grades would be nearly identical. The same is true of students with poor grades, although perhaps not to the same extent. The typical student was anonymous.

Biochemistry 401: Basic Biochemistry

Catalog Information:

Credits: Total Credits: 4 *Lecture/Recitation/Discussion Hours: 4*
Prerequisite: CEM 252 or CEM 352 (Organic Chemistry II)[29]
Restrictions: Not open to students in the Biochemistry or in the Biochemistry/Biotechnology major.
Not open to students with credit in: BCH 200 or BCH 461[30]

[29] Prerequisites for the prerequisite include only chemistry and mathematics classes, though virtually all biology teacher candidates would have completed BS110 and BS111.
[30] BCH200 was Introduction to Biochemistry and BCH461 was Biochemistry I. These were courses required for biochemistry majors.

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Description: Structure and function of major biomolecules, metabolism, and regulation. Examples emphasize the mammalian organism.

Schedule Information:

Maximum enrollment: 285
Number enrolled: 181
Class meeting times: 8:00 a.m. – 8:50 a.m., Monday, Tuesday. Thursday, and Friday.
Location: C103 Kreher Hall[31]
Instructor: James McNair

The Instructor:

James McNair was seventy something and came across as slightly eccentric. He was thin, rode his bicycle to class and wore a visor during class to shade out the bright studio lights. One leg of his pants was often in a bicycle clip throughout class. He smiled and made the occasional joke. He was a biochemist who researches biochemistry of the eye – perhaps explaining the visor.

In our first meeting, he spoke of his history, coming back to school after completing service in World War II. He warned me of the dangers of alcohol and other intoxicants and said how he had wasted some of his earlier days. I wondered if something in my appearance or demeanor acted as a catalyst for the advice and concluded that he offered this kind of advice often and without anything to provoke it.

He also shared his frustration with teaching classes of this size. He believed that the way he taught the same course in the summer to a class of approximately 20 was far superior. The summer course was part of a program for minority students. In the summer, exams were all essays. During the year, exams would be all true and false. And

[31] This was the location listed in the course schedule. Class was actually held in an Instructional TV classroom and broadcast to the room listed on the schedule. The ITV room accommodated about 90 students and was typically half full. The listed classroom had fewer than 10 students present during my two observations there.

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the setting made it so that many students would only be seen in person at the exams, as the majority watched on campus cable, in the library or not at all.

The rooms for BCH401

As noted in Chapter 2, there are a variety of ways to "go to class" in BCH401. On the first day, class met in the large auditorium in the wing of one of the 60s era dorm complexes. The auditorium (C102 Kreher Hall) easily held the nearly 200 students who arrived. This classroom is also where tests were taken. This classroom would be the only classroom many students would see live – while most students did not come to class as they watched it on cable or on tape, every student should have come to class for the seven midterm exams and the final exam. The room is described in some detail below and diagrammed in Figure 3.5a.

On that first day of class, students were notified that class would be held in one of the instructional television (ITV) classrooms in the communication arts building. That classroom was also an auditorium, but a considerably smaller and newer one. It could accommodate approximately 90 students. Class would be both taped and broadcast live from this ITV classroom. It would be broadcast to the large auditorium listed in students' schedules (C102 Kreher), on campus cable and on one of the university television stations carried by local cable companies in the cities and towns surrounding the university. Not only would it be broadcast live, but it would also be rebroadcast at 4:00 p.m. The tapes would also be available in the main library's media room by 7:00 p.m.

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C103 Kreher Hall

The room was a large auditorium, similar to B108 Gilmour Hall where BS111 met. The room was a regular octagon, with walls cutting off the front and back corners – it appears to be a regular octagon from outside the building (it is a separate wing), but a decagon from the inside. See Figure 3.5. From the inside, the octagon has been modified by the addition of a screen cutting across the front corner and a projection room cutting across the back corner. The room is approximately 60 feet across, from flat wall to flat wall. The side sections run right to the wall, unlike in the BS111 classroom. Like B108 Gilmour, this classroom was considerably larger than the home I lived in during my observations. It was still somewhat smaller than the other lecture hall, however.

Like in Gilmour Hall, the floor gradually sloped to the front so that the professor stood in an area about four feet below the doors at the back of the room. The color scheme of the room was unique. Most of the walls were concrete block painted off-white. The front three sides are paneled in rich wood you see here and there on university campuses that include forestry programs. The seats were upholstered in navy blue, with a few either reupholstered or brought in from a different auditorium. Those that were not navy were lavender.

In the front of the room were two overhead projectors pointed toward the large screen that dominated the front wall -- approximately 20 feet long. The room does not have the same obvious handicap access as the BS111 room, one of the indications that this room had not been recently renovated. There is a large 1960s era framed photo of the football stadium on the wall above seats on the south side. Two university banners hang at the end of the south paneled section and one on the end of the north paneled ection of w...

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Figure 3.5
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section of wall. There was a bulletin board at the back of the room that hawked notes for sale and provided information about upcoming meetings, primarily of Christian student organizations. Other details are shown in Figure 3.5.

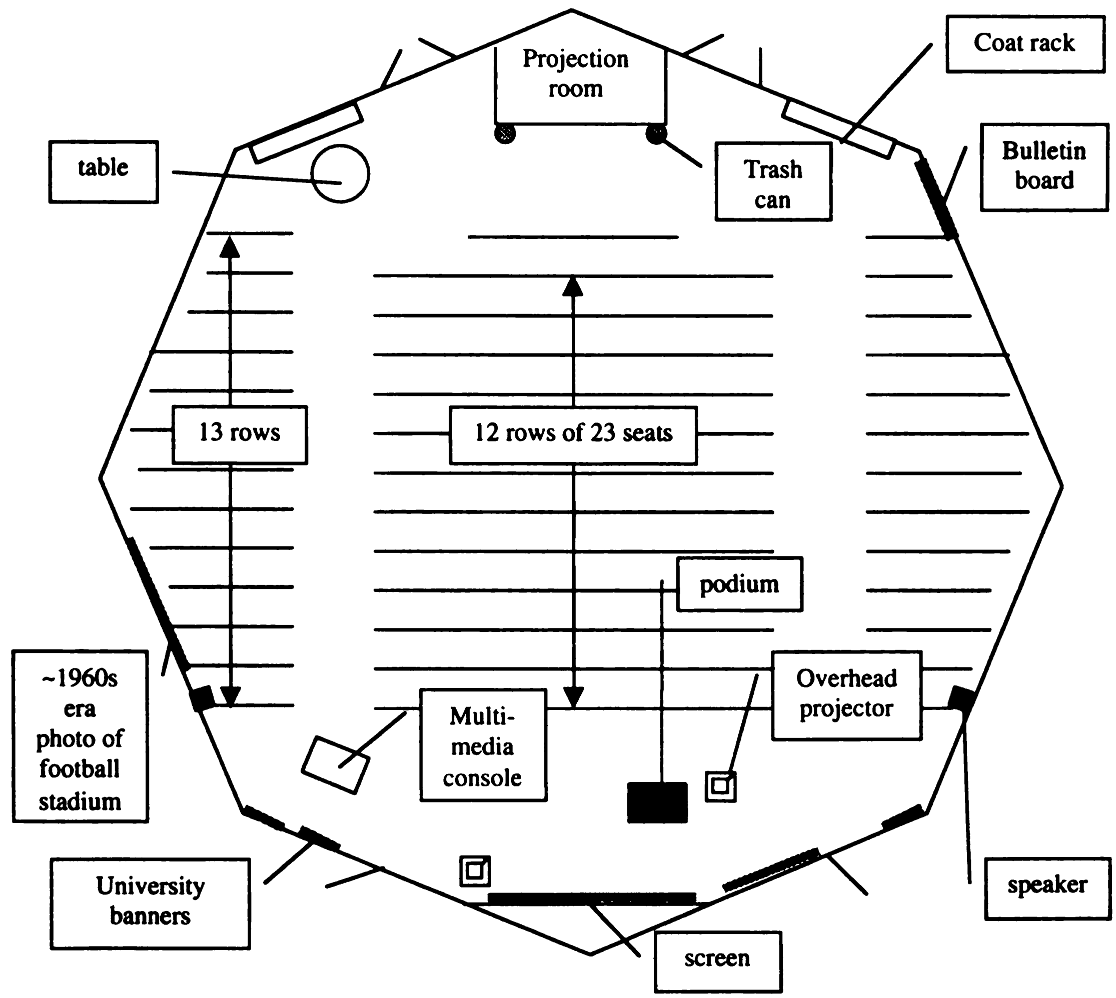

Figure 3.5 C108 Kreher Hall:
Scheduled classroom for BCH401. This is where class met the first day and took exams. The class was also broadcast live to this classroom on the projection screen. Few students came to watch the broadcast that was also available on campus cable. The drawing is not to scale.

In other words, this is a large university lecture hall that has likely not seen renovation or remodeling (other than replacing broken chairs with those from other classes m

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classrooms) since its construction some thirty years ago. It is not a pleasant room, nor is it distinctly unpleasant. It does, however, have a sort of dingy feeling.

108 Communication Arts (ITV Studio Classroom)

The room was a small auditorium with nicer appointments than the other two auditoriums. It was obviously newer than C108 Kreher and there was more invested in the room, not only in terms of the audiovisual and broadcast equipment, but also in the wood paneling and more comfortably upholstered seating. Like in the other auditoriums, the floor was sloped (but more steeply) and all the seats pointed to the lecturer and the large screen for the projector that dominated the front wall. Television monitors were high along the sides of the room. McNair used an opaque projector rather than a standard overhead projector for transparencies. This was easier to read on television monitors (and on the cable broadcast of the class) than overhead projectors. Again, this classroom was clearly designed for, and almost mandated, lecture (Orr, 1999).

The first week of BCH401...

Since this class was held at the same time Mondays and Fridays as BS111, I was not able to attend first sessions for both classes. The first class was not broadcast. I attended the second and third (Tuesday and Thursday) classes in the first week for BCH401.

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Lecturer: James McNair, Assistant: Wong, Yanping

STUDENT SURVEY

Your name and student number: ________________________________

Your class: (Sophomore, junior, senior, grad student, Life-long education, auditor or whatever:) ________________________________

Your intended or past degrees: ___________________________

Your career goals: ____

What grade do you expect to earn from this course? _____________

Besides the grade, what do you expect to get out of this course?

Figure 3.6: BCH401 Student Survey.
This form was completed in the first week of BCH401. It was included as part of the course-pack; placed after the syllabus and general course information and before the readings and course notes.

In the first session, a course overview was given. The students were also asked to complete a form that is reproduced in Figure 3.6. This form was included in the course pack and was described thusly: "STUDENT SURVEY: Please fill out the student survey on the next page and give it to the course assistant. It provides the instructor with important information on your background and motivation." This immediately indicates an important difference between Peters and McNair. McNair sought out information from his students on something besides knowledge of course material.

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The first class also included the reading of an article from the journal *Science* about a recombinant antigen that shows promise for the production of oral immunizations from potato plants (Haq, Mason, Clements, & Arntzen, 1995). Again, an immediate important difference between Peters and McNair: Peters briefly described several important scientific breakthroughs related to the field and their applications. McNair had students spend time focused on a single one of these breakthroughs. This occurred again in the second class. This difference may be due in part to the nature of the content taught and the text used. However both texts made clear attempts to convey the ecological and health relevance of the content.

The second class session was the first I observed. It was also the first in the ITV classroom. When I walked in five minutes before 8:00 a.m., Chet Atkins's finger style guitar version of *Borsalino* (Atkins, 1997) was playing gently over the classroom's high quality sound system. Acoustic music such as this was regularly played both in the ITV classroom and over the campus cable prior to the start of class. For me, the music coupled with the nicer (and smaller) classroom set a more relaxed tone for the start of class than in BS111.[32]

Students were scattered about the small auditorium and several were reading *The Midwestern News,* the campus newspaper. When class began five minutes later, perhaps two thirds of the 90 seats were occupied. The music faded and newspapers were folded and put away as Dr. McNair stepped up to the podium and began to speak.

Other than being slightly older, students did not appear categorically different from those in BS111. Again, most wore shorts, some wore baseball caps, and a few

[32] This, of course, is an individual preference. The music being played was a CD I had recently purchased. It seems unlikely that most students would recognize this music.

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appeared unkempt. While there was no one with magenta hair in this class, the appearance of the students looked to be a typical cross-section of college students in 1998. The same description, as is no real surprise, also applies to the students in both of the education classes.

Class began with the sharing of the phone number for the studio – after some confusion the number was shown on the bottom of the television monitors that showed the broadcast version of class. Students were encouraged to phone in questions from home. Dr. McNair made a joke about his call-in program. Class then focused on the reading assigned for the previous day, the *Science* article described briefly above. Lecture moved to a specific diarrhea-causing pathogen and the science behind it.

In talking about the antigens, McNair asked, "What is the control in this experiment?" He waits several seconds before answering his own question. A few minutes later, I heard for the first time a student comment directed to an instructor. It was "Your notes are off the screen." McNair apologized and fixed the problem, only to have it recur in a matter of minutes, when he moved onto the next diagram. See Figure 3.7. When he wrote off screen this time, the comments were more general and no one asked him to bring the notes back on screen.

The lecture topic then moved to the reading for this class – an article by Jane Brody from the New York Times (Brody, 1990). As the transition took place, the camera remained on the class; as Dr. McNair moved onto the next topic, the camera came back to him and remained focused on him for the remaining twenty minutes of class.

This next article described a program to identify mothers and potential mothers who were treated as infants for phenylketonuria (PKU), an inherited metabolic disorder.

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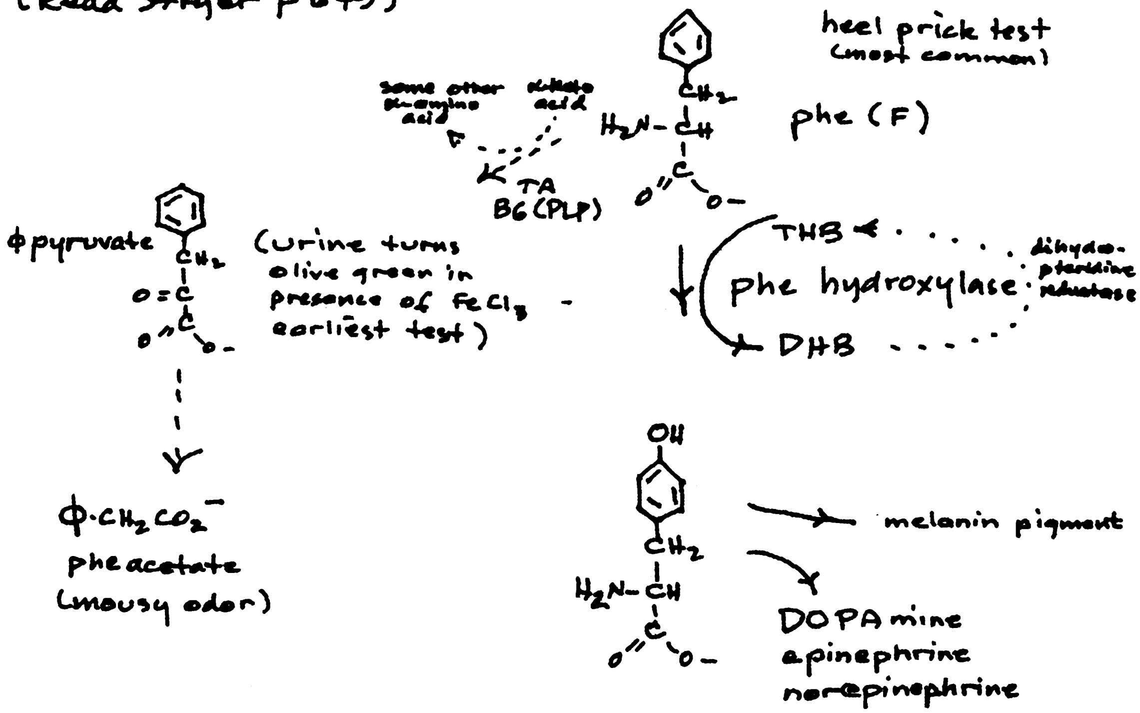
Some basic science background for the Jane Brody PKU article (Read Stryer p 649)



- Human phe H'ase is a monomer ~54 kDa (~478 amino acids)
- PKU is genetically & phenotypically heterogeneous
- phe/tyr blood ratio used to be used as test for heterozygote ($\bar{x}$ ~ twice normal)
- prevalence of heterozygote ~ 0.02
- IQ penalty
- PCR

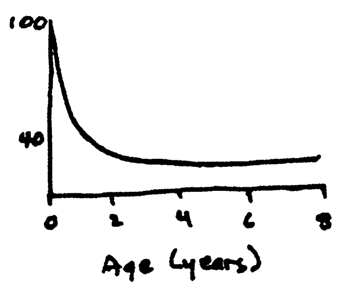


Figure 3.7 Notes from the BCH401 course-pack describing the biochemistry behind issues described in a New York Times article on PKU (Brody, 1990).

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As children, a simple heel-prick test diagnosed these women as having PKU and they were placed on protein restricted diets that prevented mental retardation. In late childhood, most of these women went off their special diets. As potential mothers, doctors believe they should be back on these special diets to prevent their children from suffering from problems related to their unusual metabolisms.

Dr. McNair described the biochemistry of PKU using his prepared notes that were part of the course-pack. These are shown on the monitors, but are not legible unless you are following along with the course-pack. This particular set of notes, reproduced in Figure 3.7, consists of hand-written notes with diagrams and a graph, all hand-drawn. Notes for later lectures typically included photocopies of diagrams from the text or other sources as well as hand-drawn diagrams.

McNair notes that students need to memorize the structure and the codes shown in the notes. At 8:50 a.m., McNair said, "I'm going to quit there and finish up tomorrow." Chet Atkins comes over the speakers and the classroom/studio rapidly empties except a few students who linger and ask a question or two.

I walked down to talk with Dr. McNair and overheard part of one of these conversations. A student was asking about what was necessary to succeed in the class. Dr. McNair responded that a typical student should plan to spend 15 to 20 hours outside of class time to do well in the class.

The BCH401 syllabus

The syllabus is included in the course-pack. The course-pack includes a cover page with the cost ($19.64), the course number (but not course name) and the instructor's

BCH401 Lecture and Test Schedule, Fall 1998 Lecturer: James H. McNair, Assistant: Wong, Yanping			
Date		Day	Topics
31	Aug	Mon	Introduction; Science article on recombinant antigen
1	Sep	Tue	NY Times article on PKU
3		Thu	Basic concepts of biochemistry and molecular biology
4		Fri	Amino acids
7		Mon	***Labor Day Holiday***
8		Tue	3 inborn errors of amino acid metabolism
10		Thu	TEST 1 (70 points) True-False and Multiple Choice
11		Fri	Protein structure
14		Mon	Hemoglobin; biosynthesis of heme
15		Tue	Hemoglobin structure, function and malfunction
17		Thu	Enzymes: LDH; reaction coupling; hydrogen shuffles
18		Fri	Enzyme nomenclature and kinetics
21		Mon	Allosteric control of enzymes; equilibria
22		Tue	Enzyme thermodynamics
24		Thu	TEST 2 (100 points) True-False and Multiple Choice
25		Fri	Carbohydrate absorption
28		Mon	Glycolysis and gluconeogenesis
29		Tue	Mitochondrial origin, structure and functions; FAO
1	Oct	Thu	Citric cycle; ATP yields of FAO, glycolysis
2		Fri	Ketone bodies; fatty acid synthesis; its regualtion
5		Mon	Fatty acid nomenclature and origins; eicosanoids
2	[sic]	Tue	Triglycerides and derivative lipids
8		Thu	TEST 3 (100 points) True-False and Multiple Choice
9		Fri	Cholesterol biosynthesis and derivatives
12		Mon	Bile acids and bile
13		Tue	Plasma lipoproteins
15		Thu	Plasma lipoproteins
16		Fri	Steroids
19		Mon	Steroids
20		Tue	Steroids
22		Thu	TEST 4 (100 points) True-False and Multiple Choice
23		Fri	Urea cycle; related amino acid metabolism
26		Mon	Creatine; ketogenic/glucogenic amino acids; SAM
27		Tue	Glycogen metabolism
29		Thu	Glycogen metabolism
30		Fri	The hexosemonophosphate shunt
2	Nov	Mon	Purine biosynthesis

Figure 3.8a Lecture schedule from BCH401 syllabus.

3		Tue	Purine catabolism
5		Thu	TEST 5 (100 points) True-False and Multiple Choice
6		Fri	Purine salvage; clynical problems
9		Mon	Pyramidine biosynthesis
10		Tue	Structure of DNA
12		Thu	DNA replication
13		Fri	DNA mutation and repair
16		Mon	Gene rearrangements
17		Tue	Gene rearrangements
19		Thu	TEST 6 (100 points) True-False and Multiple Choice
20		Fri	Gene rearrangements
23		Mon	Transcription
24		Tue	Transcription
26		Thu	***Thanksgiving***
27		Fri	***Holiday***
30		Mon	Transcription
1	Dec	Tue	Transcription
3		Thu	Transcription
4		Fri	Translation
7		Mon	Translation
8		Tue	Translation
10		Thu	TEST 7 (130 points) True-False and Multiple Choice
11		Fri	To be announced
18		Fri	7:45 – 9:45 am FINAL CUMULATIVE EXAM – TRUE-FALSE AND MULTIPLE CHOICE QUESTIONS

Figure 3.8a Lecture schedule from BCH401 syllabus (continued).

name. The first page is a title page that repeats the information from the cover page and adds the course assistant's name. After the publication permissions' page is the course schedule, reproduced in Figure 3.8a.

Further select excerpts from the syllabus are included in Figure 3.8b. The next section of this chapter includes a description of the textbook taken from the syllabus. The grade expectations outlined in the syllabus for BCH401 are quite similar to those in BS111, so similar that it was not necessary to reproduce them. In BS111, an 83% is a 4.0; in BCH401 an 85% is required. The remainder of the scale varies by about the same amount between the two courses.

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The course grade is based exclusively on exam grades, as in BS111. However, students may replace their average grade with the final exam grade if the final exam grade is higher. The exact text explaining this policy is reproduced in Figure 3.8b. The syllabus also describes that students would be given answer keys to the exam in exchange for their Scantron answer sheets when they leave the exam. This, along with a paragraph about cheating, and "even the *appearance* of cheating," are the only points in the syllabus that convey a negative tone. The paragraph closes with "Both/all parties will receive zeroes, so keep completely to yourself." So, even here where the message is strong, the tone is still conversational rather than preachy as in the BS111 syllabus's lists of **DOs** and **DON'Ts**, perhaps as a result of more mature students, perhaps a result of different pedagogical approaches.

Unlike in BS111, students are allowed to make up exams. "Written (essay-type) makeup exams will be given at the end of the semester to students who miss midterms. You should understand, however, that the essay tests examine your knowledge in more detail than multiple choice/true false tests, and the typical student performs more poorly on essay tests."

The syllabus also included information related to the taping and broadcast of the class. The campus and local cable channels are provided with the caveat that it may be necessary to verify channels. It is also noted that a portable phone will be available from the course assistant in Kreher Hall, so questions may be called in from the lecture hall. The syllabus ends with the instructions for the student survey described above.

CONTENT: This is a one-semester introductory course in biochemistry and molecular biology. Because the material in this discipline of biology has grown with such enormous rapidity, it has become impossible to address every topic that used to be covered in such a course. Therefore the instructor has consciously omitted many topics and abbreviated others, in order to concentrate on fundamentals of protein, carbohydrate, lipid and nucleic acid metabolism. For example, vitamins despite their importance in metabolism are mentioned only when a vitamin-derived compound participates in a reaction included in a lecture. Students are encouraged to read the textbook on their own to satisfy their curiosity about many topics not raised in lectures. However, students should also be aware that a number of lecture topics are not treated in detail, if at all, in the text.

TESTS: As you can see from the lecture schedule above, there are 7 semi-weekly tests and a cumulative final exam. **All of the tests will be given in room C108 Kreher Hall**, which is large enough to allow alternate seating of students...

... The cumulative final exam is intended to allow any student to improve her/his grade: if you score a 4.0 on the final, you will receive a 4.0 for the course. However, if you do better in the course than on the final, you will receive the better of the two grades. While this may sound a little like blackjack, it is designed to sustain your motivation, even when things look bleak! Students learn subjects at different speeds. Some who learn rapidly remember very little in the end, while some who learn more slowly retain a great deal and understand more. If you are inclined to gamble, you can in theory skip all the semi-weekly tests and just take the final. For the average student, however, this is a formula for disaster.

PRACTICE QUESTIONS are included at the end of every unit in the course-pack. There are no required recitations for the course, and no take-home problem sets. At the back of the course-pack you will find keyed copies of Spring 1998 tests.

MISTAKES IN LECTURES OR ON EXAMS: If you feel the instructor has made a mistake in lecture, please call it to his attention. Correction will be made during a subsequent lecture. Grade changes will be made if the instructor's mistake on an exam warrants.

OFFICE HOURS (HELP SESSIONS): These will be held in room 114 Biochemistry Building from 3:00-5:00 pm Monday and Tuesday. There will also be E-mail office hours at any time you log on; the instructor will try to respond with 24 hours of receiving you questions EXCEPT on Wednesday s preceding Thursday midterm exams, when he will not respond. The E-mail address is McNair401@----. If you have obviously skipped a lecture or not done your homework before asking for help, he will tell you so and direct you back to the videotape. With over two hundred students asking E-mail questions, time is precious. You may also arrange office hours with the course assistant at mutual convenience.

Figure 3.8b: Excerpts from the BCH401 Basic Biochemistry Syllabus.

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The BCH401 Text and Course-pack

Biochemistry 4th Edition by Lubert Stryer, published by W. H. Freeman. (Stryer, 1995)

The text is described in the syllabus as follows:

> "TEXT: While there are texts with better illustrations and more information, Stryer does a good job of focusing on basics, while keeping up with the important changes which drive thinking and research in the field. There are no formally assigned readings, but it would be prudent for you to read corresponding material in the text. You usually can find it either by using the table of contents or the index. Most of the figures and tables in the course pack are copied directly from Stryer, although other sources are also used."

Clearly, BCH401 is less textbook-driven than BS111. This is clear not only from the way the text is described here, but also from the course schedule's lack of explicit references to the text. This approach is more in line with reforms suggested by the TIMSS Reports that suggest textbooks drive the curriculum too much in American K-12 science education and that they should instead be used more as reference books than as curriculum.

The course-pack is 268 pages, beginning with a sheet of reproduction permissions for diagrams from texts and articles as well as the two articles used in class during the first week. This sheet is followed by the course syllabus described above, the student survey shown in Figure 3.6 and then by the two articles used in the first week of classes. The remainder of the course pack is a collection of notes to be filled in during lecture and study, practice questions for most chapters or other readings and for lectures. The course-pack ends with all seven midterm exams and the final exam from the previous spring. The exams make up the last 50 pages of the course-pack.

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The set of practice questions for "Inborn Errors of Amino Acid Metabolism, Protein Structure and Post-translations Modification etc" is shown in Figure 3.9. This is the set of study questions for the class focused on in the description of a typical day below. There were study questions for each set of daily notes in the coursepack.

A typical day in BCH401

Class often began informally with McNair talking about the weather or other pleasantries. When it was nice, he talked some about his garden. This typically took but a minute and he would then delve into the content for the day.

It was not unusual for him to speak some of the history of our understanding and how conceptions in biochemistry had changed. He noted that when he came to Midwestern University, introns had not yet been discovered and that all enzymes were believed to be proteins. It is now known, he said, "Believe it or not, some of them are RNA."

The coursepack contained no further articles from the popular press beyond the Brody article used in the first week (Brody, 1990)[33], so here too the explicit connections to the world outside of class diminished (but only slightly). One example of a connection was when McNair made explicit connections to Parkinson's Disease and mental retardation while describing inborn errors of metabolism and revisiting PKU. That day, September 11, was particularly interesting. For one thing, much of the class addressed urine. Something we all know at least a little about.

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[33] In fact, there were no further articles in the coursepack at all.

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Practice Questions on Inborn Errors of Amino Acid Metabolism, Protein Structure and Post-translations Modification etc [sic]

Draw and map the metabolic pathway of the first 4 compounds in normal human phenylalanine metabolism. On your map, indicate the basis for PKU and alcaptonuria.

Draw the structures and map the pathway involved in normal banched-chain [sic] amino metabolism. On your map, indicate the basis for maply [sic] syrup urine disorder.

Write the reaction for a typical transanimation. Draw the structures of Vitamin B6 and pyridoxal phosphate.

Identify and explain the principal characteristics of the peptide bond.

Draw the peptide SEKDEL.

Write the codons for the start and finish of eukaryotic transcription.

Draw the following post-translational protein modifications.

A. proline 4-hydroxylation, lysine δ-hydroxylation
B. glutamate γ-carboxylation
C. Serine, threonine and tyrosine O-phosphorylation
D. (asparagine) N-linked glycosylation
E. lysine/lysinal cross-linking
F. lysine oxidative deamination
G. α-amine or cys-SH fatty acylation
H. serine or threonine O-glycosylation

Figure 3.9: Practice Questions for the BCH401 class described below.

Early in class, I noted that the girl sitting next to me was fighting sleep with frequent severe head-bobs. This kind of behavior was common. When I remembered to look for it, I could virtually always find someone asleep in either BCH401 or BS111. I also noticed that she still had the "L" sticker on her shirt, indicating that she had recently purchased the size-large shirt. I suspected a hangover.

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At 8:12 came the first question (according to McNair) in two weeks. He was very pleased to be asked and reminded folks at home to call in (this never happened during my observations). The question was, "What does that say?" He was using a Sharpie-type marker that was losing sharpness. Much of what was written that day was very hard to read.

When describing alcaptonuria, a very rare hereditary disorder that is characterized by the excretion of large volumes of dark colored urine, he was asked a more substantive question that sought an explanation about a statement just made related to blockage in alcaptonuria. The student said, "You're saying it causes a blockage. A blockage of what?" McNair responded, "A metabolic pathway is not completed because of a deficiency of the enzyme homogentisic acid oxidase; therefore, the further metabolism of homogentisic acid is prevented. Perhaps blockage isn't quite the right word."

It is interesting to note that this question, which actually sought explanation, passed without comment whereas the question about an illegible word received encouragement. Of course, that encouragement may have served as a catalyst for this question.

When McNair flipped the page he found that his pen had bled through so he said "I'll need to talk you through the next page of notes." Then he redrew some of what was in the notes – a chemical structure associated with Maple Syrup Urine Disorder. This genetic problem produces "∝ keto acid DH (speaking as he wrote), which makes the urine smell and taste sweet, like maple syrup."

McNair continued writing notes mostly in the form of chemical structures. He broke into song as he drew on the overhead the hexapeptide MYPAIN. He sang (to no time I rec

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tune I recognize), "My pain is your pain," and talked about a colleague who sang the sequence. I think, for the viewers at home, this redefined edutainment.

As he wrote with the not-so-sharpie, his diagram contained much that was illegible. No one commented on this, perhaps because they could read chemical structures better than I, but I suspect that did not address the entire audience in the lecture hall or watching from home. Of course, many were not watching in real time, so they could not ask questions. I drew about a third of the molecule before giving up because I could not read enough of his writing to hope to be able to translate this when I got back home and had time to pour over the notes. The coursepack page with my notes on MYPAIN is shown as Figure 3.10.

Much of the class was far over my head, but I saw him connecting applications of the science he was teaching. Observations in BCH401 became more difficult for me as the semester progressed since much of the language was foreign to me. The following was said as part of the same lecture described above, and it reflects common terminology used in the class: "Hyperalinemia. High levels of valine. It doesn't even transaminate."

McNair said, "That's the end of the amino acid disorder discussion." He asked a few questions that he waited a few seconds for answers and answered himself. He told the students to "anticipate confusion" as they worked on the study questions. He then drew a pair of cystines in a disulfide linkage, quickly said a bit about that and moved on.

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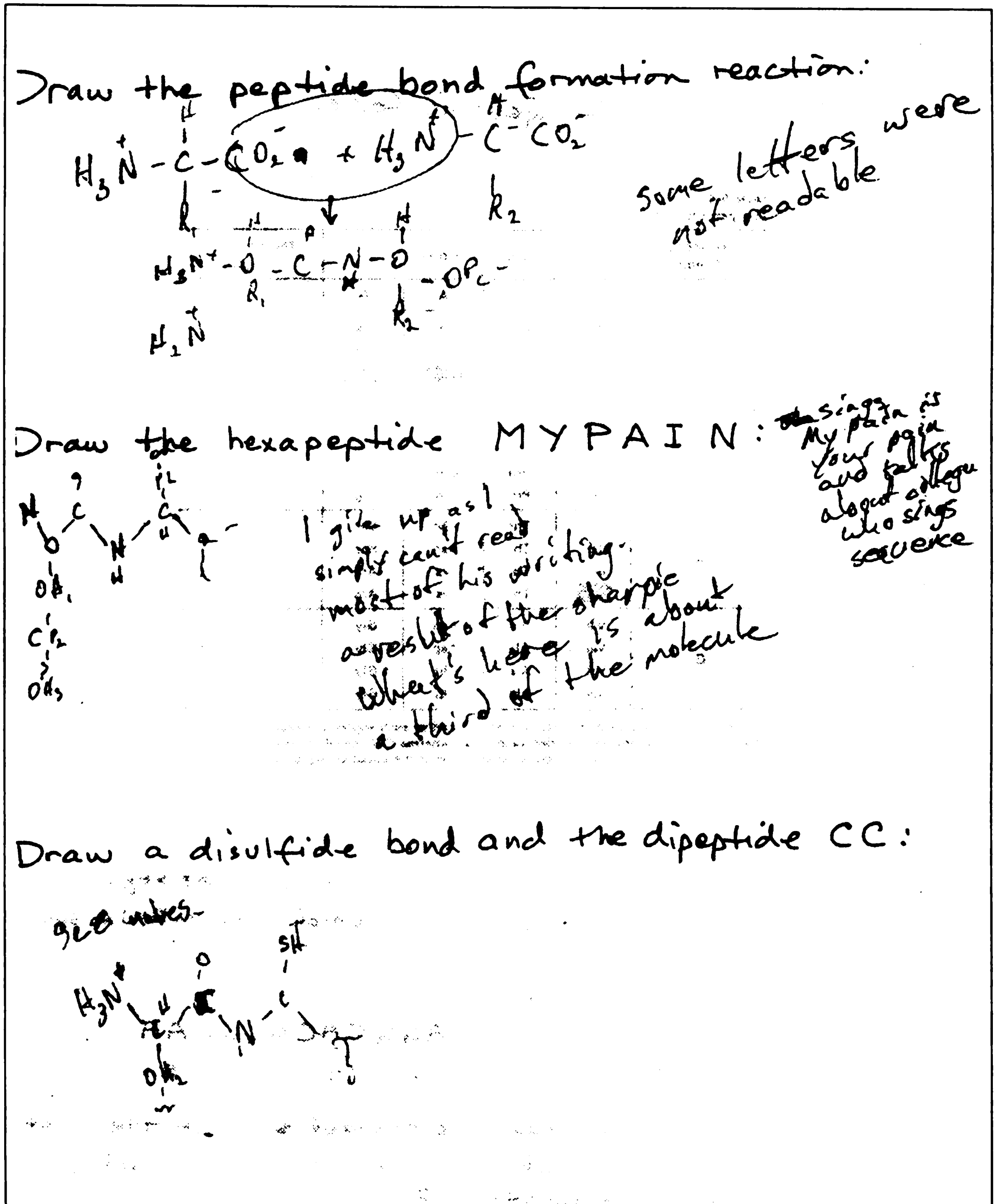

Figure 3.10: One of five pages of notes from the BCH401 course-pack for 9/11/98. This includes the notes that I wrote in the coursepack during class. I took notes both in the coursepack and in my own notebook. Notes in my notebook were field notes, as were some of the notes above. While the notes are somewhat difficult to read, they show the nature of the coursepack.

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I was somewhat relieved when at the end of that class of September 11, McNair moved on to a table in the coursepack reproduced from the text (Stryer, 1995). The table was labeled "The genetic code," and McNair walked the class through the algorithm to write peptide sequences. Algorithms I can follow and I actually was able to crank through the example ahead of him. I had no idea what it meant, however.

He closed class by saying, "Time to go back to bed!"

The frustration I felt in getting a handle on what was going on was shared by at least some of the students. In the spring semester when I dropped in on Andy Frank's section of TE402 to talk to students about interviews, two of the students who were taking BCH401 along with TE402 came in and asked if I was still looking for people to interview. They were clearly frustrated. They had taken a test that morning and were dismayed about the material they had been expected to memorize. One of the two women took out her BCH coursepack and said, "Look at what we're expected to know!" She almost violently flipped through page after page of molecular structures, saying that they all had to be memorized. Her fist pounded the table with each page. Her colleague made the point that she would never need this material again for the rest of her life, and if she did, she could look it up!

Over the course of the semester, I went to the lecture hall in Kreher once for lecture (on the big screen) and once for an examination. By the time class had started, there were eleven in the room besides me. One was the TA. They watched campus information scroll down the screen before the lecture began as acoustic music (again, Chet Atkins) played over the sound system. A drop in attendance was evident in the studio classroom in the first week as students tuned into class in other ways, watching from ho

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from home or watching the tapes in the library. This visit was early in the term, and I suspect attendance dropped here too.

Assessments in BCH401

Tests took place in C108 Kreher every two weeks. They were objective tests (again, much to Dr. McNair's dismay) and almost exclusively true-false. He would have preferred asking the kinds of questions in the study question sets on the exams. Both of these forms of assessment required considerable memorization for the student to be successful as is common for biochemistry classes. As the term progressed the tests included more molecular structure.

The syllabus has the following information related to tests:

> "TESTS: As you can see from the lecture schedule above, there are 7 semi-weekly [sic, the tests were biweekly] tests and a cumulative final exam. **All of the tests will be given in room C108 Kreher Hall,** which is large enough to allow alternate seating of students. The total possible points on the semi-weekly tests are 700. If you score 595/700 (85%) you are guaranteed a 4.0 in the course. 525 points (75%) guarantee you a 3.0, and 455 points (65%) a 2.0. The cumulative final exam is intended to allow any student to improve her/his grade: if you score a 4.0 on the final, you will receive a 4.0 for the course. However, if you do better in the course than on the final, you will receive the better of the two grades. While this may sound a little like blackjack, it is designed to sustain you motivation, even when things look bleak! Students learn subjects at different speeds. Some who learn rapidly remember very little in the end, while some who learn slowly retain a great deal and understand more. If you are inclined to gamble, you can in theory skip all the semi-weekly tests and just take the final. For the average student, however, this is a formula for disaster."

It is worth noting that neither of the science classes I observed curve exam grades.

Again, answer keys are exchanged for completed computerized answer sheets as students exit each exam.

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Each exam began with a structural description of the exam itself: "There are four pages and 56 question on this exam: 52 of the questions are worth 1 point and four others are worth more: Question 12 (3 points), 24 (5 points), 41 (5 points). The total possible points is 70." Some sample items are shown in Figure 3.11

In the ELISA test employed by Haq et al [1995] to quantify antigen production by plants, (TRUE = 1, FALSE = 2)

8. the antigen was LT-B (T)
9. the first antibody was raised by injecting mice with LT-B (T)
10. The second (enzyme-linked) antibody was anti-LTB (F)
11. The antigen was trapped (immobilized) by excess ganglioside (T)

12. (3 points, TRUE = 1, FALSE = 2) subsequent to the Haq et al [1995] experiement, children were successfully immunized at the University of Maryland Medical School against *E coli* enterotoxin LT-B by gavage with recombinant antibodies to LT-B (F)

The structure at right is accurately described as TRUE=1) or (FALSE=2)

31. deaminated cytosine (F) ADD DRAWING
32. methyluracil (T)
33. thymine (T)
34. found in transfer RNA but not messenger RNA (T)

Figure 3.11 Excerpts from test number one in BCH401.
Correct answers are indicated in parentheses.

Later tests included more elaborate molecules. An example from exam number four is a multiple choice question with a diagramed molecule that reads: "(4 points) The structure at the right is ① phosphatidylcholine; ② phosphatidylserine; ③ phosphatidylethanolamine; ④ phosphatidylinositol; ⑤ cardiolipin" Tests tended to have a few questions that directly addressed diseases and disorders, but the vast majority did not explicitly have connections to common experience that would be recognized by a layperson.

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The cumulative final exam is described in the syllabus and in the syllabus section above. As described above, scoring a 4.0 on the cumulative final will result in a 4.0 for the course. This option is the only way in which students with final grades of 4.0 could differ and McNair made clear that it was fairly unlikely for a student to fail or skip midterm examinations and earn a 4.0 on the cumulative final examination.

Summary Comments for BCH401:

Like BS111, Basic Biochemistry was an intensive facts-based and lecture-based course. However it was different from BS111 in important ways. Connections to "real world" applications were more common. The amount of memorization required was also greater. The role of the textbook was less than in BS111. Like BS111, the course was punctuated with humor and the instructor came across as quite likeable although perhaps a bit eccentric.

Like in BS111, students were treated as if they were a homogeneous group. Their most common class activity was note taking – this and breathing seemed to be the only appropriate classroom activities. In fairness, questions were encouraged but rare. Most students had extraordinarily limited contact with the professor, as most students did not come to class at the same time or in the same space as the person teaching the course. In spite of the professor's wishes to work more closely with the students, he saw the class size as being an insurmountable obstacle for a close working relationship with most students and consequently the relationship hardly existed at all.

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Teacher Education Classes:

There were a few basic logistical differences between the science courses observed and the education courses observed. First, both education courses had small enrollments. TE250 had 32 students. TE401 met in subsections of about 20; the total enrollment for the course with three instructors was near 60. As noted above, the science classes had well over one hundred students in the smaller of the two classes. Second, the meeting times of education classes were twice the length of the meeting times of the science courses, though they were typically less frequent.[34] While Teacher Education classes were twice as long, the descriptions below are not twice as long as the ones above. The nature of what happened in the two different kinds of classes was distinctly different which led to a different kind of description. Third, in the education classes, faculty introduced themselves using their first names and students commonly referred to faculty by their first names. In the science classes I observed the faculty were never referred to using any name. If students said anything loud enough for the rest of the class to hear, it was always directed toward the professor, so names were not needed. Consequently, I tended in my writing to use first names for education faculty and refer to science faculty by their last name or title. This follows the practice of the seniors in their interviews.

There were multiple sections of TE250, unlike either of the science courses. TE401 also had multiple sections with the same course name, but each targeted different secondary school disciplines. The elementary teacher candidates took a course of the

[34] TE401 has unique structure that is explained in the section on that course. It has a science component, a reading in the content area component and a field component in the schools. Depending on how you look at TE401, it could be said that it met two, three or five times per week and carried six semester hours of credit.

same name. Like for secondary teacher candidates, this was the first course of a four-course sequence. For elementary majors the sequence covered all core disciplines.

Teacher Education 250: Human Diversity: Power and Opportunity in Social Institutions

Catalog Information:

Credits: Total Credits: 3 *Lecture/Recitation/Discussion Hours: 3*
Prerequisite: none
Description: Comparative study of schools and other social institutions. Social construction and maintenance of diversity and inequality. Political, social and economic consequences for individuals and groups.

Schedule Information:

Maximum enrollment: 32
Number enrolled: 32
Class meeting times: 10:20 a.m. – 11:40 a.m. Tuesday & Thursday
Location: 103 Plant & Soil Science Building
Instructor: Chika Hughes

The Instructor for TE250:

Unlike all the other faculty members mentioned in this study, Chika Hughes was not of European ancestry. She usually wore dresses with a somewhat formal look. She exudes energy and enthusiasm. In our initial discussion about my observing her class, she was more than willing to participate and welcomed my participation in the class as well as my observation. She had done research in classrooms before.

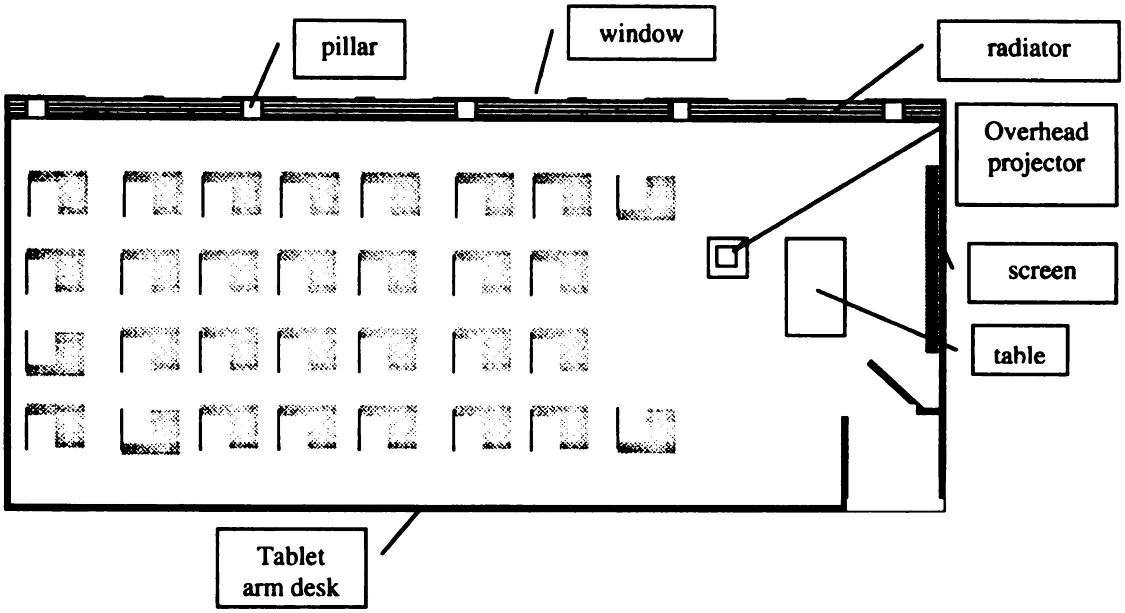

Figure 3.12a 103 Crop & Soil Science Building, before class. TE250.
This schematic shows the configuration of the classroom before teacher education students entered and rearranged the room for class. The desks were returned to rows at the end of class.

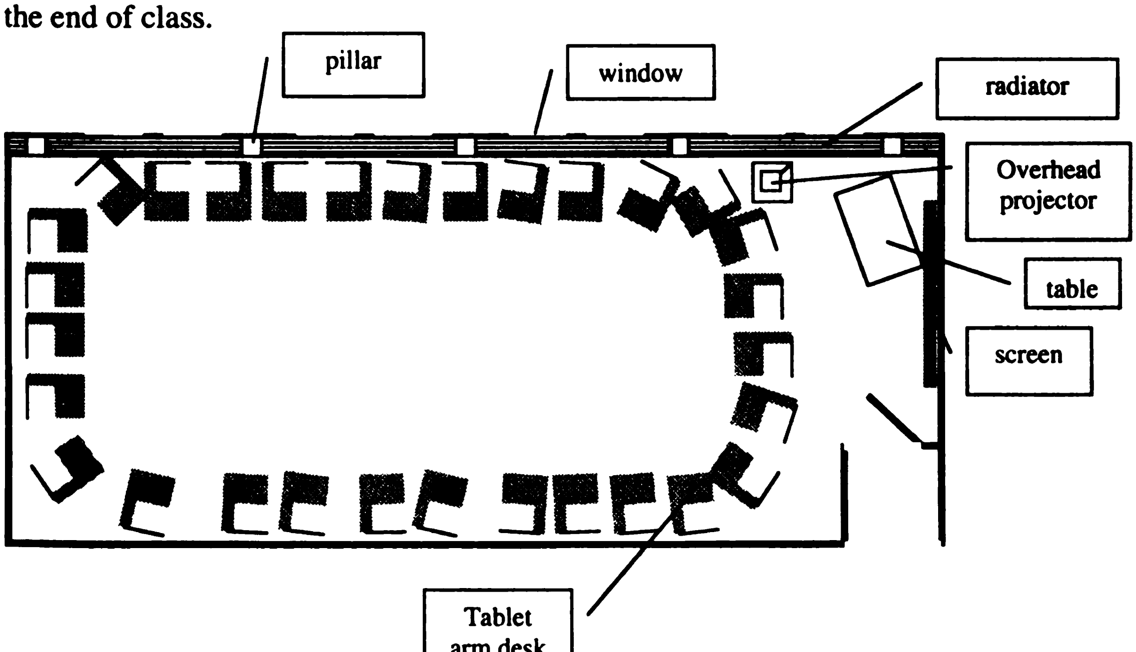

Figure 3.12b 109 Crop & Soil Science Building, during class. TE250.
This schematic shows one common configuration of the classroom during class. Desks were also sometimes gathered into groups of two, three, four or occasionally more. The desks were returned to rows at the end of class.

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Chika's biography on the College of Education's webpage describes her as follows:

> Chika Hughes is an assistant professor of teacher education. Her primary research interest is the study of educational reform from a cross-national perspective and its impact on the contribution of schooling--particularly the role of teachers--to worldwide inequalities produced by economic, political, and social development in peripheral populations. She has written on teacher education reform and its effects on teachers, teaching practice, and learning.

The room for TE250

The room was a small classroom in the university's Plant & Soil Science Building. In the hallway outside the classroom there was an emergency shower, though the classroom was not a lab facility. The front wall of the classroom had a retractable projection screen above blackboards that ran the length of the wall. Underneath the blackboards, light blue Formica in a large sheet covered the concrete wall. The other walls were concrete block painted off-white. Again, the school colors were blue and white. See Figure 3.12.

When students entered the classroom, the 30 or so tablet arm desks were arranged in neat rows. At the end of the class, they were returned to this state. During class, the chairs were repositioned as needed, most often in a large circle, but sometimes in two circles or into small groups of two, three or four. There was a single door at the front of the room, set back slightly from the hallway.

The first week in TE250

The first session was Tuesday, September 1 at 10:20 a.m. I arrive at the Crop and Soils Building and entered the room later than I had hoped at 10:19 a.m. The classroom had already been arranged into a circle of desks rather than the rows that the room was always in when students entered and left the classroom and Chika had already started. She explained that students were to draw a concept map related to inequality and share these in groups of four.

The students looked similar to those of the other classes I had seen, but perhaps less ethnically diverse. This was the third class I had observed. The day before, I had seen BS111 and first thing that morning I had seen BCH401. In this class of thirty-two, there was only one person of color. While people of color had been a distinct minority in the other classrooms, they numbered more than one in thirty.

Chika explained briefly about how to draw a concept map and had the students break into groups. These would be used in the students' introductions of themselves to the class. Students got to work, drawing their maps and talking quietly in their small groups. I was asked to draw one as well. At 10:30 a.m., Chika notes, "There's a form in the syllabus that I'd like you to fill out so I can get to know you." Students looked to the syllabus and filled out the form if they had completed their concept maps.

Students completed the TE250 Background Information Form which, like in BCH401 (see Figure 3.6) asked for some basic information, but asked for more of it and asked for more specific information. The survey for BCH401 was a half a page long. The Background Information Form for TE250 was two full pages.

In addition to requesting e-mail address, advisor's name, major and courses completed in education, the form also asked, "What are you expecting to learn from this class?" a question quite similar to that asked by McNair (see Figure 3.6). The form went on to ask, "What does the title of the course, Human Diversity, Power and Opportunity in Social Institutions suggest to you?" and several related questions. This includes questions dealing with personal experience related to the course topic, i.e., "Have you experienced unequal treatment in any way or form? How? When? What do you attribute this situation to?"

The form also asked about teaching experience, availability for tutoring and if the student had read any of the course texts. The form closed with the question, "17. Is there anything else you would like to say about the course or any related matter?" and finally, "Thank you for your cooperation!!"

At 10:35 a.m., about ten minutes after students had gotten to work on the tasks of completing the concept maps and the Background Information Forms, student were asked to, "share your concept maps -- introduce yourselves." Desks were slid back to reform the circle and a student was pointed to to begin. Brad began by stating his name, and saying that he, "...went initially to a school where everyone was rich and didn't fit in and then moved to a school where most were black and he still didn't fit in." Tom, who was sitting to Brad's right, spoke next. He said, "I want to become a teacher so that I can give back to all those who have done for me," and said that he was math major and a history minor.

This continued around the circle and in the next fifty-five minutes all thirty-two students would say at least a few words about themselves, with occasional prompts, clarifications and guiding questions from Chika.

Students' descriptions of themselves and their experiences with inequality varied. Many didn't mention their experiences with inequality. Many stated why they were interested in becoming teachers. Mary introduced herself as an elementary major with a Spanish minor and said that she loves to work with kids and hopes to teach middle school

Spanish. Chika talked about the value of learning language at an early age. Lisa was an elementary major who had worked summers in the parks and recreation department in her hometown. She talked about inequality in the application process to the teacher education program and how she believed that certain kinds of work experiences were valued over others in the writing of essays. She described how she, "...didn't have the luxury of working in a summer camp with little pay because I need to pay my own way." Chika responded by talking some about meritocracy and how, indeed, in our society, some kinds of work, "...rightly or wrongly, is valued more than others. This is an issue you will face frequently as a teacher, both in relation to yourselves and your careers and related to your students."

Sally spoke next describing how a great social science teacher in high school had inspired her. She then spoke of feelings of inequality in her summer work doing road construction. She was the only "girl" on the crew and caught grief from the men. She used her fingers to delineate the quotes around girl. Karl identified himself next simply by saying, "I'm a sarcastic guy." Chika told him and the class that now is the time when you distinguish your personal and professional self.

Gaston, the lone black student said that he was a mathematics major from [a large mid-western city] and he had seen "lots of kids dropping out around me through high school and I want to be a role model." He also said that both his parents were teachers.

At 11:18 a.m., there were still ten students to go and Chika said that the pace needed to pick up. Matt describes himself as a political economy major who works construction and makes great money but doesn't want to do that all year. He decided that by teaching, he could still work construction in the summer and that he decided on high school over elementary, "cuz I can't stand crying." He was not the first to explain pragmatic reasons for teaching – Lou an English minor and theatre minor had said, "I'll be honest. I'm lazy. I want summers off."

More commonly though, motivations for teaching (when stated) were far more altruistic or emotional. "I *love* kids" was said more than once.

The last twenty minutes of class was spent distributing and discussing the syllabus. Like in the science classes, the syllabus was reviewed section by section and the review felt somewhat rushed. The syllabus is described in the next section.

During the class, everyone's voice had been heard. After class was over, several students lingered. Unlike in the science classes students talked with each other after class as well as with the instructor. About as many (around 10) students lingered after this class of 32 as had stayed in the science classes of over 100. They lingered longer than in the science classes, but also had no class starting within ten minutes of the end of class in the same room (as was the case for BS111).

The syllabus for TE250

The syllabus was ten largely single-spaced pages, which made it the longest of the four syllabi by a large margin. It opened with a Paulo Freire quote from Pedagogy of the Oppressed:

> There is not such a thing as a *neutral* education process. Education either functions as an instrument which is used to facilitate the integration of the younger generation into the logic of the present system and bring about conformity to it, *or* it becomes "the practice of freedom," the means by which men and women deal critically and creatively with reality and discover how to participate in the transformation of their world. ((Freire, 1993) p. 15)

What was done in a paragraph in each of the science courses studied, the course description, is done in three single-spaced pages. The course overview described some of the promises and politics of schools in the U.S., following up on the Freire quotation above. After this brief introduction, the syllabus stated two sets of assumptions "thought to influence the operation of American schools" that were to be explored in the course. Those assumptions were:

> a) American schools are constrained by the socio-economic and political contexts within which they function (e.g. inequality in schools reflect inequality in the larger society);
> b) American schools are largely public institutions with some degree of autonomy relative to other public institutions and their stakeholders (e.g. teachers, administrators, parents, and students) have some influence over the direction, organization, contents, and processes of schooling. Consequently, schools have the potential for mitigating the unequal tendencies of the larger society and for promoting social equality.

The syllabus continued on to describe how the course would "uncover the origin and consequences of social differentiation in the U.S., and the differential effects of educational policies and practices on students' learning." This investigation will be concurrent with critical analysis of how schools provide differing experiences and unequal treatment of students. The course will also study ongoing attempts at decreasing these inequalities by "improving learning and critical thinking among teachers" and other involved individuals.

The next section of the syllabus explained the five course themes in slightly more than two pages. Each of the themes is stated as a question or set of questions and then the implications of those questions are explored with connections to the required course readings. For each theme, a paragraph explained the implications of the theme further and a second paragraph, in italics, more explicitly stated the focus of study for the theme.

Each of those italicized paragraphs begins with "*In this theme we will critically examine...;*" "*In this theme we will study...*" or "*we will study...*" Those themes are:

1. How does social class structure condition individuals' educational opportunities? How is the federal government attempting to address issues of diversity, power and opportunity in schools?
2. What is the interaction between social class, social/cultural capital and the school curriculum?
3. How do such individual attributes as race, language, gender, and physical ability among others, affect the balance of power and educational opportunity in schools?
4. How are schools organized to deal with individual diversity and how does this organization limit possibilities for change?
5. How can the sources of inequality in schools be challenged? What are some alternatives to traditional schooling for a more equal society?

Theme 4: How are schools organized to deal with individual diversity and how does this organization limit possibilities for change?

Schools are social institutions that by definition were created to impart common values and knowledge to a [sic] increasingly diverse population. As waves of educational reform have swept our schools, recurring concerns with the function and organization of schools and the way they structure inequality have prevailed. A dilemma that schools confront is their need for efficiency (educating large numbers of diverse students within a limited time-frame) while attempting to address the needs of diverse students. The evolution of the one-room schools into larger and complex institutions was modeled after industrial models. The organization of the modern school divided students artificially by grades and other characteristics and exposed them to a pre-designed curriculum expected to address their learning needs. Educational researchers argue that classifying students in this manner is detrimental to student learning and have found that poor students end up receiving watered-down curriculum whereas economically better off students receive better education. At the same time, the complexity of the school organization added to its highly bureaucratic structure has made it difficult for families (one of the equalizing forces in schooling) to intervene and serve as advocates for their children's better access to a quality education.

In this theme we will study the impact of the organization and structure of schooling – such as tracking and ability grouping – on students' learning. Using a case study, we will take an inside look at a school analyzing the limitations encountered by teachers and parents when attempting to gain access to more academic school knowledge for a group of minority students in the school.

Figure 3.13 Theme 4 from the TE250 syllabus.

The full text for Theme 4 is shown in Figure 3.13 as an example of how this is laid for each theme in the syllabus. Theme 4 was chosen because it links to themes within this dissertation.

The next section of the syllabus was entitled, "Course Expectations and Requirements," and began with the listing of required readings (see the following section on course texts). In addition to listing the texts, eight guiding questions to consider while reading are included. The questions include "What does this reading have to do with particular aspects of diversity, power, opportunity, inequality, and/or schools," and "How does the argument relate to other material you have read or to your own experience in school?"

The next subheading in this section was class participation. The syllabus states:

> "Attendance is expected at all sessions. You should read the material before hand and be prepared to discuss it intelligently and analytically... The success of this class depends on active participation. Group work and whole class discussion will be a key part of this course. Three missed classes is the strict maximum. If you miss more than three classes you will be asked to talk with the class coordinator or with the department chairperson."

For this section the class coordinator and class instructor are one in the same. Dr. Hughes was the faculty member in charge of all sections of TE250. There were 8 sections which each enrolled approximately 30 students. Graduate students under the tutelage of Chika taught most sections of the class. The language on attendance was common to syllabi for all sections of the class though there was freedom in syllabus and course design in general. All sections also included an emphasis on "Demonstrated writing proficiency," which was "a minimum requirement for satisfactory completion for this course." Students who knew they had writing difficulties were instructed to see the

instructor to arrange assistance. Written work that reflected inadequate writing skill was to be returned without a grade.

Weekly memos: You are expected to turn in a typed-one-page memo to me every week. The memo is meant to be reflective of the material you are reading. The memo should state an idea, question or proposition that occurred to you at the time of doing the readings for the week (you can use the questions stated above as you read and write your memo). In addition to stating an idea / question you should discuss the need for raising the question or the relevance of the idea or proposition subject of your memo. You will need to briefly discuss the readings and how the reading material informs your question / idea or proposition. As you write your memo please be careful to reference the readings clearly so I can look up the specific section of the reading object of your memo if needed. The memo should include reflections and / or a critical reaction for the readings of the week in which the memo is due (so weekends are a good time to get the readings done and write the memo!). Memos should not be longer than ONE-TYPED page and should be turned in every Tuesday before the beginning of the class. You should bring two copies of your memo so that you can keep one of the copies for discussion in class. I will not accept late memos. If you do not turn in your memo *before the beginning of class* on Tuesdays your grade for that week will be a zero. I will not accept memos after the class has begun on Tuesday has began, my reason is that I do not want any of you to miss class on Tuesdays because you are late typing your memo. In total a number of 11 memos should be turned in with the first memo due on Tuesday 9/8 and the last due Tuesday 12/1 (memos are due 9/8, 9/15, 9/22, 9/29, 10/6, 10/13, 10/27, 11/3, 11/10, 11/17, and 12/1). The only Tuesdays that will not require a memo will be Tuesday 10/20 and 12/8 which are the weeks the mid-term and final paper are due, and on Tuesday 11/24 Thanksgiving week.

Team presentations: You are asked to form a team and prepare a presentation for the whole class. The teams should be larger than 4 and will be formed the first day of class after we introduce each other. You should then choose a theme that interest you and within the them a sub-theme and the day your team would like to present. I will provide guidelines for a lesson plan as a way to organize your presentation. The team and I will meet one week before the presentation so I can give you support as you prepare to appear before the group.

Service learning: Every time I teach this class, students ask if there are opportunities available to them to work with children. This semester we have that opportunity. Students in this class are strongly encouraged to involve themselves in a service learning activity in West Jahunga Public Schools tutoring or mentoring students one-on-one two days per week in the late afternoon after school. Students who have time or work restrictions are encouraged to find alternative service activities later in the day or on weekends. If you feel it is not possible for you to do service learning, or that you are already involved in a service learning activity please come and talk to me after class. Attendance to service learning activities will, in addition to give you important insights into how different children learn, count toward your grade. Insights from your experiences should be reported in your weekly memos.

Mid-Term and Final Papers: The mid-term and final papers' purpose is to help you integrate the readings, films, cases, discussions and other class experiences in a coherent and useful manner.

For the mid-term paper: I will ask you to select and respond to a question I will provide to you two weeks before the paper is due. Your answer to this question should be type-written in a minimum of 5 double spaced pages and a maximum of 7. I will not read papers that are longer than 7 pages. The mid-term paper is due Tuesday 10/20 before class begins.

Figure 3.14 Course assignment descriptions and requirements from the TE250 syllabus.

For the final paper you will have a choice. You can, as in the mid-term, answer to [sic] a question provided by me or write a paper on a topic of your choice related to the themes in the course. The final paper should be no longer than 10 double-spaced pages (and a minimum of 7). The question will be distributed two weeks before the paper is due. If you decide to write on a topic of your choice I need to receive from you a brief proposal with the title topic of the paper and a paragraph stating the reason why this is an important issue to address (please write you [sic] name and phone number on the proposal page). The last class session 12/10 will be devoted to an [sic] informal oral presentations of papers. The final paper is due Thursday 12/10 before class begins. Please bring two copies – one for me and the other for your presentation and to keep.

Note: All written work must be prepared solely by you this semester for exclusive submission to this course. With the rare exception of a formal medical excuse or serious mitigating circumstances, no Incomplete grades will be given.

Course evaluation

Weekly memos	30%
Team presentations	15%
Service learning	15%
Mid-Term Paper	20%
Final Paper	20%

Figure 3.14 Course assignment descriptions and requirements from the TE250 syllabus (continued).

The section goes on to describe the course assignments. This text is included in its entirety in Figure 3.14.

As in the science syllabi, there are stern words related to class expectations. There was no provision for late papers here similar to the prohibition against make-up exams in BS111. Supportive language is used here as well as the firm rules, particularly as related to the presentations.

The course schedule was four pages in the syllabus. The topic, the reading(s) and frequently, the principal activity, described each day's class. Videos were listed for seven of the thirty class sessions. These videos included a variety of genres from videos of lectures given by authors of readings for the course, to a segment from the PBS series, *Eyes on the Prize* to the film *Stand and Deliver.*

The schedule for addressing Theme 4 is shown in Figure 3.15.

Theme 4: How are schools organized to deal with individual diversity and how does this organization limit / facilitate possibilities for change?	
Thursday, 10/29:	*Tracking and ability grouping in schools* Oakes, J. (1986). Keeping track, part 1: The policy and practice of curriculum inequality. *Phi Delta Kappan,* 68, 12-17. Oakes, J. (1986). Keeping track, part 2: Curriculum inequality and school reform. *Phi Delta Kappan,* 68, 148-154. Education Letter (1987). *Organizing classes by ability.* Cambridge, MA: Harvard Graduate School of Education. *Debate: For and against tracking*
Tuesday, 11/3	*Parental involvement in schools* Edwards. P. & Garcia, G.E. (1991). Parental involvement in mainstream schools: An issue of equity, in Foster, M. (Ed.) *Readings on equal education.* NY: AMS Press [Hughes] (1998)

Figure 3.15: The course schedule for Theme 4 from the TE250 syllabus.

The TE250 texts

This course required four books, three booklets and a substantial course-pack.

The four books are:

Freedman, S.G. (1990). *Small victories: the real world of a teacher, her students and their high school.* New York: Haprer & Row

Kotlowitz, A. (1991). *There are no children here: The story of two boys growing up in the other America.* New York: Anchor Books.

Meier, D. (1995). *The power of their ideas.* Boston: Beacon Press

Orenstein, P. (1994) *Schoolgirls: Young women, self-esteem, and the confidence gap.* New York: Anchor Books.

The three booklets were all publications of the National Center for Education Statistics, a unit of the U.S. Department of Education's Office of Education Research and Improvement. Those booklets are: The pocket condition of education; the mini-digest of education statistics; and The educational progress of women.

None of the course texts were textbooks laid out in units with questions at the end of the chapter as was the case in the two science classes. The course-pack consisted of a collection of articles and book chapters, again substantially different from the course-pack for BCH401, the science class that had a course-pack. BCH401's course-pack did include two short articles, but the bulk of it was fill-in-the-blank notes, study questions and old exams.

A typical day in TE250

There was little obvious difference between the students in this class and those I had seen in the two science classes. Whether in science or teacher education, some students looked clean and fresh, a few appeared to be unkempt, some wore baseball caps backwards, about half were male and about half were female, and a small percentage were ethnic minorities. In both settings, there were a few students who were noticeably different (eccentric?) – i. e. magenta hair in BS111, and the way Joseph carried himself in TE401 (described in more detail in both the typical day in 401 and in the next chapter). The differences between these classes were not in whom was taking them, but what those students did when they were in the classroom.

The typical day was not tremendously different from the first day in character. Like on that first day, Chika was the most visible actor in the class, and most student voices were heard in class on most days I observed. Unlike in either of the science classes, a day did not pass where some student voice was not central to the happenings in the classroom.

A few students would arrive before class began, sometimes before Chika, and arrange the chairs in a circle. Students would filter in and fill the chairs, filling most of the room, but absences were more conspicuous here than in science classes. If four students were gone, it was noticeable in part because full attendance meant virtually no empty chairs.

It was not unusual for class to begin with students making announcements about volunteer opportunities, followed by Chika discussing the students' memos. They did show improvement over the course of the term and she would regularly ask students to talk about the comments they received and sometimes ask students with better grades to pass their papers around the circle.

Class discussion was typically grounded in the readings and sometimes connected to videos watched in class. Videos segments I saw were fairly short – less than a half an hour and used as a launching point for class discussion. On one occasion I noticed students doing things not related to class during the video. One woman was reading from a geography study guide, others were reading other things, including one student reading the newspaper. Unlike in the science classes, I never noticed anyone sleeping.

Usually part of class time would be spent in small groups either discussion of the readings or video or working on some kind of other assignment. The topics of discussion that I saw (and participated in) were related to issues of equity in schools and to understanding social difference. On September 17, the class activity had students split into groups to discuss the reading, (Lareau, 1987), which described representatives from four different socioeconomic groups. Half the class discussed Working Class in comparison to Middle Class and the other half of the class compared Professional families to Executive Elite. The class came back together to share their small group discussions and complete a grid on the chalkboard summarizing what was discussed. That grid is reproduced in Figure 3.16.

While note taking was not a primary student activity in TE250, some kind of writing was fairly common, for at least some members of each small group. This might take the form of writing on the chalkboard or completing a prepared handout.

Working Class (WC) + Middle Class (MC)			
	What do they have in common?	What are the differences?	
Role of T	Lost enthusiasm No analysis, restricted	Catch up Family issues	Explain/expand Rules (general)
Role of S	Learn for job (routine)	Have to be there There just to get through	Some creativity – for fun Right answers
Role of subject matter	Not curious, creative or for discussion Busywork	Survival skills Basic mechanics Rote	Textbook T lecturing
Professional + Executive Elite			
Role of T	Non-restrictive structure Ts are guides	Executive Elite Ts seem to have more	
Role of S	-must have greater understanding of material - Are given freedom to do things differently at their own pace	Ss in Executive Elite more understanding of empirical The affluent [used interchangeably with professional in discussion] were more creative	
Role of subject matter	-Encourages independent thought -prepping Ss to the best of the best	EE preparing to be elite, need certain things Affluent – preps Ss to be professionals	

Figure 3.16 TE250 Discussion summary recorded on chalkboard.

Students would often be engaged in conversation with each other or with Chika before and after class. Students also participated in conversations during class that were targeting the class content, diversity in American schools. The class always had a comfortable feeling about it and my observations led me to believe that students generally enjoyed the class. One observation that indicated that the class was enjoyed was comfortable conversations that were the heart of the class, another was that students tended to linger after the class was over talking with each other and with Chika.

Assessments in TE250

In describing the assessments used in TE250, I will be beginning by stating what the assessments are not. They are not traditional tests, either objective or subjective. They are, as described in the syllabus, all written assignments done outside of class time. Unlike in either of the science courses, assessments are diverse, both across the semester and across individuals. That is, one assignment looks different from the next (compare service learning to writing a paper to doing a team presentation). And one student's 4.0 level course work probably looks substantially different from another's. Papers are the most heavily weighted assignments and other kinds of work influence the grade substantially as well. This includes presentations and the service learning component of the course. Skills relating to person-to-person interaction were intended to be assessed here.

The written work of the students received substantial written feedback from the professor, and common trends in the students' work were discussed in class when assignments were returned.

Summary Comments for TE250:

This course could be described as small and personal. Students came to know each other through the activities of the class and came to know the professor as well. In the sophomore level science course, students were encouraged to work in groups outside of class. In this class, they were required to work together in class and out of class to prepare presentations. Anonymity was not an option here. Student voices were a part of class every day and it was not unheard of for every student in class to speak to the entire class.

The work of the course was practically oriented and assessed in a variety of ways. The volume of content covered seemed far less than in either of the science courses and there seemed to be nothing to memorize. Note taking was uncommon whereas it seemed to be the primary student activity in both science classes.

This course was largely about diversity (multiculturalism) and relationships. Understanding diversity and what it means for the operation of classrooms (and therefore how to navigate relationships) was central to the course. This was not only part of the course content, but also part of what the instructor incorporated into her teaching. In this class, as opposed to the science classes, the professor sought to know each individual student – to have a relationship of a sort. She also actively fostered relationships between class members during class time while the science professors only verbally encouraged the development of relationships outside of class time (study groups).

Teacher Education 401: Teaching Subject Matter to Diverse Learners

Catalog Information:

Credits: Total Credits: 5 *Lecture/Recitation/Discussion Hours: 3* *Lab Hours: 8*
Prerequisites: Completion of Tier I writing requirement.[35] TE301 (Learners and Learning in Context)[36]
Restrictions: Not open to freshmen or sophomores. Open only to students admitted to the teacher certification program.

35 University writing requirements are described in the appendix.
36 TE250 is a prerequisite for TE301.

Description: Examining teaching as enabling diverse learners to inquire into and construct subject-specific meanings. Adapting subject matter to learner diversity. Exploring multiple ways diverse learners make sense of the curriculum.

Schedule Information:

Maximum enrollment: 35[37]
Number enrolled: 60 (approximately 20 per subsection)
Class meeting times: 12:40 p.m. – 2:30 p.m., Tuesday & Thursday; 4:20 p.m. – 6:10 p.m., Wednesday s, + 4 hours/week in field
Location: 121 South Aquino Hall
Instructors: *For science subsections:* Karen Jones, Larry Glanton, Andy Frank
For Content Area Literacy subsection: Peggy Schick, Amy Magin

The Instructors for TE401:

There were sections of TE401 for each of the major secondary subjects. In this context, science is considered one subject. Sections for other (non-core) disciplines were taught in other colleges and departments; i.e., the agricultural education section was taught in the College of Agriculture. The science section was subdivided into three sections because of large enrollment. The three subsections generally met separately, but would meet together on occasion most often when there were guest speakers (either practicing teachers or current teaching interns).

There, again, was a content area literacy subsection that met for half the semester.[38] For this portion of the course, there were two instructors: Peggy Schick and Amy Magin (both graduate students). Between the two of them, they split the science, home economics and agriscience students into two sections for each instructor. For each instructor, one section met on Wednesdays from 4:30 to 6:20 p.m. and the second met the same time on Thursdays. Although Amy's section was observed three times, it will not

37 As noted in Chapter 2, the enrollment exceeded the cap and a third instructor was added. The catalog never reflected the third instructor and the change in enrollment cap.

be described in great detail here. This portion of the course was in line with the culture of teacher education.

There were three instructors for the science portion of TE401. Karen Jones was the faculty member who coordinated the three sections and her subsection was the focus of my observation in TE401. Karen was a Ph.D. biochemist with a deep interest in education. After completing her Ph.D., she enrolled in the Midwestern University's teacher certification program. As she worked her way toward certification, she became more involved in the program than a typical student and ended up working for the university in a variety of ways. By the fall of 1998, she had worked in a joint appointment between the Colleges of Education and Natural Science for more than five years. This appointment included teaching in the teacher education program; co-teaching with Patti Giltner, the instructor for NSC401, a course for graduate students on teaching college science; and involvement in multiple projects that typically relied on her ability to act as a translator between scientists and educators.

Karen wore her long brown hair in a single braid and dressed casually. Karen worked comfortably in both colleges. She was the daughter of a prominent scientist and her husband was on the faculty in Physics and Astronomy. She was intimately familiar with the culture of science and had immersed herself into the culture of education. She had cut her teeth working in an urban middle school as a teaching intern (after completing her Ph.D.), as a field instructor of interns and in projects where she worked collaboratively with teachers.

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[38] In the Spring, there would be a similar structure for addressing instructional technology.

Larry Glanton was a retired science teacher who, like his wife, worked part time for the university. Both Larry and his wife worked in a variety of ways in the Teacher Education Department. Larry supervised student teachers and co-taught a subsection of 401. Of the three instructors, Larry was the only one who would not follow this set of students through the two-year course sequence. He was essentially acting as a long-term substitute for Mike Burns, a full professor who had planned to teach the course, but had teaching time bought out to meet the demands of various research projects. Mike would return to teach the remaining three courses in the two-year sequence and would occasionally visit the course during 401.

Andy Frank was a first-year graduate student who came to Midwestern State University with ten years of experience teaching high school physics and calculus in the Pacific Northwest. He was tall, lanky and decidedly silly. He and I shared a common bond in that we had both taught high school physics at least in part because it was a job that provided an excuse for playing with toys -- in front of an audience.

The rooms for TE401

The classroom for Karen's subsection of TE401, 121 South Aquino Hall, was the only classroom in my study that was in a building that predated the 1960s era of rapid campus growth. The south wing of Aquino Hall was built early in the century[39] and the classroom had the look of the old laboratory classroom that it was. It was the only classroom that I observed in that had any real character.

39 The north wing of the building was an addition during the 1960s building boom.

Of the classrooms I observed in, this room was the most cluttered by far. This was likely due to the fact that this classroom is a home base for science education. All of the other classrooms visited were used by a variety of instructors from a variety of disciplines. This classroom and 110, its mirror image down the hall, were used for classes in science education, for science teacher professional development programs and not much else. The instructors who used these classrooms all knew each other and, with the exception of graduate students in education, had worked together for many years.

The large demonstration table along the front of the room and the lab bench along the side were both made of black polished slate. The floor was Formica in what seems to be its most common shade – beige with specks of brown. The seating in this room was around lab tables that were frequently rearranged. The lab tables had light blue-green laminate tops that I assume replaced earlier tabletops. The legs were made of hardwood, probably maple, and there was also an apron of hardwood below the tabletop. The apron and the tops of the legs were covered with graffiti on every table. The tables were sometimes arranged in clusters of two tables, occasionally in rows and often in the horseshoe arrangement shown in Figure 3.17.

Chairs were the newest furnishings in the room. They had aluminum frames and blue plastic backs and seats. They were stackable. No chairs are shown in Figure 3.17, though there are about 36 typically in the room. The online course schedule states the room capacity is 36.

Again, TE401 was divided into three subsections that sometimes met together. One of the other subsections met in a room down the hall in 110 South Aquino that was a mirror image of 121, with a slightly different assortment of clutter. 110 is the classroom for Natural Science 401 – a class mentioned by most students in their interviews that will be very briefly described in the next section of the chapter. The third subsection of TE401 met around the corner in North Aquino, the newer wing of the building. The arrangement of this classroom was similar to that of 109 Crop & Soil Science, the room used for TE250 (see Figure 3.12). The North Aquino classroom had been more recently remodeled, however and was carpeted.

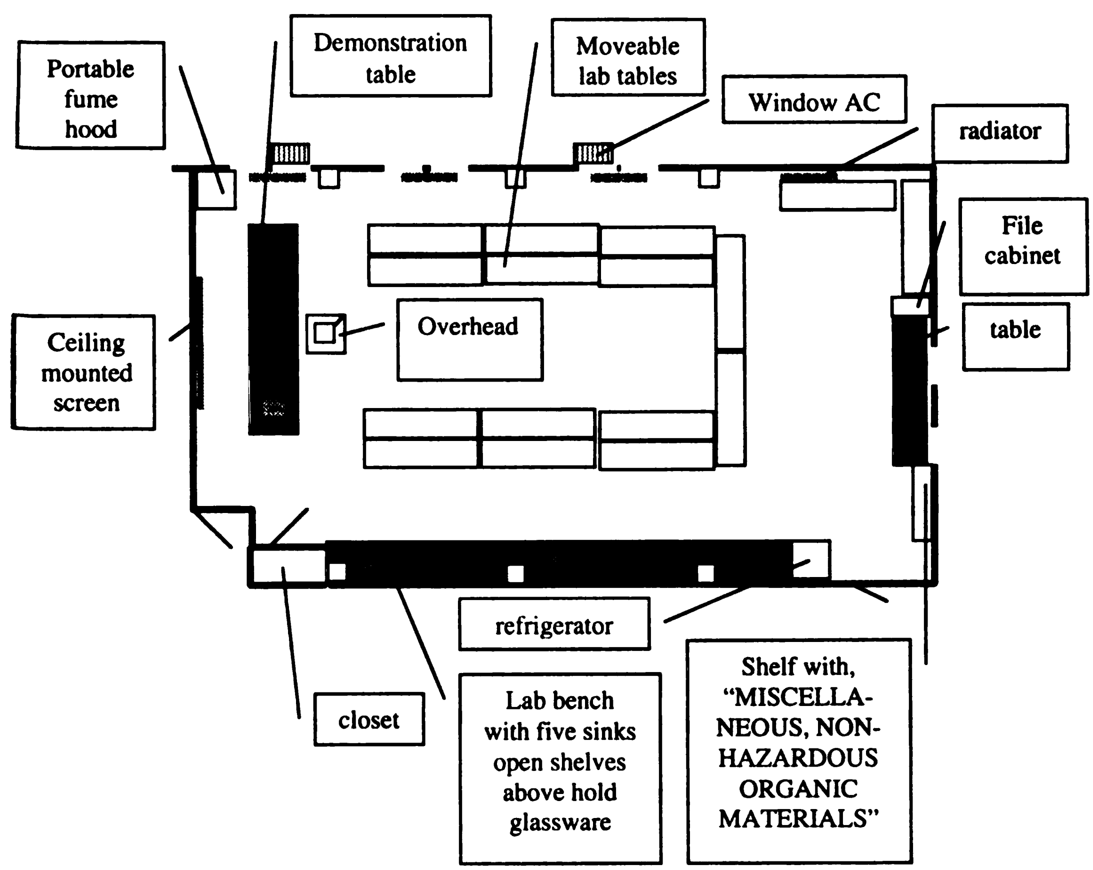

Figure 3.17 121 South Aquino. TE401. This schematic shows one common configuration of the classroom during class. Tables were also sometimes set up in pairs to facilitate group work, and occasionally set up in rows.

There was also a separate classroom for TE401's Content Area Literacy subsection. This room was in the College of Education's building and was similar to the other smaller classrooms. It was carpeted and furnished with new tables and chairs that were, in each of the three of these classes I observed, arranged in a circle or large square.

The first week of TE401

By the time TE401 began at 12:40 on Tuesday afternoon of the first week of classes, I had been to all of the courses I was to observe for the dissertation. The class began with a very full classroom – the class had many of the 60 or so students in 121 South Aquino, a room that the schedule stated can accommodate 36. Some had already been redirected to where they were meeting, so it was not too near double capacity. Karen began class with a brief introduction, "I'm one of the three and a half instructors for this course." She went on to say a bit about what that means. Mike Burns was the half instructor who would be there occasionally this term and then throughout the remaining three semesters. Mike showed up at exactly 12:40 and pointed latecomers around the corner to Larry's classroom. These were the students he and Larry would share or trade off. He also pointed students to Andy's room down the hall.

The students left behind in Karen's room were all white and the class was about an equal mix of men and women. A few minutes into class (during the instructor's introductions) a black male came into class and found a seat.

Karen then handed out surveys (see Figure 3.18). Students got to work quietly on the survey and Karen took roll, reading off the names from her class list. Students also made name placards that they placed on the tables in front of them. She then introduced herself (again): "I'm Karen, Karen Jones and I'd like to introduce you to a few other people around the room that you'll be getting to know. Mike Burns. Mike do you want to tell any of your stories?" Mike started about by saying, "I'm here today and gone tomorrow," and stated that he would not be here much this term as he had been "sold off into indentured servitude." He described how he would be out of the country teaching in an area of the world recently rocked by terrorist bombings. "I need to go so consequently, I will." He ran through his travel schedule. He would be back for the next term and through the next two after that. Mike talked about his experiences as a teacher, noting, "I've been at this business a while, as you might tell from the wrinkles and sags in my cheeks and all of that sort of thing. It's a very delightful career that you're embarking on, it's an exciting one, it's a very demanding one. If you're in it because you think it's easy, forget it. Just because you have those nice long summer vacations and the high pay teachers get, umm, it's a very challenging career... It's a lot of fun. I wouldn't have missed it for the world. I look forward to working with you."

Karen then introduced me and I described my background as a high school Earth science and physics teacher in Upstate New York, and went on to say, "I'm sitting here today, not as a teacher but as related to my dissertation interests." I briefly described the nature of my study, noting what courses that I was to be observing. Karen asked how many are currently taking BCH401 and a student asks for clarification, if I'm just interested in those taking the course now. Several hands go up, distinguishing those who had already taken from those who were taking it currently. I count up the students and let them know that they will be hearing more from me.

TE401 Secondary Science	**K. Jones/L. Glanton/A. Frank**
Name____________________	Local Phone____________________
Local Address________________	Email:____________________
________________	Major:____________________
________________	Minor:____________________

Perm. Address____

Where was you TE301 Field Placement?

School____________________	Teacher____________________
Subject(s)____________________	Grade level(s)____________________

Please briefly describe some of your experiences that are relevant to your future career as a teacher.
Which school activities (if any) would you like to advise/coach as a teacher?
Did you have a good summer? What did you do?
What hobbies/interests do you have?
Do you have any concerns/special needs that would be helpful for us to know as your instructors?

Figure 3.18 The survey administered early in the first TE401 class. Spaces for answer to questions were deleted.

Introduced next was Andy Corrigan, the faculty member who coordinates and supervises the grad students teaching the content area literacy portion of the course. Andy talked about logistical issues of where, when, and who and handed out a schedule showing that science students would be taking the content area literacy portion of the course starting today and be done at the midpoint of the semester. He then talked about the conceptual issues this portion of the class would address, "The first part of the course will deal with what you're going to do when you get placed in a high school and you've got kids in your class who can't read or write. The next part we'll talk about what kinds of things you can do about that. The last part will talk about how you can get involved in practical ways. ...We have requirements for the course, but they are all pass/fail." He described, reading from the handout, that this section of the course only lasts through the first seven weeks of the semester. He also pointed out that the technology portion of the course for this class would be the first seven weeks of the next semester and that he would not oversee that portion of the class. Andy said that this structure for the course, the separate section for content area literacy, was new this year and that feedback is strongly encouraged to make the course as valuable as possible. He asked for questions. Two students asked logistical questions dealing with schedules that Andy answered easily. Andy said, "I look forward to seeing you tomorrow" and moved on to another subsection. Andy did not mention that he would not be the actual instructor for these students.

Karen then asked, "How many of you are bio majors?" Twelve of twenty hands went up.[40] "Keep your hands up. How many of the bio majors are chem minors? *Every*body. Ok. Chem majors?" Three hands rose. "Physics or physical science?" Three hands went up. "How about Earth science?" Two more. "Anybody else?" One student was a math major who wanted to teach science. There was a smattering of other minors. She asked each non-science minor what their minors were. Two were history; two were "poli sci;" one was sociology and one was math. She told the students that they would get a chance to work in their minors in their internships and in the next term.

Karen next instructed the students to write "The three things you really want to learn in this class so you can feel secure going into the internship." She repeated the instructions and added, "Then we'll go through the syllabus and see how it all fits together." She also told the students that these would be collected and the instructors would read through them. As the students worked, Karen walked about to touch base

[40] The fall 1998 science education seniors had a substantial majority of biology majors. In a typical cohort, about half would be biology, for this large (that is, all 60 students enrolled) group it was two thirds.

with students and to help her clarify names. Specifically she spoke to both of the sets of duplicate first names – two Brads and two Susans. She made a visible effort to associate names and faces. She noticeably scanned the room looking back and forth between name placards and the faces associated with them.

Karen asked the groups to come up with lists of what they wanted to learn to prepare themselves for the internship. Each group's list had to have at least one suggestion from each member of the group. "You might have duplicates. That's fine."

"Before you start, learn everyone's name." Karen elicited suggestions on strategies for learning names and a student suggested using association. "Sure," Karen responded, "and then you can all put your nametags down, practice." She then directed them onto work and added, "You collectively are each other's best resource." The volume of noise in the classroom went up considerably as the groups got to work on the task.

I joined the group with one of the Brads, Duey (a.k.a., Duane) and Diane. Both Diane and Duey were post baccalaureate certification candidates. We briefly introduced ourselves and talked about ways to remember names. Because the room was louder, much of our conversation was not audible on the tape and I did not take copious notes as I was engaged in the conversation. However, our conversation was clearly punctuated by laughter and some points were audible. Diane said the most important thing that she wanted to learn was how to handle a class. As each member of the group offered suggestions, there was also a conversation relating this to the previous courses in the teacher education program.

Karen asked each group to report one thing from their lists and wrote the suggestions on the overhead projector. This information is shown in Figure 3.19. When she came to our group, Diane's suggestion was read by Duey and Karen asked, "What do you mean by 'handle'?" Duey responded, "control, be comfortable with, practically reach everyone." Karen responded to each fragment with an "ok" or a "uh huh," and moved onto the next group. Karen made sure to hear from all of the groups at least once in completing her list on the overhead.

Reach slow + gifted Ss*
Control a class
Instructional technology
Levels of content
Lesson plans
Labs
Creative methods
Science ed joined w/TE
Motivate Ss
Unit planning
Interest
Efficiency
Teach for retention
PR
Practice teaching
Using textbooks

Figure 3.19 The list of topics seniors wanted to learn before the internship as recorded by Karen on the overhead.
*Ss is an abbreviation for students.

What she wrote on the overhead was usually an abbreviated version of what the student suggested and did not reflect the back and forth conversation that took place on many points. For example, when, "teach for retention" was written on the overhead, the conversation began with a student saying, "How do you teach students so they retain, not just memorize?" Karen responded by saying "Oooh, hey, good one. We want to *teach for retention*" [as she wrote].

Karen then transitioned into syllabus review: "There should be a pile of syllabi for your group somewhere. Pull that out, pass 'em around and flip to the third page to see our schedule. Let's see where each of these components comes up." Students shuffled about and found their syllabi and flip to the course schedule.

Karen proceeded into syllabus review, using the just generated list to guide her through what would be her longest monologue of the class. Excerpts from that mini-lecture of seven minutes are included below. In her review of the students' list of topics, she gave a preview focusing on this course and provided a glimpse of three following it in the science education course sequence. She said a few sentences about each topic on the list in the order written on the overhead, pointing students to the appropriate spot in the syllabus as she went:

> "Teaching slow and gifted students, ok, comes in the planning. We have to plan ahead for that. In this semester, we're going to concentrate on lesson planning... You see in caps there, 'lesson planning?' Next semester, we're going to concentrate on unit planning, that is, planning for bigger chunks. As you think about planning, you need to think about who our students are. It's not going to be the same if we have a remedial class, if we have an honors class or if we have a generic class. So that will come in the planning.
>
> Controlling a class. Ok. Flip to the second part. We're going to spend a whole section on management, but, before that, we're going to think about management in terms of specific strategies. How do you manage a lab with all that equipment out and kids are free to move around? How do you manage... um... when you're showing a video, when kids are antsy or starting to fall asleep or whatever? We're going to think about management in specific strategies and overall this semester.
>
> ...The level of content. What should we teach? That's the very first topic we're going to deal with. We'll follow that with lesson planning and then we're going to talk about specific strategies. What are the strategies for (pause) October 27th is going to be lab. We're not going to do labs generically. We're going to think about labs for chemistry, labs for biology, labs for Earth science. We're going to try and do things very practically.
>
> ...For practice, you're going to get two kinds of practice in actual teaching. By the end of September you will teach a lesson here, in this

class. In October, out in your field placement, and again in November you will teach a lesson as part of your field work. Second semester, you will get to teach three days in a row. You will have to plan for three consecutive days. That's the kind of practice you're going to get.

[After textbooks, the last item on the list]... Are there any questions about the kinds of things we'll be doing?"

This course overview grew out of student generated requests within the instructors designed framework. While it was the instructor speaking, it was markedly different from long monologues in either of the science classes. It also ended with a (non-rhetorical) question directed to the students and ample wait time to answer it. Student did ask questions about field placements and Karen assured them that placements would be discussed when the all three subsections came back together as a whole class, but she also immediately addressed some aspects of the question. Other questions were asked and addressed as well.

At 1:28 p.m., she announced that there would be a break and previewed what would happen after the break at 1:35. Students took the break, some wandering down the hall to the bathroom and vending machines, others lingering in the classroom chatting amongst themselves and with Karen. At 1:35 p.m., all three TE401 instructors and sixty students reconvened in 121South Aquino. It was standing room only in the old science laboratory classroom with a seating capacity of 36. Students and instructors occupied not only all the chairs in the room, but also most of the counter space and still many were left standing. I gave up my chair to a student and found it difficult to continue my note taking. Note taking did not appear to be a concern of the students.

Karen started back up noting that the class had not yet been all together and therefore not everyone knew all the instructors. "We're going to practice names. My name is…?" Many students responded in chorus "Karen." Karen moved toward Larry and said, as she gestured toward Larry, "This is…?" Again, many students responded with a clear, "Larry." Karen said "Larry, Larry Glanton. His name and email address are listed here [as she pointed to the front page of the syllabus.]" She moved on to the other instructors and me.

Karen noted that email and phone contact information was on the front of the syllabus and that there would be a class email listserv set up for discussion and information sharing. She invited students to call, email or drop by on the instructors as they try to make themselves as available as possible.

Karen reviewed information relating to the content area literacy portion of the class that met on Wednesday or Thursday afternoons of the current semester and the instructional technology section that would meet in the same time slot for the first half of the next semester. The second half of the next semester would address the students' minors.

Karen then moved onto the pieces of the syllabus not addressed in small group – required readings, (which were not yet available in the bookstore). There were two required books – one the state science standards and the other was AAAS's *Science for* All Americans (AAAS, 1989), an optional text on classroom management and a course pack that was a small collection of articles (referenced in the syllabus's schedule).

The attendance policy was reviewed next and then students were told that they would be getting photos taken in groups of five, which would be labeled and the instructors would post to help them learn names. As the photos were taken, students were dismissed though many hung on and chatted with each other or the instructors.

The syllabus for TE401

The syllabus for TE401 was four pages long, the same length as the syllabus for BS111 and shorter than the other two syllabi. It was the shortest syllabus packet as it did not include any other materials besides the syllabus. Like the others, it led with instructors' names, offices and contact information, meeting times and places and required reading. The required reading is listed in the next section of this chapter. The section on times and places included the logistics for class meetings in Aquino Hall and the following other requirements:

> Plus:
> 4 hours (2 x 2 hours) of arranged time at your field placement site starting in October
> 2 hours Wednesday or Thursday afternoons where you will address the state's requirements that you understand content area literacy and instructional technology and where you will have some opportunities to work on teaching in your minor.

Although it does not say so in the syllabus, the Wednesday and Thursday activities are spread across the year, not just the semester. Karen and Andy Corrigan made this clear in the first class.

The next section of the syllabus addressed course goals. The goals are reproduced in their entirety in Figure 3.20a.

Course Goals
Next fall you will prepare to become the primary adult in a science classroom. You will be responsible for the well-being and learning of the students in that classroom. Our goal for TE401 and 402 is to prepare you for those responsibilities. By the end of this school year, we hope that you will be *well-started beginners* ready to learn from your experiences and the people around you from the MSU and public school communities. Below we outline some of what goes into becoming a well-started beginning science teacher.

As you already know, teaching is a more complex profession than it appears to a student. We hope that during this course you will *develop your own understanding of the multiple facets of teaching science.* One way to think of the process of teaching science is to use the framework of Magnusson, Krajcik, and Borko. In this framework, and effective teacher needs to understand: 1) *the content* s/he is teaching; 2) *how people learn*; 3) *how particular students learn particular topics*; 4) curricula or *ways to teach particular topics*; and 5) *how to assess or follow student progress* (Magnusson, Krajcik, & Borko, 1994). We will learn how to pick out each aspect in real classrooms, and we will begin to learn how to plan for, implement, and reflect on each aspect.

In today's world there are many demands on science teachers. We will look at *state and national documents that describe the modern vision of what and how a science teacher should teach.* Two of these are required reading for the course.

We would like you to learn *many practical things* this year, such as how to give clear directions to a group of students, how to plan and implement labs, how to make particular topics relevant to students, how to manage students' behavior and prevent discipline problems. However it is impossible to learn all of the particulars of science teaching even in the two years that we have together. Therefore we will also study some *theoretical frameworks* that will help you to evaluate new ideas, reflect on your own practice, and thus support your continued growth as a science teacher after you complete the teacher certification program.

Figure 3.20a: The course Goals as stated in the TE401 syllabus.

The largest single section of the syllabus was the course schedule with assignments. That is reproduced in Figure 3.20b.

Date	Class Activities	Assignments due
Sept. 1	Course Overview Science Autobiography	
Sept. 3	WHAT SHOULD WE TEACH? Elements of memorable teaching Overview of SEGOSE[41] Multiple dimensions of understanding science	Science Autobiography
Sept. 8	Identifying key ideas Setting objectives for teaching – "using" objectives Introduction to cases for peer teaching	
Sept. 10	LESSON PLANNING What are the elements of a lesson plan? Learning cycle Mercedes model	SEMSPlus reading
Sept. 15	Guest speakers	
Sept. 17	Prepare for peer teaching	
Sept. 22	Application & process in standard content Peer teach an application	Lesson plans for peer teaching
Sept. 24	Process of science SEGOSE – "constructing" & "reflecting" objectives Peer teach an application	Zen and the Art of Motorcycle Maintenance reading
Sept. 29	Examples of how and we know or how we can find out Peer teach an application	Bring Benchmarks
Oct. 1	OBSERVING THE COMPLEXITIES OF CLASSROOMS STAM as an observation tool Peer teach an application	
Oct. 6	Pedagogical content knowledge (PCK) PCK in an observed lesson Peer teach an application	Magnusson, et. al. Reading
Oct. 8	Private Universe – how students learn science	
Oct. 13	Reports from the field Preparing to teach/writing objectives	Journal entry on first week of observation
Oct. 15	Preparing to teach/planning activities & assessment	Journal entry on objectives
Oct. 20	Lectures/projects	Lesson plan for teaching
Oct. 22	Mini-lecture for peers	
Oct. 27	Labs	Journal entry labs or demos

Figure 3.20b: The class schedule and list of assignments from the TE401 syllabus.

[41] SEGOSE is the State Essential Goals and Objectives for Science Education (a pseudonym).

Oct. 29	Models/simulation	
Nov. 3	Reports from the field	Reflection on 1St teaching
Nov. 5	Math in science class	
Nov. 10	Whole class discussion/question asking	Lesson plan for 2nd teaching
Nov. 12	Videos	
Nov. 17	RESOURCES Organizing resources Textbook as resource	
Nov. 19	Textbooks	Journal entry on resources your CT likes to use
Nov. 24	MANAGEMENT Concept map Giving directions	Bring Weinstien
Nov. 26	Thanksgiving	
Dec. 1	Swap Shop Discipline	Swap Shop material
Dec. 3	Helping Ss read	Analysis of a textbook
Dec. 8	Helping Ss write	
Dec. 10	Planning for TE402	Reflection on 2nd teaching

Figure 3.20b: The class schedule and list of assignments from the TE401 syllabus (continued).

The final short segment of the syllabus was grading criteria and course requirements. That is shown in its entirety in Figure 3.20c. The Private Universe reference on October 8 refers to the *Private Universe* video series, so here like in TE250, videotape was used in instruction. The schedule also reflects other employed in-class instructional strategies. This includes guest speakers, peer teaching, reports from fieldwork and a swap shop of teaching materials. This contrasts sharply with the single teaching method employed in both science classes.

Grading	
5%	Science autobiography
30%	3 lessons
20%	4 journal entries
15%	Reflection on 1st teaching
10%	Analysis of a textbook
15%	Final reflection paper
5%	Participation

This semester this course includes three required elements:

- ⑨ Our time together on Tuesdays and Thursday,
- ⑨ The module of content area literacy that you attend on Wednesday or Thursdays during the first of half of the semester,
- ⑨ Your attendance and performance in your field placement

All of these components must be completed successfully for you to pass the course. If you fail to complete any of these components, you will receive a grade of 0.0 or Incomplete. The content area literacy will be graded on a pass-fail basis. Once you have complete [sic] it successfully, your grade will be determined by you [sic] performance in Tuesday-Thursday seminar and field placement. .

Figure 3.20c: Grading and course requirements from the TE401 syllabus.

As in all the other syllabi, there are stern words related to student expectations and clearly spelled out consequences for failure to meet expectations. Like in the senior level science syllabus, there is much here that is incomprehensible to the lay person. What, for example, is meant by "Mercedes model" or "STAM?"

The TE401 texts

The course required two books and a coursepack and recommended a third book. The readings as listed in the syllabus were:

State Essential Goals and Objectives for Science Education (1991)[42]

Course packet

[42] A pseudonym

Project 2061: American Association for the Advancement of Science (1993). *Benchmarks for Science Literacy.* New York: Oxford Press

Optional reading – Weinstein (1996). *Secondary Classroom Management.* New York: McGraw Hill.

The 63 page coursepack included a state generated document on unit planning, an excerpt from Pirsig's Zen and the Art of Motorcycle Maintenance, (Pirsig, 1974), and (Magnusson et al., 1994). The Weinstein text was used, at least as an optional text, in all the courses specific to secondary teacher candidates; that is all courses after TE401.

A typical day in TE401

The first day in TE401 was in many ways a typical day. The most conspicuous person in the room was Karen, the instructor, but student voices were heard regularly and not simply in the asking of questions, but also in the sharing of information and opinion.

There was usually time spent in small group discussions that typically had some specific task to be completed. During these conversations, I learned information not only about how students approached the tasks designed for them but also about the students themselves. I was surprised to learn when talking with Earth science majors that at least two of the four who were in my group would not be graduating in time to complete their internship the following academic year. It made wonder what they were doing there.

These Earth science majors were working together in a group as they were planning a lesson on volcanoes. As a former Earth science teacher I was drawn to the group. Another group was working on a lesson on DNA fingerprinting and a third group was focused on wetlands. At Karen's suggestion, I sat between two groups but I found it difficult to keep straight what was going on in either group. I felt somewhat guilty in hearing and not responding to factually incorrect information in the volcano group, in part because I would have (wrongly) felt guilty for interfering with what I was studying[43].

Each group was to generate a statement that incorporated a big idea and an application for the science they were addressing. At the end of this segment of group work, the students wrote their groups' statements on the chalkboard. Those five statements are listed below.

> ① "Plate tectonics: Volcanoes are the result of one plate subducting under another." This was almost immediately rewritten to read, "Plate tectonics: two types of volcanoes, Hawaiian and Pyroclastic, can result from one plate subducting under another.
> ② DNA is a double helix structured molecule that carries unique information for development, growth, and reproduction for each living organism.
> ③ The molecules/chemicals derived from plants, such as corn, are essential components in food products used in daily life.
> ④ The journey from egg to butterfly involves 5 major steps in which there is a total rearrangement of the organism with no resemblence to the previous step.
> ⑤ Diversity is exhibited in an ecosystem such as a wetland when a range of species inhabiting the area include members from all or most of the 5 kingdoms: Plant, Animal, Fungi, Monera, Protista.

This exercise was the beginning of planning to teach a lesson to the class. Over the next few weeks, the students would continue to develop the idea and iron out problems – like the idea that Hawaiian volcanoes do not form from one plate subducting under another. Hawaii is in the middle of a tectonic plate, and while that plate is subducting under another at its distant edge, this is not the direct cause of the volcanoes at Hawaii. This was the error that troubled me in the Earth science group.

---

[43] I was also concerned about my own misconceptions – they were using labels for volcano types that I had not heard used before to classify all types of volcanoes – pyroclastic and Hawaiian. I had learned and taught that volcanoes were classified as shield, cinder cone or composite. An Internet search found that these labels are more common than those used by the 401 students. A pyroclastic cone is a cinder cone.

Following the presentation of the ideas, students were directed to their coursepacks to read about the learning cycle (Berkheimer, 1992). For their lesson planning, groups were to choose between this framework and the Mercedes Model (Gallagher, 1992). The Mercedes Model is discussed in Chapter 6 as a tool for the science educator to draw connections between college science courses and teacher education courses.

As the semester progressed the groups taught their lessons with varying amounts of success. The group presentations are done in other subsections, so Karen's students taught Andy's students and so on. The peer teaching I saw had students involved in creating something – one group had students describe parasites that they created, another asked students to create food webs. A third had student groups create a fictional critter with five stage life cycles. These lessons seemed to follow a pattern established by Karen – students presented some information and then had the rest of the class work in groups on an activity. At the end of their lessons they had students report back to the class. Each presentation ended with a round of applause.

Both of these models were explicitly modeled in the class throughout the semester. Karen would occasionally ask questions like, "What did I just do?" and point the students to one of the conceptual models used in class or a teaching strategy.

Modeling was a key idea in the daily practice in TE401. Karen would present a topic like objectives, show a few examples and model her thinking about creating them as she stepped through writing an objective.

Longer classes required a break and students would chat informally during the downtime. Often this related to their work in the field and concerns related to finalizing the placement early in the term, and for some students, concerns about what their mentor teachers did with students.

Like in TE250, readings were typically directly related to class activity and explicitly used in class. For example, when the section from *Zen and the Art of Motorcycle Maintenance*(Pirsig, 1974) (pp. 92-96) was assigned, the in-class activity mapped the process of figuring out what was wrong with a motorcycle to the states' science objectives related to the nature of science. Again, the process here was an explicit model. Karen told the class that this reading and activity was done for two reasons: to help the teacher candidates fill in gaps in their own thinking relative to the nature of science and to give them "a reading you might use with your own students on the process of science other than that really boring first chapter of your textbook."

Assessments in TE401

Assessments in TE401 took more forms than in any of the other classes. As is the norm for Teacher Education classes at Midwestern, there were no sit-down tests of any kind. Part of the assessment was pass/fail, the content area literacy section where students produced written papers. Students were graded on their class participation, part of which was working in groups to teach the rest of the class some science content. Attendance was also part of the assessment and evaluation in TE401.

Students were expected to behave professionally in their field placements. This requires being present and punctual and completing the tasks the mentor teacher requests from or is promised by the teacher candidate. Failure to live up to these expectations leads to failure of the course. The most heavily weighted assignments were reflective in nature – based on their experiences teaching lessons in the field, what did they learn? What would they do differently next time they teach? These two papers constituted almost a third of the course grade. 95% of the course grade is determined by somewhat open-ended written work. Certainly, the work of one student with a 4.0 at the end of the term could look substantially different from the work of other students receiving the same grade.

Like in TE250, papers were handed back during class time with a fair amount of teacher-written feedback, and like in TE250, general themes the teacher noticed in grading were discussed. For example, when lesson plans were returned, Karen noted that students typically did a good job with both the science statement and with the objectives, but the match between these two components often had problems.

Summary Comments for TE401:

TE401 was heterogeneous in many ways. The class had several components – fieldwork in schools, content area literacy taught by grad students, and the three subsections taught by Karen the faculty member with a dual appointment in two colleges, Andy the grad student in Teacher Education, and Larry the retired teacher. The focus of my observation was Karen's piece of this that was itself heterogeneous. In each of my visits, a variety of teaching strategies was employed, with student voice always playing a central role.

There was also attention to student differences in at least a few different ways. The instructor first made a visible effort to learn each student's name. Students were also broken into groups according to their majors. Like in TE250, relationships among students and between students and the instructor were fostered during class time. The reader should pause and consider the relationship of this course to the three frameworks sketched out in the overview of the dissertation.

Natural Sciences 401: Science Laboratories for Secondary Schools

This course was not observed as part of the dissertation study, however, it was mentioned by most seniors in their interviews and was also a required course for teacher certification in biology. Some of the same information that was gathered for the above courses was also collected for NSC401 and is provided below.

Catalog Information:

Credits: Total Credits: 4 Lecture/Recitation/Discussion Hours: 2 Lab Hours: 6 4(2-6)
Restrictions: Open only to seniors in the College of Natural Science with a teacher certification option. Completion of Tier I writing requirement.
Description: Laboratory equipment, supplies, demonstrations, exercises, and safety. Care of live organisms. Disposal of biological and chemical wastes. Field trips required.

Schedule Information:

Maximum enrollment: 35
Number enrolled: 32
Class meeting times: 8:00 a.m. to 8:50 a.m., Tuesday & Thursday; 9:10 a.m. to noon, Tuesday & Thursday
Location: 121 & 110 South Aquino Hall
Instructor: Patti Giltner

The Instructor for NSC401:

Patti Giltner was a biologist by training who has worked for many years primarily teaching courses geared for both practicing and preservice teachers. She describes her work as follows on the WebPages for faculty in the education division of the College of Natural Science.

> My primary responsibility and interests lie in promoting science content knowledge of both preservice and inservice teachers. I teach an intensive laboratory course for seniors in the College of Natural Science planning on becoming science teachers, NSC401. The intent of this course is to provide students with a toolkit, which includes laboratory work in the basic sciences, developing laboratory exercises, reading scientific literature, teaching with everyday objects, etc. I also am director of the Division's graduate programs (Interdepartment Physical Science and Interdepartment Biological Science for 7-12 certified science teachers; General Science for K-8 certified teachers) for inservice teachers. I teach, along with [biology faculty member], the series of Cell and Molecular Biology courses for secondary teachers. We also organize and oversee our students' summer research projects as well as their written theses.

Patti has also co-taught the graduate course on teaching college science with Karen Jones and has worked with her on several other projects.

The rooms for NSC401

The course was taught in two of the three classrooms that were used for TE401 – one was South Aquino 121 which is the room diagrammed for the TE401 section of this chapter. The second classroom, which was where the class usually met, was a mirror image of South Aquino 121 and just down the hall. While the bricks and mortar were simply mirror images, the room arrangement was different. The arrangement of the chairs and tables in 121 changed on occasion. Generally, the tables and chairs in 110 were left as they were. See Figure 3.21 below.

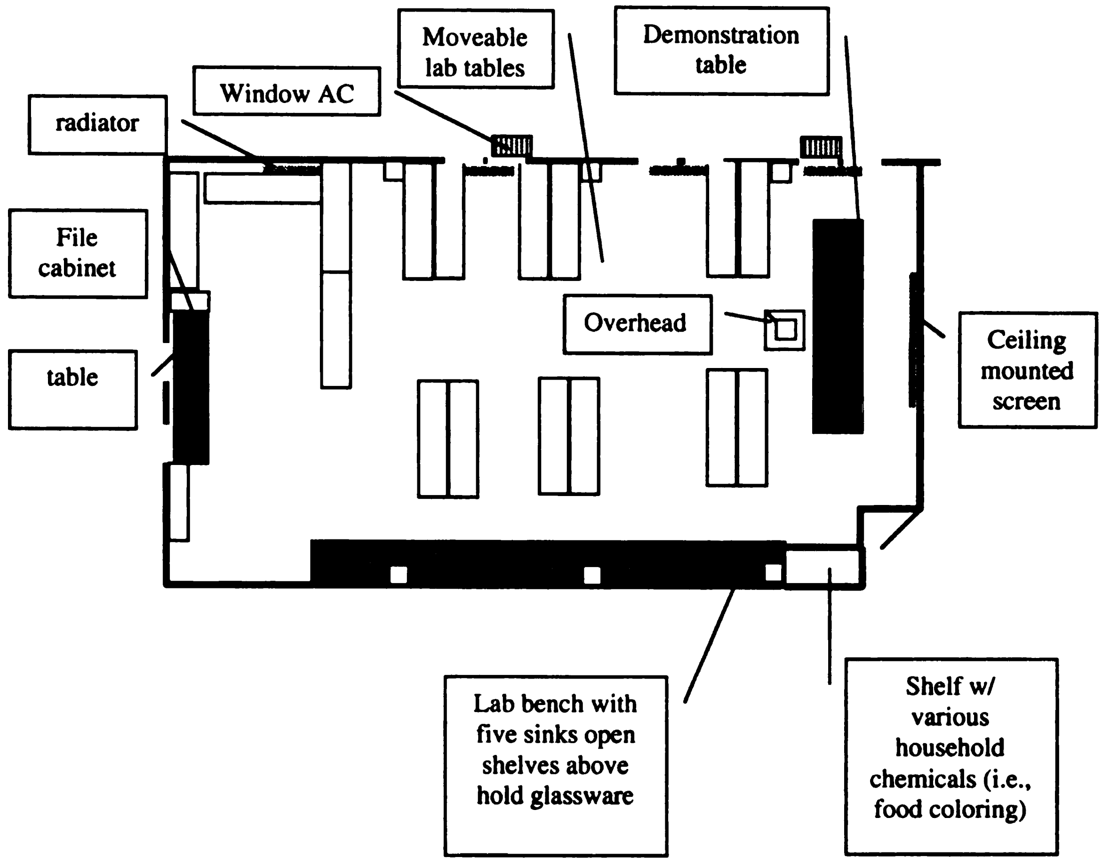

Figure 3.21 110 South Aquino. NSC401. This schematic shows the common configuration of the classroom. Student designed experiments were often set up on the tables near the back of the room.

Summary and Interpretation

Students appeared to be generic – they were about as likely to be neatly or sloppily dressed, to appear hungover[44] or not, whether they were in a science class or a teacher education class. What they experienced in the two settings (in the two cultures) was strikingly different.

"Two settings" from the four classes is a logical demarcation. If there were no sound, it would be difficult to tell one science class from the other or one education class from the other education class. The science classes used the same mode of instruction every day that I observed instruction. The professor stood at the front of the classroom writing notes on the overhead and talking. Both education classes had days with students presenting, and students played some kind of active role in every education class I observed. Also, both education classes used multiple texts and videos while the science classes each used a single text and no video.

The first new piece of information that struck me (the notion of big versus small and lecture versus discussion were not revelations to me) was that in both education classes, anonymity was impossible, whereas in the science classes anonymity was the norm. In the first day of both education classes, students wrote their names on folded 5" x 8" index cards and placed them on their desks or tables.

In the science classes, there was one active actor in each class, the professor, and scores or hundreds of students who were generally passive. In the teacher education classes, student voices were central to each class I observed.

In reviewing my field notes months later, I was struck by how I felt compelled to take the wrong kind of notes in the science classes. It was too easy to slip back into what I had been programmed to do by years and years of science classes. Rather than taking notes *about* the students and professor and the general classroom dynamics, I often took notes *like* the students. I did recognize every time this happened that it had happened, but I retreated to this in almost every class I visited in BS111 and in Biochemistry.

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[44] A complete judgement call – I never asked, never smelled their breath and those who had this look about them were a small but noticeable minority in the four classes observed.

This problem did not occur in the Teacher Education classes, likely in part because students so infrequently took notes. There were a wider variety of conspicuous activities in the teacher education classes to take note about. In all four classes, I ended up frequently engaged as a student would be, which meant taking notes in science classes and typically discussing something or other in the teacher education classes.

The science classes assumed homogeneity while the teacher education classes not only assumed heterogeneity, but treated that heterogeneity as a resource.

Comparison Tables

The following pages include tables summarizing the courses in various ways along with some explanatory text. These tables are intended to bring back attention to the fact that students were moving between their science and education courses everyday or every week. The presentation of material in the bulk of this chapter addresses science and then education. In daily interactions, students move from one culture to the other. Again, see the typical senior's student schedule in Figure 3.1.

Table 3.1 and 3.2 gives a very brief overview of the four courses in a format allowing for side-by-side comparison. The tables begin with full course names and catalog descriptions for the four courses in this study. Note that both science and teacher education course titles and descriptions rely heavily on discipline specific vocabulary. Also note that both course title and course description are considerably longer for the Teacher Education courses than for the science courses.

Table 3.1: Sophomore Level Courses Observed		
Characteristic	Biological Sciences 111 Cells and Molecules	Teacher Education 250 Human Diversity: Power and Opportunity in Social Institutions
Catalog Information	**Credits:** Total Credits: 3 *Lecture/Recitation/Discussion Hours: 3* **Prerequisite:** CEM 141 or CEM 151 (General Chemistry). **Not open to students with credit in:** DVS 145 **Description:** Cell structure and function; macromolecular synthesis; energy metabolism; molecular aspects of development; principles of genetics.	**Credits:** Total Credits: 3 *Lecture/Recitation/Discussion Hours: 3* **Prerequisite:** none **Description:** Comparative study of schools and other social institutions. Social construction and maintenance of diversity and inequality. Political, social and economic consequences for individuals and groups.
Instructor	Jon Peters (for the first half of the semester) Phil Opanashuk (for the second half of the semester)	Karen Jones
Class Size	**Number enrolled:** 391	**Number enrolled:** 32
Instructional Strategies	Lecture. There was also a lab for the course that was required for a subset of the students in the class including the teacher candidates.	Primarily discussion and cooperative group work. Videotapes were shown regularly and discussed. Groups of students also presented to the class.
Nature of Student Voice	Questions were encouraged but rare. In the few instances that questions were asked, they were seeking clarification of factual information, typically asking what a word on the overhead is because the writing was illegible. Rarely questions were asked of the class. These sought one word or short phrases for answers.	Student voice played a central role in every class session observed. This took a variety of forms – in whole class discussion, small group work and student presentations. Generally students spoke at some length when they spoke, that is, they did not typically state one word answers to questions.
Text & Other Instructional Resources	**Textbook:** Campbell, Neil A. (1996) Biology 4th Edition, Benjamin/Cummings Publishers, Menlo Park, CA. Overhead transparencies and handwritten notes on the overhead were also used.	**Four books:** Freedman, S.G. (1990). *Small victories: the real world of a teacher, her students and their high school.* New York: Haprer & Row Kotlowitz, A. (1991). *There are no children here: The story of two boys growing up in the other America.* New York: Anchor Books. Meier, D. (1995). *The power of their ideas.* Boston: Beacon Press Orenstein, P. (1994) *Schoolgirls: Young women, self-esteem, and the confidence gap.* New York: Anchor Books. **Three booklets:** all publications of the National Center for Education Statistics. Those booklets are: The pocket condition of education; the mini-digest of education statistics; and The educational progress **Several articles and videos** (too numerous to mention)

Table 3.1: Sophomore Level Courses Observed (continued)		
Characteristic	Biological Sciences 111 Cells and Molecules (continued)	Teacher Education 250 Human Diversity: Power and Opportunity in Social Institutions (continued)
Assessment	Three multiple choice midterm exams and a cumulative multiple choice final exam. Questions were typically factual recall.	Weekly memos – responses to readings Team presentations on one of the course themes Service learning work Midterm paper Final paper Classroom discussion was an additional, informal assessment

Table 3.2: Senior Level Courses Observed		
Characteristic	Biochemistry 401: Basic Biochemistry	Teacher Education 401: Teaching Subject Matter to Diverse Learners
Catalog Information	**Credits:** Total Credits: 4 *Lecture/Recitation/Discussion Hours: 4* **Prerequisite:** CEM 252 or CEM 352 (Organic Chemistry II)[45] **Restrictions:** Not open to students in the Biochemistry or in the Biochemistry/Biotechnology major. **Not open to students with credit in:** BCH 200 or BCH 461[46] **Description:** Structure and function of major biomolecules, metabolism, and regulation. Examples emphasize the mammalian organism.	**Credits:** Total Credits: 5 *Lecture/Recitation/Discussion Hours: 3* *Lab Hours: 8* **Prerequisites:** Completion of Tier I writing requirement.[47] TE301 (Learners and Learning in Context)[48] **Restrictions:** Not open to freshmen or sophomores. Open only to students admitted to the teacher certification program. **Description:** Examining teaching as enabling diverse learners to inquire into and construct subject-specific meanings. Adapting subject matter to learner diversity. Exploring multiple ways diverse learners make sense of the curriculum.
Instructors	James McNair	*For science subsections:* Karen Jones, Larry Glanton, and Andy Frank *For Content Area Literacy subsection:* Peggy Schick, Amy Magin
Class Size	**Number enrolled:** 181	**Number enrolled:** 60 (approximately 20 per subsection)
Instructional Strategies	Lecture.	Primarily discussion and cooperative group work. The class generally met in subsections of 20 or fewer. Groups of students presented to the class regularly. Videotapes were shown occasionally and discussed.

[45] Prerequisites for the prerequisite include only chemistry and mathematics classes, though virtually all biology teacher candidates would have completed BS110 and BS111.

[46] BCH200 was Introduction to Biochemistry and BCH461 was Biochemistry I. These were courses required for biochemistry majors.

[47] The Tier I requirement is met by taking a course from a long list across the university which requires written work.

[48] TE250 is a prerequisite for TE301.

Table 3.2: Senior Level Courses Observed (continued)		
Characteristic	Biochemistry 401: Basic Biochemistry (continued)	Teacher Education 401: Teaching Subject Matter to Diverse Learners (continued)
Nature of Student Voice	Questions were encouraged but rare. Students questions were asked in two of the six observations. In one instance the question was substantive and led to a conversation between the professor and a student about the Haq article. In the other class with questions, the questions were about illegible text on the overhead.	Student voice played a central role in every class session observed. This took a variety of forms – in whole class discussion, small group work and student presentations. Generally students spoke at some length when they spoke, that is they did not typically state one-word answers to questions.
Text & Other Instructional Resources	**Textbook:** Biochemistry 4th Edition by Lubert Stryer, published by W. H. Freeman. (Stryer 1995) The text was used as a reference and readings were not explicitly assigned. **Coursepack:** The course-pack is 268 pages, beginning with a sheet of reproduction permissions for diagrams from texts and articles as well as the two articles used in class during the first week. The articles were a Jane Brody piece from the New York Times (Brody 1990) and an article from the Journal *Science* (Haq, Mason et al. 1995). The bulk of the course packet was fill-in-the-blank notes, but it also included sets of study questions for each unit. Overhead transparencies and handwritten notes on the overhead were also used.	**Books:** State Essential Goals and Objectives for Science Education (1991)[49] Project 2061: American Association for the Advancement of Science (1993). *Benchmarks for Science Literacy.* New York: Oxford Press *Optional reading* – Weinstein (1996). *Secondary Classroom Management.* New York: McGraw Hill. **Coursepack** This 63 page document included a state generated document on unit planning, an observation rubric developed by two of the course instructors and an excerpt from Pirsig's Zen and the Art of Motorcycle Maintenance. (Pirsig 1974), and (Magnusson, Krajcik et al. 1994). Overhead transparencies and handwritten notes on the overhead were also used.
Assessment	Seven biweekly exams that were almost exclusively true-false and a cumulative true-false final exam. Questions were typically factual recall.	Science autobiography 3 lessons 4 journal entries Reflection on 1st teaching Analysis of a textbook Final reflection paper Participation

Both Chika Hughes and Jon Peters gave clear reasons why class attendance is important. The reasons, shown in Table 3.3 are quite different. Peters seems to believe that the important things are what he does as the instructor. Chika Hughes emphasizes instead what the students do during class time.

Science	Teacher Education
BS111 "Most important… is that you *do* come to lecture. I know you've been preached to before. I don't like to preach… A live lecture is much different than if you're listening to the lecture on tape; buying notes from those people that sell them outback, which you've already gotten little pamphlets about… I don't condone that at all. I think it's an infringement on my rights, however, I have no legal way that I can stop the course from being scribed. I *do* think by being here you get a lot more out of the lecture. The way I emphasize things, the way I point to things, the things I write on the overhead are all part of the learning experience. So I do believe if you come to lecture you get a lot more out of it."	TE250 "Attendance is expected at all sessions. You should read the material before hand and be prepared to discuss it intelligently and analytically… The success of this class depends on active participation. Group work and whole class discussion will be a key part of this course. Three missed classes is the strict maximum. If you miss more than three classes you will be asked to talk with the class coordinator or with the department chairperson."
Reasons for attending lectures as expressed by Dr. Peters in the first class.	Reasons for coming to class as described by Chika Hughes in the syllabus.

Table 3.3 The professors' reasons for going to class in BS111 and TE250.

The courses described here map on well to the Two Cultures Model described in the outset of this dissertation. What students experience as they move between science and education courses is strikingly different. The two science classrooms operate in largely the same way: they are both large lecture classes with purely objective assessment. Each science course relies primarily on its own textbook (although this is less true for biochemistry). Students are generally anonymous and passive during class time. In contrast, the education classes are small, personal with varied assessments and teaching strategies and resources.

[49] A pseudonym

The two cultures can be viewed separately for the convenience of making models, but for the reality of students' lives, they are connected through those students. What is the nature and meaning of that relationship?

Chapter 4

WHAT THE SENIORS HAD TO SAY ABOUT THEIR COURSEWORK

Don: How would you describe your typical teacher education course?

Bill: I would describe it as exactly opposite of any science course that I've ever taken. All my TE courses were classroom courses as opposed to lecture hall classes. They were 30 or less students, I'd say. And they were mainly discussion. A little bit of general reading and writing. It was a lot different than science. I think that's what turned me on to education.

This chapter uses interview data from the seniors to build on observational data described in the previous chapter. The seven seniors[50] were interviewed early in the second semester of their senior year using the protocol from the Salish New Teacher Preservice Program Interview (included as Appendix B). During the time of the interview, they were all enrolled in TE402, the second course of the four-course science-specific education sequence. At this point, they had each spent over a semester working in the same high school or middle school classrooms and had done at least a small amount of teaching in those classrooms. In most cases, they were expecting to be engaged in the yearlong teaching internship starting the following fall. Joseph was planning to attend professional school in the fall.

The initial interviews followed the New Teacher Preservice Program Interview protocol from the Salish Project (included as Appendix B). The second group interview

[50] As noted in Chapter 2, the seniors interviewed were all of those Biological Science Majors enrolled in TE 401 at the time of observation who had either taken BCH401 with McNair or who were taking it concurrently with TE401.

was less structured and began by sharing transcripts of the earlier interview. This group interview included the three seniors who were able to attend. Before beginning the group discussion, the seniors were asked to draw a concept map or other representation of their science and education classes showing the connections between the two sets of classes.

The Interviews

Joseph, Bill and Brad

Seven senior Biological Science majors were interviewed. As noted in chapter 2, these seniors were selected because they were taking TE401 at the time of the observations and they had taken or were taking BCH401 with Dr. McNair. All seniors who met that description agreed to be interviewed in the initial interview. Three of those seven were able to take part in the group discussion the semester following TE401. Those three will receive the most attention in this chapter.

Joseph, Bill and Brad were representative of the seven seniors in a number of ways. Each was from one of the three subsections of TE401. Joseph was in Karen Jones's (where I did my observations). Bill was in Andy Frank's; and Brad was in Mike Burns's. Joseph was planning to go to professional school the following year. Bill and Brad would go on to complete the teaching internship, as all those interviewed except Joseph planned to do.

Joseph was the most vocal of the seven interviewed and was also the most critical of the program. Eccentric is a label that might be appropriate for Joseph. In some ways, Joseph appeared to be an outlier, but Bill and Brad affirmed much of what he vocalized in the group discussion. Closer inspection shows that his answers were not surprising in light of Salish data. He seemed unafraid to say what others might have thought but hesitated to say.

Joseph and Brad both saw themselves more closely affiliated with science than with teaching. Bill saw himself more affiliated with teaching and, in fact, would have pursued social studies as a certification area if he were to start college over again. He had started college as a pre-med student so when he decided to teach, biology was the area where he had the most credits. Brad was the quietest of the three. Like most of participants, these three started college with no plans of going into teaching.

The words of Bill, Brian and Joseph

What follows are the words and drawings of Bill, Brian and Joseph. Selected excerpts are taken from each of their individual interviews, schematics that are representations of work done by seniors at the start of our group discussion[51] and some interesting points from the group discussion. Before the discussion began, I gave the seniors their interview transcripts from the first interview rearranged in tabular format so that the parallel questions about science and teacher education courses and their answers were side by side. I have significantly abbreviated and slightly reformatted those tables in what follows. I gave the seniors a chance to review their transcripts and then I asked the seniors to either diagram or describe the relationship between their college science courses and their teacher education courses. At the beginning of the group discussion, each senior shared what they had written or drawn.

[51] Strict formatting guidelines for dissertation printing preclude the inclusion of the senior's actual drawings.

Bill

If Bill, whose quote opens this chapter, were to start college over, he would have chosen to be a social studies teacher rather than a science teacher. Bill chose science because he started in premed and then decided to be a teacher. Bill was a Biological Sciences major and Chemistry minor. Table 4.1 includes selected excerpts from Bill's interview and it is followed by Figure 4.1, a schematic of the representation he drew of the connections between his science and education coursework.

Table 4.1. Selected excerpts from Bill's New Teacher Preservice Program Interview	
Science	**Education**
General Comments:	
"I'd have to say either science courses are lectures, lecture format or they're a lab format. And every once in a while they like to throw in a recitation section in the lecture. It's pretty much non-interactive lecture. ...The instructor stands up in front of the class and imparts the information to the class." Bill described his college science labs as mostly cookbook though there were a few biology labs that were more open-ended. One diffusion lab had students develop their own procedures. Of chemistry labs though, Bill said, "I don't recall a single chem lab that had a genuine investigation or experiment." Bill drew attention to differences between bio and chem more than once – lab groups in biology were cooperative groups but this was not at all the case in chemistry. All chemistry labs were cookbook while there were a few examples of bio labs that were not.	Don: "How would you describe your typical teacher education course?" Bill: "I would describe it exactly opposite of any science course that I've ever taken. All my TE courses were classroom courses as opposed to lecture hall. 30 or less students, I'd say. And they were mainly discussion. A little bit of general reading and writing. It was a lot different than science. I think that's what turned me on to education." "I think my field experiences were the most interesting parts of my college career, as far as going into education. I learned as much as more in field experiences as I did in any of my courses, even my teacher ed courses."
On Assessment and Evaluation:	
"I don't think I can ever remember having an essay exam other than – Maybe every once in a while there was a quiz in recitation that might have had a few word	"Papers – As far as how they evaluate the papers, it's different every semester. I

short answer fill-in-the-blank questions."	guess I don't feel at all that there's any wrong answer in any TE course, which makes me very comfortable because I'm very afraid of being wrong (laughing) even these questions. I'm afraid that I'm answering *these* wrong. I think that it kind of goes back to the objective of – getting students to think critically about… concepts. As long as you're thinking critically about something, you're right."
Important Experiences:	
Bill believed bio labs were important because he'll be a bio teacher and he needs to know how to do labs and it helped him learn the concepts. "Chemistry labs, because of the way they were formatted, I don't remember much of them anyway so I don't think they were very important. (laughs) The lectures, I don't see as all that important because I could have learned all that stuff on my own but I had to pay money to get credit so I could actually graduate."	"I have to say TE250 was one of my most memorable courses because we covered a lot of social issues in education that I hadn't previously been exposed to or [made] aware of. And then 401 and 402 in particular because they're content based. And the field experiences…. [and] I think Andy Frank has a very unique perspective on teaching... I think that's the reason that 401 and 402 have been a couple of the most important courses I've taken." NSC401 was important because it gave him ideas about how to perform labs in his own classroom and he learned content – "It may have been content I was supposed to have learned earlier" (We both laughed heartily).
Texts and other instructional resources:	
"Basically the objective was to present the ideas that are in a textbook in a verbal format. I didn't see any process approach to it. I don't recall ever having a coursepack in a science class other than in lab classes. There was [usually] a single textbook. A lab manual was typically full	"Usually there's a course pack with a collection of articles assembled by the instructor; a few – educational research books, I guess you could call them. Kozol, Jonathon Kozol. I remember reading a few articles by Lisa Delpit stuff like that. Every once in a while we'd see a movie or

<table>
<tr><td>of information that everyone skipped over and skipped onto something else.... We used computers every once in a while in simulations of genetics."</td><td>two."</td></tr>
<tr><td colspan="2">On Faculty:</td></tr>
<tr><td>"[In the] typical science course the instructor was pretty much there if you needed help. And if not, he didn't want to see or hear from you. I guess it was pretty impersonal. I didn't take advantage personally. I always felt that if I didn't understand a concept or something that was my own fault. You know, I took a lot of responsibility. And often times there were concepts that I didn't understand that I tried hard to figure out what was going on and I still didn't take any initiative to go and talk to the instructor because it seemed like the instructor was so – hard to approach. And I often felt that my understanding was so minimal that I wouldn't be able to relate to the instructors."</td><td>Don: How would you describe the student - faculty relationship in your teacher education program?

Bill: It's much less formal and much more personal than the other courses, the science courses.</td></tr>
<tr><td colspan="2">On connections between science and education courses:</td></tr>
<tr><td colspan="2">"[U]ntil TE401 and 402 there was no correlation at all [between science and education courses]. In 401 and 402 having an instructor that comes from a physics background, even then I don't think that biology courses, chemistry courses that I previously took come into play as often as they should."</td></tr>
<tr><td colspan="2">How the student perceived the program philosophy:</td></tr>
<tr><td colspan="2">The philosophy of the education department, as Bill saw it was, "to get away from traditional instruction where a teacher stands up in front of a class and lectures and does pretty much same as my college instructors in college science. So they kind of, it's kind of like they're battling against each other. The way science classes are usually taught and the TE classes are saying this is not how it's supposed to be done."</td></tr>
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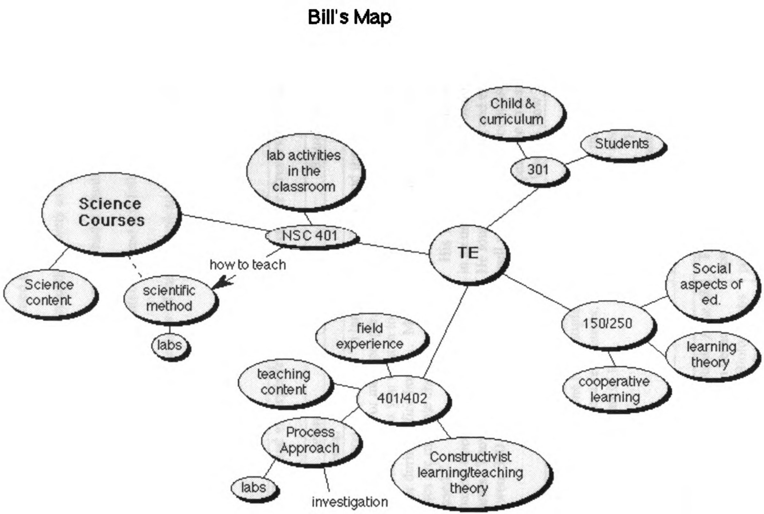


Figure 4.1. Bill's map of connections between science and education coursework

Brad

Brad was a quiet student who paused to consider answers before responding to questions and sometimes paused to reformulate answers as we spoke. Brad had a double major in Biological Sciences and Zoology and he had a Chemistry minor. Table 4.2 includes selected excerpts from Brad's interview and it is followed by Figure 4.2, a schematic of the representation he drew of the connections between his science and education coursework.

Table 4.2. Selected excerpts from Brad's New Teacher Preservice Program Interview

Science	Education
General Comments:	
The typical science course was " a large lecture class, a hundred or more people, not much interaction, unless you went in to see the professor during office hours... Most of the classes are multiple choice exams and fact based." "The smallest science class I took was 70 or 80 students. They averaged around 150 and some were 300 or 400."	Don: "You said the objectives for the science courses emphasized learning facts. What would you say about the objectives in your TE classes? Brad: "There really weren't any facts." His TE401 and 402 field experience was in an urban high school biology classroom. He found it interesting and enjoyable as well as an interesting contrast to his own high school experience in a small rural high school in Upstate New York.
On Assessment and Evaluation:	
Most assessment was done by multiple choice exam. Labs and, in a few classes, essay exams were also part of the evaluation.	There were quizzes in the early education classes. (Brad was the only of the seven to say there were any tests or quizzes in education classes). "For the most part, [evaluation was] based on papers and projects."
Important Experiences:	
"Labs were definitely important. A lot of times I'd complain about them because they were a lot more work... Biology labs were helpful. Chemistry labs – I'd just do the procedure, I wouldn't really know what was going on." The labs were important,	The diversity class (TE250), "It just opened my eyes to a lot of different perspectives and how to reach people with different needs.... NSC, Patti's class. That was good. We had to write out labs... and think about a lot of different options for

"just because they were hands-on."	teaching something."
Texts and other instructional resources:	
I usually ended up reading the textbooks for the first test and then I found out I didn't need to read it. I could get it all out of lecture.	On instructional resources: "Not textbooks but *books*."
On Faculty:	
The relationships with science faculty were "impersonal... In the smaller classes it wasn't so bad." He had gotten to know one professor a bit, "I wish I had gone and met with all of my professors during office hours." He clearly did not generally take advantage of office hours.	"Really good," is how Brad described his relationship with education faculty. "I've really enjoyed TE401 and 402 [with Larry Glanton]. The instructors he had in some earlier classes were graduate students and he had been less impressed with them, though he had good relationships with them.
On connections between science and education courses:	
(long pause) "There really isn't a whole lot of relationship I can think of... In 401 and 402 there has been more chemistry and biology, but the [things we learn in science classes] are at such a high level compared to what we'll teach that there isn't much of a relationship. NSC is more of a tie between my science and education classes."	
How the student perceived the program philosophy:	
Teach less content, but in greater depth.	

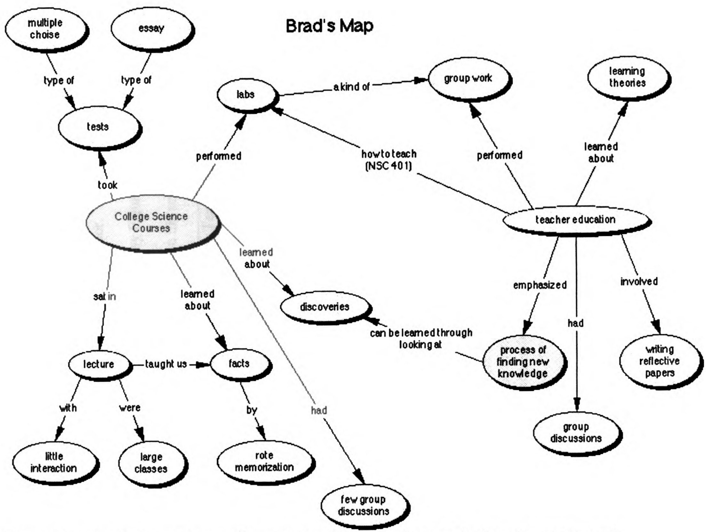


Figure 4.2. Brad's Concept map of connections between science and education coursework.

Joseph

Joseph was a genuine character. He was passionate about what he believed and wouldn't hesitate to share his opinions. Joseph had a double major in Biological Sciences and Zoology and he was a Chemistry minor. Table 4.3 includes selected excerpts from Bill's interview and it is followed by Figure 4.3, a schematic of the representation he drew of the connections between his science and education coursework.

Table 4.3. Selected excerpts from Joseph's New Teacher Preservice Program Interview

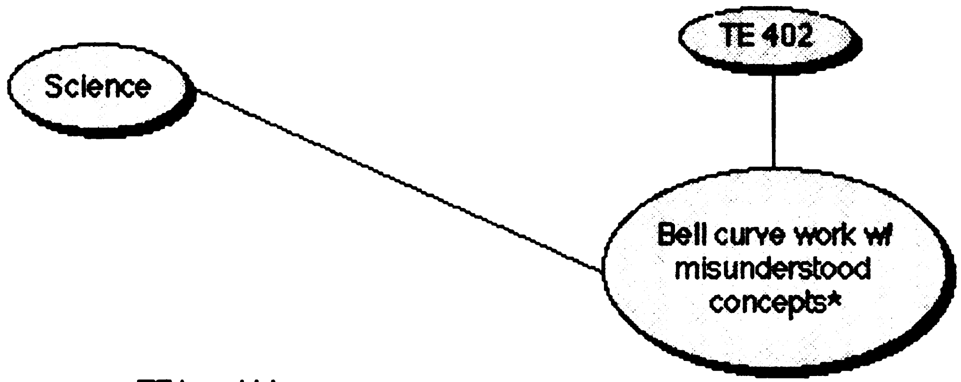
Science	Education
General Comments:	
When asked to describe his science classes his answer was "very populated – lecture – note-taking – very little interaction – three tests." He did note that some classes targeted concepts, some targeted processes but that most had the learning of facts as the primary objective. He said, "We have to memorize names – It's really dumb. Some kind of ego-science thing... If someone's really interested, they're going to learn the names, but why force us to do that?" Labs were cookbook and while the intention of the instructor was to teach concepts the labs ended up only teaching lab skills.	When asked to describe his education classes his answer was "Pretty laid back. Comfortable – modeling, coaching. What we're about to do ourselves, Karen did do, while she's explaining it." He spoke primarily about Karen's class. "A big, huge thing is how to make material relevant to students' lives.... We do a lot of bell work... addressing our own misconceptions.... Often we have the same misconceptions because we were taught in the same way. We're the reform. We have to deal with our own misconceptions." Field experience was boring. "Really well behaved kids – nothing interesting ever happens. I'm trying to figure out how to get more out of it.... I don't know how many scientists learn by sitting back and watching someone else work."
On Assessment and Evaluation:	
Assessment was almost exclusively by exams and exams were almost exclusively multiple choice, and, "I'm not a good multiple choice test-taker." His genetics course had a few short answers and fill in the blanks and his evolution class had "some really good, really thoughtful [essay] questions." Those good questions included explaining processes so a kid	"Papers. Lots of papers. We get assessed using those things with lots of boxes – [rubrics?] Yeah, rubrics. No tests."

could understand them. Two professors taught the course, each for half the semester. The other professor gave multiple choice exams. Some intro labs were graded on attendance. Some upper level chem labs were graded on lab results, i.e., percent yield. Cancer Biology, an elective with about a dozen students, was assessed completely by three extensive (library) research papers.	
Important Experiences:	
His Cancer Biology class with 10 or 12 students was important because of the small class size and because the research papers made him go into real depth with a subject he chose – lung cancer.	"I *loved* Patti's class. All the labs are great, all the hands on stuff.... I like the way Karen teaches."
Texts and other instructional resources:	
"Some of the books came with a CD ROM. I wouldn't even open those – you get more money when you sell the book back."	"SEGOSE[52] are used a lot." On computer use, "We use them basically for word-processing. I guess there's a so-called tech requirement, whatever that means. A one day thing."
On Faculty:	
Joseph was the only senior who said he took regular advantage of office hours and was the only student who spoke highly of most of his science professors. He worked in botanical research and as a TA for one professor who he described as "super, super nice." He used similar terms to describe a number of other science faculty.	"They're pretty cool... There's good mutual respect." He said of his professor for his diversity class (TE250), "I liked my professor, *loved* my professor." He spoke highly of every education professor he mentioned though he was sometimes critical of their techniques.
On connections between science and education courses:	
Science and education we related in that you needed the science content to teach it and you that background also helped you to think about how to organize the content. "The *knowledge* for teaching. That's where the relationship lies." There was also science content understanding in the science methods class when doing the aforementioned bell work.	
How the student perceived the program philosophy:	

[52] State Essential Goals and Objectives for Science Education, a pseudonym.

The philosophy of the teacher education program, as Joseph saw it, was to make the content relevant to the students. "Karen is always asking, 'how are you going to make this connect to the kids' lives?'" In the group discussion, Joseph talked about depth of knowledge, "They have all that depth, they might only teach the surface, but it will influence the way you teach the surface."

Joseph's
Map &
Description



Scientific
Process
Investigation

TE taught how to allow Ss to learn on their own

(401, 402)
In teacher education classes we take common concepts of science and talk about how they might be commonly misunderstood. In addition, we practice breaking up concepts into parts, and organizing them into a lesson where we teach students. We call this writing lesson plans. In 301 we overkilled and learning theory that exists and in 250 we talked about problems of minorities & their socioeconomic classes. The one main application class was NSC 401. It made connection b/t science & teaching throughout the whole course. We took what we learned from science classes & turned that knowledge into teachable labs.

*The instructor used the term. "bell work." not "bell curve work."

Figure 4.3. Joseph's map and description of connections between science and education coursework

The Group Discussion

Late in the second semester the three students described above gathered together with me to talk about the issues that arose from their original interviews. As noted above, this gathering began by reviewing interview transcripts and then drawing or describing the relationship between science and education courses. Those drawing are represented schematically in the Figures 4.1, 4.2 and 4.3 above. The discussion began with the students sharing their representations.

Brad described his drawing first:

> I put teacher education on one side and college science courses on the other and just kind of branched off from there. They're only connected by a few lines. For teacher education I had how we learned about learning theories, -- involved writing reflective papers we had group discussions, group work, emphasized the process of finding new knowledge, and -- for the college science courses I had took test which were essay or multiple choice, sat in lectures, with little interaction, and there were large classes. The lectures taught us facts. We learned about facts by rote memorization. We didn't have many group discussions. And performed labs. The labs -- tied in with the teacher education by the class NSC401, How to teach labs and they also tied in with group work in teacher education cause labs are a kind of group work. Also in the college science courses I had we learned about discoveries and so -- that can be tied in with teacher education because it's the process of finding new knowledge which probably could tie in with labs as well. So that was mine.

Bill and Joseph both saw their representations as quite similar to Brad's. Bill said, "I can go next because mine probably just about put it right on top of Brad's. It would be the same. I have science course on one side and TE on the other side. And just like Brad, actually, the only link that I have between the two is NSC401 (laughs all around)."

What's Your Major?

One of the most interesting questions I asked was, "How do you answer the question, 'What's your major?'" This question was not part of the original Salish protocol and was asked only of the three seniors who participated in the group discussion. Their answers reflect both the disconnect between their science and education courses and the complexities they face in adding these two disparate pieces together. I include their responses in their entirety.

> Don: This is kind of weird question, but I'm going to ask it anyway. How do you answer the question, "What's your major?" (chuckles around)
>
> Bill: That's kind of funny because I just got my graduation announcements this past weekend. They asked me what my major was and I didn't want to put down biology because I didn't – most of my relatives that I'm going to send these graduation announcements to really don't know what is going on with my life. I haven't seen them in years, so I decided that I didn't want to put biology and I didn't want to put education, so I put science education. That's usually what I tell people what my major is.
>
> Don: What about you, Brad?
>
> Brad: Well, it all depends (laughs). It's different every time. I don't know. I have a double major in zoology and biology and a chem minor, so it takes like a minute to say it all (laughs all around). I usually just say either zoology – or say education or secondary education. I never really know what to say to tell you the truth.
>
> Joseph: I'm in the exact same situation as him. I usually don't like saying it either. I'll just say I study science. If you have any further questions, and they really want to know, and I don't like answering that question anyway, but if they really want to know, major in zoology, well biology too, education department has me get a minor in chem, whatever that means (laughs all around). But that's basically it. It takes too long to say that and plus it's always everybody's always, "What's your major?" I don't really like talking about school that much. I mean I love school but I'm so much in it that I (inaudible). I like other things too.

This exchange also demonstrates the felt need for affiliation. None of the three appear comfortable with the *de facto* ambiguity of their major. They are, again, all Biological Sciences Majors, (and Brad and Joseph have second majors in Zoology) but none of them find this label terribly descriptive of what they do or who they are.

Was it good for you?

The last question I asked in the group discussion was "Has this been helpful for you?"

> Bill: I think so. It's gotten me to think about a lot of things that would have completely passed me by had you not brought them to my attention.
>
> Joseph: I've thought about a lot of that stuff. I mean it's fine for me to think about it, but the only way I could answer yes to that question is if something gets changed, you know, or something comes about, you know, but if it stays in my mind, it's only for me to think about.
>
> Brad: Yeah, I especially agree with Bill, that there's a lot of stuff I didn't really think about before and it was good to think about and I'm sure I'll continue to think about it. And how – what I can do to help – as I'm teaching my students – to prepare them for college and how they can make better connections between material.

Patterns of Response

There were two key issues arising from these interviews. The first is that their responses, with minor exceptions, resonated with those of the Salish participants three years earlier. The second key issue arising from these interviews is that the seniors typically saw the course *Natural Sciences 401: Science Laboratories for Secondary*

Schools, as the only programmatic connection[53] between their college science courses and their education courses.

Comparison to Salish and Seymour and Hewitt

The participants all described their program as sharply dichotomous as the Salish participants had three years prior. Their descriptions of science classes also resonated with the participants in Seymour and Hewitt's study that addressed why undergraduates leave the sciences (Seymour & Hewitt, 1997)[54]. Like the students in Seymour and Hewitt's study, the seniors interviewed were generally critical of their science programs and especially of the teaching. Seymour and Hewitt's study is discussed in some detail in Chapter 1.

All seven respondents described their typical classes in generally similar ways that followed the patterns shown in Table 1.1 in Chapter 1. In science, classes were large, the professor expected students to memorize facts. Textbooks were the primary texts. Assessment was almost exclusively objective exams. Science faculty were seen typically as impersonal or simply as busy individuals who the students did not know. Only Joseph said that he made regular use of office hours and knew science faculty well. All identified the primary goal of the typical science course was to teach content. Maria spoke of the amount of information in a way typical to all the seniors, "I kind of felt like they had a set amount of material they had to get through. They had to get through it no matter what.... The lecture is kind of cramming information." All seven spoke of the

[53] The seniors in the group discussion saw the interviews and group discussion as helpful in making connections between their science and pedagogical preparation.
[54] This study is discussed in Chapter 1.

focus on memorization (as both Peters and McNair had mentioned explicitly in their first lectures).

The students were all biology majors with chemistry minors and they were typically more critical of their chemistry labs than their biology labs though, as a group, they thought quality labs were fairly uncommon. When I asked Maria what was the smallest science class she had taken she said, "I had some pretty small ones in the honors college, so my smallest class was probably 70 in an honors class." I was surprised that a class of 70 students was regarded as small! Only Joseph and Darcy had had college science classes with fewer than 60 students in a class, though all had some experience with smaller recitation and lab sections. Darcy's smaller classes were in The DaVinci School briefly described below.

The students did not speak with an absolutely uniform voice, of course. Most notably different was Joseph, who liked more of his science program and more science faculty than the others interviewed. He also was the only one who made it clear that he made a consistent effort to get to know the faculty he took classes from. This also resonates with the Salish sample. The Salish participants who had engaged in scientific research (as Joseph had done) were far more likely to think positively of their program and to think more positively of the science faculty than those who had not engaged in research. It remains unclear what might cause this association. Does the research experience change attitudes or do people who seek out the experience start with a different attitude?

There is one way that the seniors I interviewed differed from the students in Seymour and Hewitt's work: they made no mention of problems associated with curved grading. Curving grades apparently was not a common practice in Midwestern University's biology courses.

The science specific education courses they had taken or were taking, TE401 and 402 were also generally well regarded although the endorsements were not as universal as those for Patti's class. The evaluation of their lower level and other courses that were not subject specific education classes varied, though they generally found them more useful than the Salish participants had a few years earlier. Joseph was the most critical and he did not plan to teach. The education courses were across the board generally well regarded though the respondents did note that some things were taught over and over again and they did not see the purpose of the repetition of teaching about cooperative learning and constructivism. This repetition was somewhat intentional, though that point was either not made to the students or not appreciated. Like the Salish responses just under half (three of seven) of the students began with "I don't know" or a similar response to the question, "What was the philosophy of your teacher education program related to science education and related to science teaching?" Most, like in Salish, did go on to state an answer, typically including the idea of less is more and to move away from traditional lecture method. The seven all expressed that they found their education instructors typically likable and approachable.

Again, none of the respondents responded in a way contrary to the responses of the Salish Participants in the New Teacher Preservice Program Interview. Salish participant responses are summarized in Chapter 1, especially in Table 1.1.

NSC401 as the connection between science and education

The only course required for their majors that was universally well regarded was Patti Giltner's Natural Science 401: Science Laboratories for Secondary Schools. This is the capstone course for the Biological Science major. Essentially all Biological Science majors are also seeking teaching certification but the requirements for certification are separate from the requirements for the major. As noted previously, this course is essentially an additional subject specific pedagogy course required for Biological Science and Chemistry majors that focused specifically on the high school laboratory. In the group discussion, Brad, Bill and Joseph all identified NSC401 as the primary connection between their science and education courses. Joseph said, "basically the only connection I made also was NSC401... I really liked it, it took everything we learned in science and we made teachable labs out of it or at least the stuff we wanted to take out of our science classes."

At the time of the Salish Project, this class was an elective. Those Salish participants who took the course regarded it in much the same way the participants in my study did. The issue that this course is seen as the only programmatic connection between science and education coursework is a problem on multiple levels. ① Not all of the future science teachers are required to take such a course (though at Midwestern University all biology and chemistry teacher candidates are now required to do so). ② Considering that making the connection between content and how to teach it is the central role of what teachers should do, this issue deserves a central and explicit role in teacher preparation. ③ The nature of the NSC401 course is not deeply investigated in this dissertation. (This third problem is of a different sort than the first two – methodological rather than substantive).

It is fair to say that the focus of this course was on how to teach using the school laboratories. The instructor describes it this way on her website: "The intent of this course is to provide students with a toolkit, which includes laboratory work in the basic sciences, developing laboratory exercises, reading scientific literature, teaching with everyday objects, etc." Joseph, one of the seniors, described the course this way: "We took what we learned from science classes & turned that knowledge into teachable labs." This is a key piece of science teaching but not by any means the only key piece. Further information on the course is included in Chapter 3.

Other Issues

Joseph also was in some ways more like the kind of student that professors imagine. He, unlike the others, consistently formed study groups in his science classes and took advantage of office hours.

The most conspicuous way that these Joseph, Bill and Brad were not representative of the group is that they were all male. Of the seven who met the selection criteria, two were female; Maria and Darcy. Both Darcy and Maria had taken some of their science course in the Honors College as had Brad. It is worth noting that three of the seven future teachers had taken some honors coursework. Maria was also a student in the DaVinci School – an integrated science program within the College of Natural Science. In this school within a school, students are in smaller classes and there is some thematic instruction. DaVinci describes itself as, "an undergraduate residential program for students pursuing broad, science-based fields of study. " Students in the program initially are housed in the same residence hall, "...where the School's classrooms, laboratories, and offices (both faculty and administrative) are located. Because of its residential nature, DaVinci offers the intimate setting and the individual attention of a small college along with the resources and opportunities of a major research university."

Conclusion

Like those in the Salish Project, these seniors saw their science teacher education program as two parallel but disconnected programs. What these seniors were taught in their science classes and what they were taught in their education had little explicit connection between them. As had been the case before, when I looked at an answer to a question about a science class and tried to imagine the opposite response, this, typically, was what was said about the education class. The lone agreed upon connection is NSC401, a class that focuses on teaching in the high school laboratory.

Science classes taught content at a level far beyond what they would typically teach was taught in a way that not only is not deemed inappropriate by education faculty, but in effective opposition to what education faculty deem appropriate. In Bill's words, "it's kind of like they're battling against each other."

Chapter 5

A CASE STUDY IN FOSTERING A HEALTHIER RELATIONSHIP – SMEC

This chapter describes The Science & Mathematics Education Collaborative (SMEC), an organization that is intended to improve communication and collaboration between scientists and educators. The chapter focuses largely on the dynamics of the groups Science Education Brown Bag Lunches (BBLs) and on the building of community.

The Science & Mathematics Education Collaborative (SMEC) is a loosely coupled organization that has improved communication and fostered collaboration among faculty in the Colleges of Education and Natural Science. The improved communication and collaboration is intended to improve mathematics and science teaching and learning from kindergarten through graduate school. We believe we are making strides towards these goals. This chapter will briefly describe the history of the organization with an eye to understanding the obstacles faced and the progress we have made. The analysis should help us to maintain and expand our work and inform the work of others. The work of SMEC will be illustrated by analyzing three cases: (1) the apparently confrontational discussions in our Brown Bag Lunch series; (2) the nature of the institutional and individual support; and (3) the development of a successful grant proposal. The first two of these cases can be described as catalysts for the formation of SMEC, but they are also more than that. The formation of SMEC can be seen as a catalyst for the third case.

The three research questions for this study are (1) What are the differences between the culture of college science and the culture of teacher education? (2) What factors, mechanisms or conditions have contributed to our progress? (3) What factors, mechanisms or conditions have limited our progress?

A diagrammatic representation of this chapter is shown in Figure 5.1.

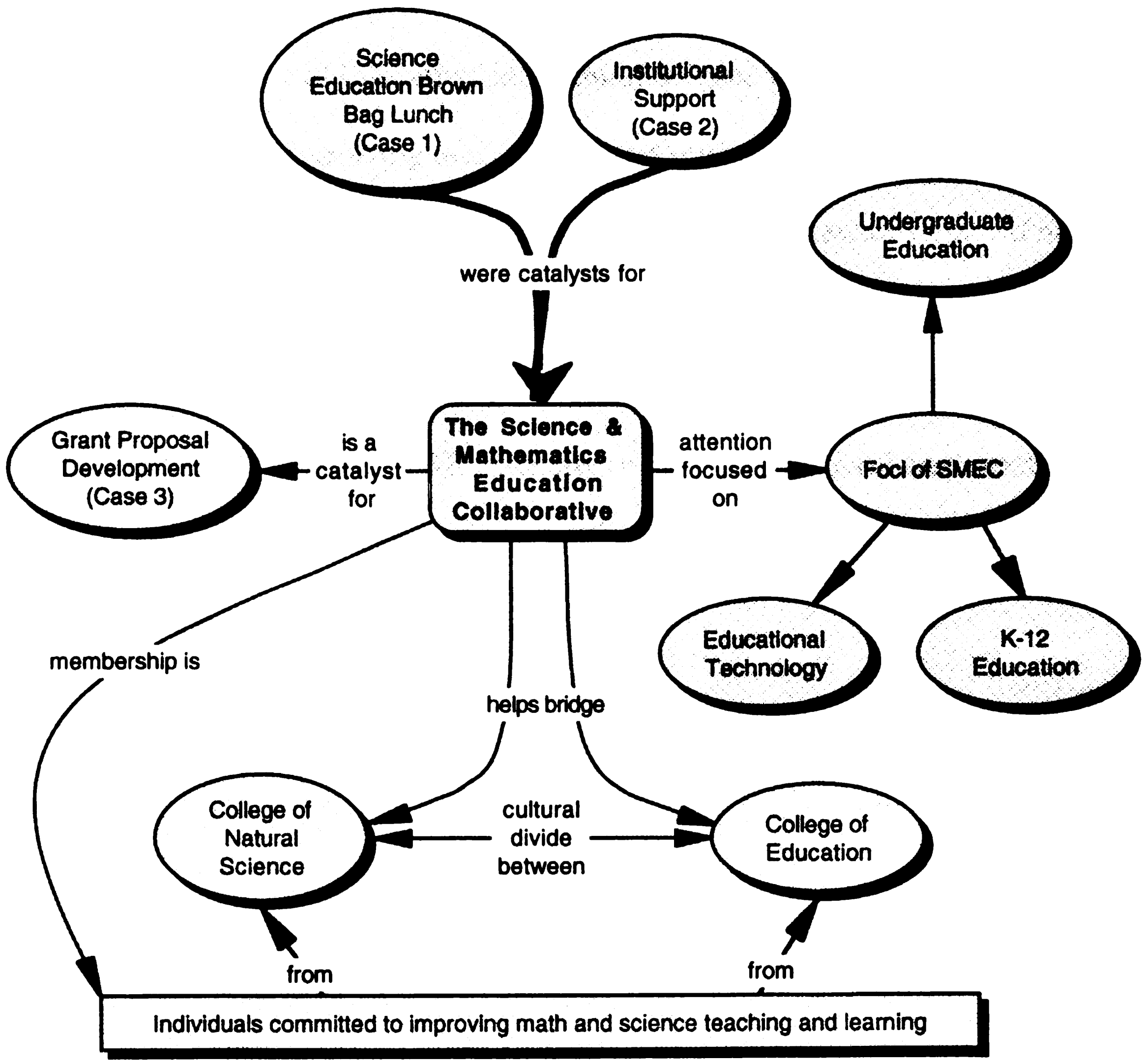


Figure 5.1: Some connections of topics within Chapter 5

Rationale for Collaboration

Criticisms of the teaching of math and science at the K-12 level are common place. See for example, (AAAS, 1989, 1993; Darling-Hammond, 1995; NRC, 1996; Schmidt, 1997; Shamos, 1995). Recently (and historically), such criticisms have also focused on undergraduate teaching. See for example, (NSF, 1996; Seymour & Hewitt, 1997). For a historic perspective see (Osburn, 1921) for example.

Within the Colleges of Education and Natural Science were many caring professionals dedicated to improving mathematics and science teaching and learning at all levels. It seemed common that faculty in one college were not aware of or did not understand the work related to these goals in the other college. SMEC was established to improve math and science teaching by improving communication and collaboration among faculty in the two colleges. While faculty in the two colleges shared students, the goals for these shared students seemed quite different, even in opposition to each other. The aims of the organization are shown in Figure 2.

Precursors

Catalysts for Collaboration

In the fall of 1994, Midwestern University hosted a meeting to review an early draft of Project 2061's *Blueprint for Science Literacy*, involving scientists and science educators from around the country. At that meeting, there was a heated exchange between physicist Greg Garno and science educator Don Walter, both (unbeknownst to each other) of Midwestern University.

Don found the conversation worth continuing and talked further to Greg and discovered they were both from Midwestern University. As a result of this conversation, Don established the Science Education Brown Bag Lunch (BBL) Group. This group has continued to meet regularly since 1994. The setting is always informal, sometimes without an established agenda, but usually focused around a particular reading or issue. Attendance typically varies between ten and twenty, and both colleges are always represented. Beginning in the fall of 1998, mathematicians and math educators with interests in issues affecting both mathematics and science education have joined the conversations. This addition has helped keep the conversations intense, and the interactions of two mathematicians and the established Brown Bag Lunch group will be the first case addressed in this chapter.

Program Structures

Several factors preceded the formal establishment of this collaborative. There is a respected, long-standing and sizable science education faculty group in the College of Education. Every fall, virtually all of the science education faculty and graduate students participate in weekly seminars, and in the last two years, a small number of faculty from the College of Natural Science have joined these seminars. The theme of this course, Teacher Education 955, changes from year to year. In 1998, the focus was on the differences in culture between the two colleges.

Under the leadership of Calvin Theiss, The Division of Mathematics and Science (commonly referred to as "The Division") formed within the College of Natural Science serving as a point of contact for the College of Education. For the last two and a half years, The Division has been under the leadership of Brian Wysor. In 1999, Evelyn Pelosi will assume the directorship of The Division. The Division is the formal structure in which masters' degree programs for practicing science teachers are housed. The Division also includes two faculty, one tenure stream and one temporary, with joint appointments in the two colleges. Several other faculty and support staff serve bridging roles between the two colleges. Institutional support is the second of the three cases addressed in this chapter.

As communication improved through channels like the SMEC website, listserv and through SMEC meetings and BBLs, another type of catalyst came into play – RFPs. The story of the development of a successful grant proposal will be the third and final case investigated in this chapter.

The Aims of SMEC

Following the first meeting in January of 1997, website development began as one vehicle for information dissemination – a primary goal of the collaborative. A listserv was also established. By the fall of 1999 the list included over forty subscribers from the two colleges, the State Department of Education and directors of the state's Math and Science Centers.

The opening text of SMEC's website defines the aims of the organization. This is provided here for context. The aims are shown in Figure 2. The text was written in the spring of 1997, shortly after the first meeting.

Figure 5.2: The Aims of SMEC

What is The Science & Mathematics Education Collaborative ?

The Science & Mathematics Education Collaborative is a new and unique group at Midwestern University. SMEC seeks to improve science and mathematics teaching at all levels. Begun under an initiative of the Dean in the College of Education, this group has received strong support from the College of Natural Science, and encompasses most of the research faculty in science and mathematics education in the two colleges. The current participants number more than forty and include staff members from the State Department of Education.

The aims of this group include:

- Creating new images of what science and mathematics education might be
- Providing a forum for consideration of needs and priorities for work in science and math education, i.e., strategic planning
- Informing our faculty better of one another's work and of relevant developments at the national, state, regional and local levels
- Facilitating preparation of collaborative projects that interrelate multiple aspects of our work
- Communicating the scope and impact of our combined efforts to administrators and policy makers
- Focusing of institutional support for major proposals
- Providing an access point for queries, expressions of concern or proposals about science and math education
- Providing a more informed, timely, and effective voice on policy matters that arise
- Fostering an intellectual community for faculty and advanced graduate students

This group is in a position to work with others around the University in strategic planning for new and continuing initiatives.

Case 1: Brown Bags and Controversy

As noted in the introduction, the Science Education Brown Bag Lunch (BBL) emerged from a heated exchange between physicist Greg Garno and science educator

Don Walter. The exchange took place in 1994 when Midwestern University hosted a national meeting to review a draft of *Blueprints for Science Literacy.* This exchange led to continued discussions among scientists and science educators through the Science Education Brown Bag Lunch group. Don Walter coordinated the BBL from its creation in 1994 through the fall of 1998 when Don passed the reins to Don Duggan-Haas and SMEC.

Throughout the history of the BBL, a wide range of topics related to science education have been discussed, including reform documents, big ideas in science disciplines, how to teach specific concepts, politics of the State Board of Education and much, much more.

Heated exchange is part and parcel of BBLs. Pounding the table to make one's point is not unheard of. There are issues discussed in every meeting in which all discussants clearly do not see eye-to-eye. In the fall of 1998, two mathematicians, David Margolius and Jeremy Richter, began regular participation in the BBL. Both are opposed to mathematics education reform and attribute difficulties their current college students are having in their classes to the reforms. They hold similar concerns about the reforms in science education.

David and Jeremy were drawn to the first meeting of the fall where the topic of discussion was Testimony of Stan Metzenberg, Ph.D. before the United States House of Representatives Committee on Science, Subcommittee on Basic Research (Metzenberg, 1998a, 1998b). Metzenberg's harsh criticisms of science education standards and educational research (which Don Duggan-Haas characterized as an attack in the meeting's agenda) appear to be in line with the criticisms of many scientists and mathematicians who have joined our conversations.

These discussions were seen as political and addressing issues where we can make no difference by some of the scientists who had participated regularly in our conversations. For that reason, some chose not to come to these meetings. The discussion of the Metzenberg piece led to the suggestion from David Margolius that we discuss how the State Standards help or fail to help teachers in planning and teaching – a much more pragmatic approach. This was the primary topic of discussion for the March 16, 1999 BBL. The specific state standards were handed out along with related text from California standards at a prior BBL.

The standards discussed dealt primarily with electric circuits and the discussion grew heated in determining what is fundamental for middle school children to learn about circuits. Mathematician David Margolius argued that knowing how to series and parallel circuits operate is fundamental. Science educator Don Walter argued that getting students to understand that electricity flows in a loop is the fundamental understanding for middle school students to understand about circuits.

Grade specific benchmarks (like California) versus standards (like this state's and the national standards) were also an issue. Don argued that the politics of the American schools preclude a grade-by-grade national or state curriculum, though there is movement toward a more coherent curriculum at the state level. David argued that such a curriculum is necessary.

After the meeting formally ended, Don and David continued to talk for a full hour. David asked Don if this was worth his time. Don responded that while it often frustrating to argue for what is generally agreed upon after years of research, it is worth his time as long as individuals remain engaged in the conversation.

The specifics of this discussion is not the point of describing it here. The point is that again and again, in discussion after discussion, scientists and mathematicians have taken initial positions diametrically opposed to those typically taken by science educators. And, more importantly, they keep talking. What appears to be an obstacle, differing world views, should be recognized as progress – they talk to each other, and more importantly, are coming to respect each others strengths. The fact that these conversations have now gone on for more than four years is a testament to their value. In the words of Scott Peck, we are, "working through the chaos" (Peck, 1998).

At the following BBL, Joe spoke about Peck's work and used Figure 5.3 in his discussion of progress in community building. Ground rules for discussion were suggested based on Peck's work. Those rule include:

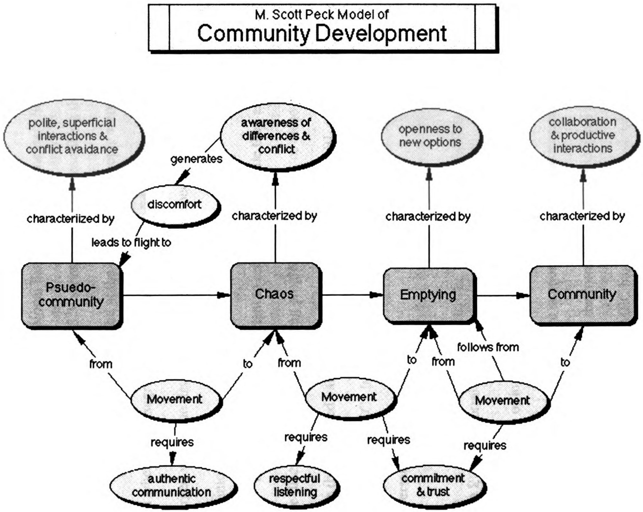
1.Say your name each time you speak and use 'I' statements.

2.Do not interrupt others and listen carefully (or use careful listening).

3.Speak only when moved to speak.

Peck provides other rules, but Joe said that this was probably a good basic set for beginning. The discussion of Peck's work and the dynamics of the group was short and I sensed that David and Jeremy may have been thinking this was "touchy-feely education crap" that Peters had mentioned in my first meeting with him. They did not say much and the meeting moved on to look at and discuss the teaching of electric circuits using one of the *Private Universe* videotapes as a focus for the conversation (The Harvard-Smithsonian Center for Astrophysics, 1995).

Figure 5.3 M. Scott Peck Model of Community Development (Peck, 1998).



The consideration of the dynamics of the organization led Joe Stewart to connect Peck's work that he had been exposed to in church work and used in building community within one Midwestern's Professional Development Elementary Schools. This model, which is sketched out in Figure 5.3, seemed useful for describing the process of the BBLs. Pseudo community existed at the early BBLs. People were pleasant and polite, even when they disagreed. This, however, really did not last very long. Genuine anger emerged within the first year of the BBLs. People became painfully aware of differences of opinion.

It is tremendously important to recognize that while they are making progress in these discussions, they are making progress with a subset of those who are willing to talk. While this is indeed valuable, it is only a beginning. The BBL was a catalyst for the formation of SMEC. It is now an integral part of what SMEC does to keep the conversation moving forward.

Case 2: Institutional Support

The kinds of institutional support for SMEC can be classified as either individual or administrative. Administrative support includes formal recognition and monetary support. Individual support is in the form of time and work from individuals without compensation or recognition. SMEC has benefited from both administrative and individual support. Deans of both colleges have attended SMEC meetings. The College of Education provides ongoing funding as well as in kind support (electronic resources like server space and prominent placement of a link within the College's website, for example). Faculty have given much of their time without load time. This section of the chapter provides an overview of institutional support.

In 1996, Dean of the College of Education launched an initiative to fund several "themes" within the college. These themes were intended to foster "intellectual communities" within the College of Education and internal funding was available. This served as a catalyst for conversation among the science education faculty group, encouraged by Joe Stewart. Continued conversation lead to the inclusion of mathematics within the "theme" proposal and to branching across the two colleges. An organizational meeting was held that lead to the writing of the internal proposal. Funding of $8,000/year was awarded beginning in January of 1997. This funding was used to hire Don Duggan-Haas as the project's graduate assistant. Funding also was used for large group meetings the most recent of which was March 18, 1999.

A steering committee formed including a scientist, science educators, a mathematician, and math educators. Brian Wysor, the first scientist on the Steering Committee, was an Associate Dean and Director of the Division of Mathematics and Science Education (DMSE) in the College of Natural Science. The Steering Committee met monthly while whole group meetings have typically taken place once a semester. These whole group meetings have lead to additional meetings of smaller groups, including those involved in substantial grant development activities (see (Duggan-Haas, Smith, & Miller, 1999) for information regarding accomplishments).

As Director of DMSE and Associate Dean, Brian served as an important bridging agent between the two colleges. His active participation and support of SMEC played a very important role in that bridging. DMSE houses masters' programs for science and math teachers. DMSE was gaining responsibility without a corresponding increase in resources. There was significant pressure to bring the non-majors' science courses into the realm of DMSE without providing the means necessary to run the courses well. Brian moved into the Director's position labeled as the Science Co-Director of DMSE, with the understanding that a Mathematics Co-Director would soon be brought on.

Two searches initially failed to fill the Mathematics Co-Director position during Brian's tenure as Director.

Linda Whitney, of the College of Natural Science, developed a science course for elementary teacher candidates that was taught in the fall of 1998. Throughout the course and in course development, Linda worked closely with science educators. The course is being taught again in the spring of 1999, and enrollment is full.

The kind of support that this course has received reflects the strengthening connections between the two colleges. Linda is a faculty member in the College of Natural Science and she is being given load time to teach a course. She wrote a proposal, along with science educators, that advocated adding sections over the next three year so that the course will eventually be taken by all elementary teacher candidates. The proposal has been well-received and course development has been facilitated by a NASA NOVA grant.

SMEC both contributes to and benefits from the strengthening connections between the colleges.

Case 3: Grant Proposal Development

Throughout the spring of 1998, a large grant writing team involving faculty, post doctoral fellows and graduates students from the Colleges of Natural Science and Education developed a Howard Hughes Medical Institute Grant proposal. A $1.6 million award was announced in the summer and work is underway ① to reform introductory biology courses for science majors, ② to expand opportunities for undergraduate research and ③ to expand faculty professional development programs.

Again, SMEC was positioned to both contribute to and benefit from strengthening ties between colleges. Don Duggan-Haas was involved in the grant writing process because of his role in SMEC. Both Joe Stewart and Don Duggan-Haas served in advisory capacity to the grant team as SMEC representatives. This grant not only brings in substantial funding, but it explicitly targets improving undergraduate science teaching, one of the primary foci of SMEC.

The grant work applies educational technology as a tool for the improvement of biology instruction. Educational technology has been central to the work of SMEC in 1999 and other grant initiatives indicate that the effective use of educational technology will remain a focus for some time to come. Even before the grant was awarded, the process of writing the proposal had produced valuable outcomes. Some valued outcomes are in the form of individual connections within the grant writing team. Another more tangible outcome is the development of DMSE's Draft Educational Principles. These are shown in Figure 5.3.

Figure 5.3. Guiding Educational Principles for Midwestern University

1. **Convey Understanding of the *Big Ideas*.** Effective science instruction illuminates accurate yet understandable renderings of the concepts, models, and theories unifying vast numbers of otherwise seemingly unrelated facts. This endows the learner with: 1) deep understanding of the causes for pattern across facts, and 2) robust power to accurately predict outcomes under a novel set of initial conditions in a domain governed by the given *Big Idea*. For most learners, *Big Ideas* best come alive when grounded in a limited set of facts carefully chosen by the instructor to be both necessary and sufficient for illustrating the phenomenological puzzle under scrutiny. It is appropriate to tell the human story behind the discovery and testing of *Big Ideas*. Analyzing experiments and the lines of reasoning between evidence and conclusions helps students begin to understand science as a process of inquiry as well as a body of knowledge.

2. **Knowledge is Constructed**. Students usually overlay newly encountered facts/knowledge as superficial layers upon a well-established framework of cherished beliefs. Since conceptual learning often requires abandoning prior beliefs, it is recommended practice to: assist students in recognizing the shortcomings of their original ideas, offer a more plausible or defensible alternative idea, model multiple successful applications of the new idea, and have students independently apply and analyze the new idea (e.g., in homework problems). It is difficult to assist students in constructing new knowledge if the teacher does not analyze and adjust to students' preconceptions and track progression toward the desired new understanding. In attempting to **pay attention to student ideas**, it is advisable to have students articulate their position precisely in their own words, drawings, or other conceptual renderings.

3. **Assessment Guides Instruction**. Teachers should provide frequent opportunity for and varying forms of assessment of student: ideas, beliefs, thinking, reasoning, and difficulties with given material. Assessments that require only instrumental understandings or factual recall are insufficient. The information gathered on students' growing understanding should be used to continuously adjust and improve teaching.

4. **Hands-on / Concrete / Relevant / Engaging**. Wherever possible, science instructional activities should embody these attributes. Such experiences heighten attentiveness, extend attention spans, spur more diligent attempts to apply new material, and are more memorable.

5. **Multiple Examples and Representations**. Science concepts and procedural skills are learned best when encountered in a variety of contexts and represented in a variety of ways, e.g., analogies, metaphors, models, applications. Students should also be encouraged to represent and communicate new knowledge in multiple formats, e.g., orally, in writing or drawing, and in new applications.

6. **Discourse Among a Community of Scholars**. Throughout the learning process, students need opportunities to reflect upon and then express their evolving ideas. Discourse with learning partners provides opportunity for feedback about the adequacy of understanding from the perspective of peers. Incongruence of perspectives can be a strong stimulus to solidify and defend one's thinking and position, or to revise and amend one's position in the face of convincing evidence or logic. Discourse surrounding disparate perspectives can be a strong stimulus for beneficial reflection.

A stated goal of SMEC is, "Facilitating preparation of collaborative projects that interrelate multiple aspects of our work." (See Figure 5.2.) The HHMI grant is a very important collaborative project for both colleges and for our students. While this is not a direct outgrowth of SMEC, more recent proposals are a direct result. This includes proposals for a Technology Literacy Challenge Fund Grant proposal and a Rural Systemic Initiative grant proposal.

Another stated goals is, "Focusing of institutional support for major proposals." Again, the HHMI grant and other proposals either recently submitted or under development have found SMEC's meetings and electronic communication avenues useful for proposal development. There is also an effort underway seeking Title II funds directed by an Associate Dean of the College of Education and involving faculty from both colleges.

In the Fall of 1998, the scope of educational technology projects in the College of Education were largely unknown to SMEC participants. This came to light as a result of Steering Committee meetings and meetings involving Joe Stewart, Brian Wysor and Don Duggan-Haas, and, eventually, faculty and educational specialists directly involved in educational technology. This lead to the January 7, 1999 meeting entitled, "Using Technology in Support of Science & Mathematics Education," and a follow-up meeting on March 18, 1999 entitled "What Should Educational Technology Look Like in Three Years?"

These meetings helped faculty involved in both science and science education understand the scope of educational technology projects underway in both colleges and to see how their work might support these efforts and to discuss new possibilities for collaborative efforts. As a result of the first of these two meetings, at least two significant new grant writing teams have formed. One proposal has been submitted and the second will be submitted within a month of this writing. The second meeting is part of still ongoing grant development and analysis of the use of educational technology in the teacher education program.

Obstacles faced along the way

Scientists and mathematicians typically know their subject matter far better than do science and math educators. Science and math educators typically know far more about sound pedagogy than do mathematicians and scientists. In good teaching, content and pedagogy are inseparable (Shulman, 1987) yet the norm on most college campuses, including Midwestern University's, is that these are separated. Content courses are taught in one college or department and courses on how to teach are housed in another.

See the Cycle of Blame described in Chapter 6, Scientists are From Mars, Educators are From Venus.

This progress has been more noticeable in science than in mathematics, at least for undergraduate teaching. Sadly, the most outspoken member of the mathematics department representing SMEC and the only mathematician on the Steering Committee passed away in 1998. SMEC has been unable to find a mathematician to take his place on the committee.

Many of the problems faced can be better understood if it recognized that there are huge cultural differences between the two colleges. There is a divide between the two cultures, similar to the one described by (Snow, 1959). These two cultures are defined by, and maintained through, the nature of interactions academics have with each other and with their students in each college. The differences perceived by students are delineated in Table 1.1.

The cultural divide is easily recognized by faculty in either college. There is plentiful anecdotal evidence of the divide, and less evidence on initiatives to narrow the divide. For example, the conversation between Don Walter and Greg Garno that acted as a catalyst for the Brown Bag Lunch series highlighted the divide. Their work together over the four years since that discussion, and their work in other border-crossing activities indicates that the gap is being closed for these two individuals. Don has been involved in the grant writing team for the successful grant proposal to Howard Hughes Medical Institute. He drafted what became the Educational Principles of The Division of Mathematics and Science Education as part of his work on the proposal. Greg has been involved in a science curriculum committee for a local district and in other curriculum development. Both have been regulars at the BBL gatherings for four years.

Conclusion

SMEC has made considerable progress towards its goals. While it is difficult to determine what is causal in regards to this progress, we believe that SMEC has offered many avenues towards their fulfillment. The connections between the Colleges of Education and Natural Science have grown stronger throughout the brief history of the Science and Mathematics Education Collaborative . Clearly, SMEC has played an important role in fostering that growth.

In the introduction to this chapter, three research questions were raised. (1) What are the differences between the culture of college science and the culture of teacher education? (2) What factors, mechanisms or conditions have contributed to our progress? (3) What factors, mechanisms or conditions have limited our progress? In closing, I revisit these questions.

What are the differences between the culture of college science and the culture of teacher education?

The differences are reflected in our interactions with each other, here explicated through the description of the Brown Bag Lunch meetings. It is also evident in how our students perceive what happens in our classrooms as shown in Table 1. Midwestern University is by no means unusual in the presence of these cultures at odds.

What factors, mechanisms or conditions have contributed to our progress?

The confluence of individual and administrative initiatives -- the Brown Bag Lunch Group coming together before the Dean of Education's "Theme Initiative," and Joe Stewart's and Brian Wysor's perseverance for several related initiatives to see themselves as related are all important pieces of the puzzle. There is also a broader stick-to-itiveness, what M. Scott Peck refers to as a willingness to "work through the chaos." (Peck 1998). Where there has been success, there has also been a willingness to work with colleagues that see the world in a different way and a willingness to listen and respect views other than our own.

There is a common draw. Everyone who is involved in SMEC, be it through grant work, participation in BBLs and large group meetings or through serving on the steering committee is committed to improving mathematics and science teaching. Without committed and caring professionals from both colleges, the effort would fail.

SMEC has worked to improve communication and collaboration among colleagues. SMEC participants are now beginning to study their work towards these goals.

What factors, mechanisms or conditions have limited our progress?

The dichotomy of academic cultures at odds is not a false dichotomy. Scientists and mathematicians tend to have conceptions of teaching and learning that are very different from those held by educators. This is reflected in virtually everything done in classrooms or for classroom teachers. We do have a small number but growing of individuals engaged in cultural border-crossing, but the numbers are indeed small. This is just a humble beginning at sustained change.

Chapter 6

THE DYSFUNCTIONAL RELATIONSHIP OF COLLEGE SCIENCE AND TEACHER PREPARATION

> What has been striking in this enduring clash of ideals has been the divorce of pedagogy from subject-matter specialties.
>
> (Cuban, 1999) p. 52

> "[The philosophy of the education department is] to get away from traditional instruction where a teacher stands up in front of a class and lectures and does pretty much [the] same as my college instructors in college science. So they kind of, it's kind of like they're battling against each other. The way science classes are usually taught and the TE classes are saying this is not how it's supposed to be done."
>
> Bill's New Teacher Preservice Program Interview

This chapter describes how the relationship between college science and teacher education is a dysfunctional relationship by comparing it to a dysfunctional marriage. The chapter then moves on to describe three interconnected potential causes for that dysfunctionality: ① The goals of college science and teacher education are at odds. ② Scientists and teacher educators are from different cultures and hold different cultural views (that often conflict). ③ It is easier to place blame for problems than to work to solve problems.

Scientists are from Mars, Educators are from Venus

The model developed in Chapter 1, based on Snow's framework, helps to portray the sharp dichotomy that is science teacher preparation. The information in Chapters 3, 4 and 5 maps onto this framework well, and it is useful way to frame the data. That is, the science content courses are essentially a separate program from the teacher education courses and the students, the future teachers, who move back and forth between these two programs see little connection between them. This simple dichotomy however, is not a terribly rich way to investigate the relationship between the two cultures (college science and teacher education) and the relationship between the two cultures is as interesting as the cultures themselves. This relationship manifests itself in one way or another on every campus where science teachers are certified. Often, and at Midwestern University, this relationship is dysfunctional.

The characteristics of a failed marriage are mirrored in the characteristics of science teacher preparation programs. Reflected in the preceding three chapters are the two primary components to most such programs – content training housed in colleges and departments of science and pedagogical training housed in colleges and departments of education. The norm is poor communication between these departments, particularly in larger institutions. Even when there is communication between scientists and educators it may not be apparent to teacher candidates in either class.

Science teachers, like most folks, have the desire to affiliate with a culture and with cultural norms. It seems teachers affiliate with content-centered teaching or with student-centered teaching as are the norms in their schools. Few teachers affiliate with understanding-centered teaching (Anderson, 1995). Making the leap to the marriage metaphor, science teachers end up like the scientists who taught their college science classes or like the educators who taught their education courses – too much like Dad or too much like Mom and not somewhere synergistically in the middle. Both Joseph and Brad readily identified themselves as more closely affiliated with science than education while Bill saw himself as more closely affiliated with education. None of the three hesitated to choose science or education, they chose one or the other. As Wideen et. al. (1998) note, the future teacher is left to add the pieces of her or his program together with little or no direct assistance in this integration. This habit to affiliate with one or the other is an indicator that that integration does not happen as well as it might.

The divorce of pedagogy and content are central to this study. The unification of pedagogy and content through pedagogical content knowledge (PCK) is fundamental to good teaching (Shulman, 1986, 1987). This work resonates with Shulman's belief that "TE programs would no longer be able to confine their activity to the content free domain of pedagogy and supervision" (1987, p. 20).

The identification of the marriage metaphor[55] led me to read *Men Are from Mars, Women Are from Venus: A Practical Guide for Improving Communication and Getting What You Want in Your Relationships* by John Gray. I found his descriptions of the relationships between husbands and wives strikingly similar to what I saw happening between scientists and educators in their discussions in the Science Education BBLs that were part of the scientist-educator collaborative SMEC and in my broader experience with scientists and science educators. Gray provides a framework that is useful for thinking about the relationships between scientists and educators and some thoughts on how to improve those relationships.

Figure 6.1 takes the opening of Chapter 1 of *Men Are from Mars, Women Are from Venus* and replaces references to men and women and Martians and Venusians with references to scientists and science educators. References to planets are also modified.

[55] This idea came to me as result of the barroom conversation described in the overview of the dissertation.

Of course, scientists and educators, like men and women, are not truly from different planets and scientists and educators did not all meet at some historic point and fall in love. Gradually, though, Universities grew teacher preparation programs while normal schools grew into universities. This evolution did bring together two different cultural views, not out of love, but out of necessity and administrative decree.

Figure 6.1: Scientists Are from Mars, Educators Are from Venus

Imagine that scientists are from Mars (universities) and educators are from Venus (normal schools). One day long ago the Martians, looking through their telescopes, discovered the Venusians... They fell in love and quickly invented space travel...

The Venusians welcomed the Martians with open arms... The love between the Martians and Venusians was magical. ... Though from different worlds, they reveled in their differences. ...

Then they decided to fly to Earth. In the beginning everything was wonderful and beautiful. But the effects of Earth's atmosphere took hold, and one morning everyone woke up with... *selective amnesia!*

Both the Martians and Venusians forgot they were from different planets and were supposed to be different. In one morning everything they had learned about their differences had been erased from their memory. And since that day scientists and educators have been in conflict.

REMEMBERING OUR DIFFERENCES

Without the awareness that we are supposed to be different, scientists and educators are at odds with each other. ... We expect the opposite sex to be more like ourselves. We desire them to "want what we want" and "feel what we feel."

...Scientists mistakenly expect educators to think, communicate, and react the way scientists do; educators mistakenly expect scientists to feel, communicate, and respond the way educators do. We have forgotten that scientists and educators are supposed to be different. As a result our relationships are filled with unnecessary friction and conflict.

Adapted from (Gray, 1992) Pgs. 9 & 10

Teacher candidates, like the children of divorced parents, move back and forth between the supervision of education faculty and science faculty. These two divorced supervisory entities each serve their own purpose in the development of future science teachers, but they are not cooperative in the endeavor.

Why Is the Relationship Dysfunctional?

"Why can't we all just get along?"

Rodney King

Why is the relationship of college science and teacher education dysfunctional, especially if scientists and educators share a common goal of preparing good future science teachers? There are a myriad of reasons but three causes seem central to the dyfunctionality: ① cultural dissonance; ② blame; and ③ conflicting goals. The cultural dissonance described in Chapter 1 could be seen as all encompassing, and indeed, the other causes I describe, blame and conflicting goals, stem from this cultural difference. While both blame is assigned and goals conflict because of the gulf between science and education, each issue can be viewed in and of itself.

Conflicting Goals

As Individuals working with the same groups of future teachers, scientists and teacher educators fill different niches. Scientists and educators should be different from each other, but the roles they serve in teacher preparation should be more complementary than the situation I observed at Midwestern. That complementarity can only come after an agreement of goals for the students who will go on to become teachers. Labaree (1998) describes three conflicting goals of education. *Democratic equality* sees schools as a key place for developing good citizens. *Social efficiency* sees education as "designed to prepare workers to fill structurally necessary market roles." *Social mobility* prepares individuals for "successful social competition for the more desirable market roles." Democratic equality and social efficiency are both public goods – they serve the society more than the individual. Social mobility is a private good. It is consumer driven ((Labaree, 1997) p. 42).

The purposes of college science are more private goods than public. Most students in science classes for science majors are, unlike the seniors interviewed for this study, not there to become teachers. Most are planning to go to graduate or professional school after graduation. They are enrolled in these classes for their *exchange value.* Students come to the realization "what matters most is not the knowledge they learn in school but the credentials they acquire there" (pp. 55-56).

The following quote is how Chika Hughes opened her syllabus for TE250, *Human Diversity, Power and Opportunity in Social Institutions*:

> There is not such a thing as a *neutral* education process. Education either functions as an instrument which is used to facilitate the integration of the younger generation into the logic of the present system and bring about conformity to it, *or* it becomes "the practice of freedom," the means by which men and women deal critically and creatively with reality and discover how to participate in the transformation of their world. ((Freire, 1993) p. 15)[56]

TE250, like most teacher education classes seemed to more target the goals of democratic equality and social efficiency than social mobility. The readings for TE250[57] are clearly targeting democratic equality and the economy has a constant need for teachers. Classes like TE250 may incidentally help students to navigate the rift between college science and teacher education, but this is not an explicit intention.

[56] One might argue that this social conflict is manifest in the differences between the way science and teacher education courses are taught at Midwestern University.

Gallagher has developed the "Mercedes model" for delineating some of the differing goals for addressing the learning of science that portrays learning for knowledge, application and understanding as complementary (Gallagher, 1992). See Figures 6.2 and 6.3. The Mercedes Model was used in TE401 to discuss relationship of knowledge, application and understanding. This is one place where connections between college science and teacher education were made for the teacher candidate, however none of the seven seniors mentioned the link[58].

Gallagher relays the story of talking with a teacher about the Mercedes Model:

> "...when I was asked by one experienced teacher who was learning about how to teach for understanding and application of science knowledge, 'Do you mean that what I have been doing for the past several years as a teacher is wrong?' I was able to reply, 'No, you were helping students acquire the essential base of knowledge. However, you did not go far enough. . . .' Then I could ask, 'What does the model suggest you should add to your lessons?'"
>
> (Gallagher, In press)

Such an approach is useful not only for working diplomatically with high school and middle school teachers who are attempting to move their teaching to an inquiry approach, but also for the scientist attempting to make the same move. Using tools that are sensitive to the strengths of the others in a relationship is one method to improve the relationship. At least as important, it is also sensitive to research findings.

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[57] Most of the readings are listed in the syllabus excerpts in Chapter 3.
[58] Joseph did mention the introduction of the Mercedes Model as one of the rare teacher education class moments where he actually took notes.

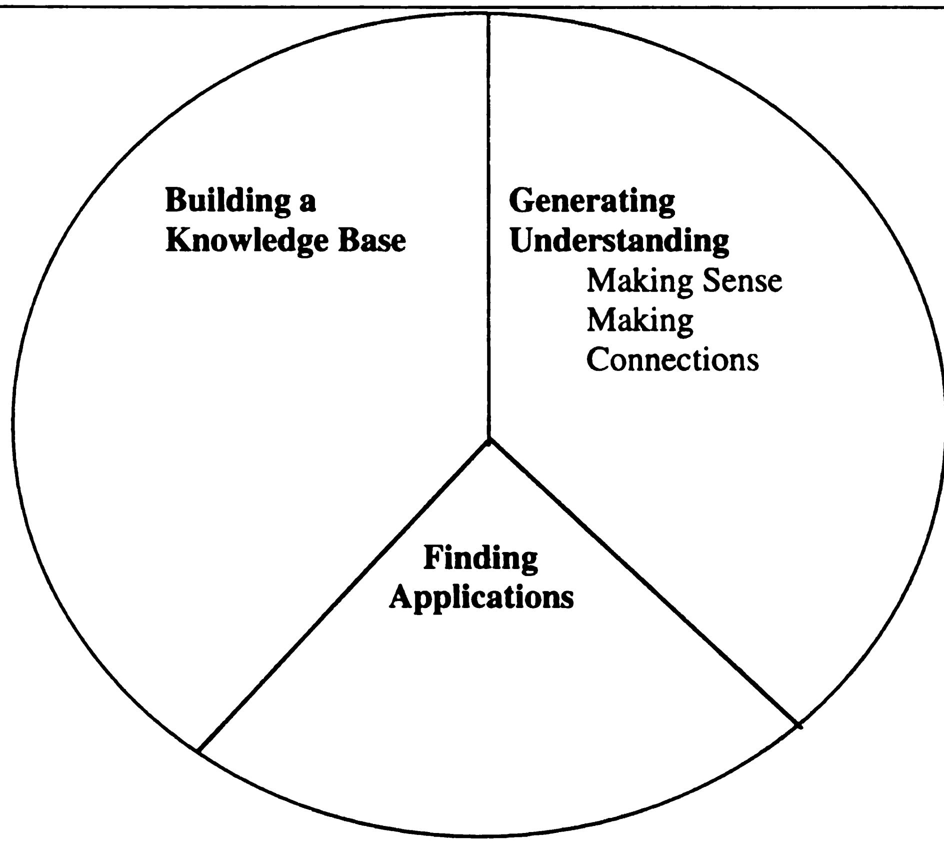


Figure 6.2. The Mercedes Model for Teaching and Learning (Gallagher, 1992)

Building a Knowledge Base	**Generating Understanding**	**Finding Applications**
Lecturing/Telling Reading text or other sources Watching films and videos Hands-on activities Most seatwork Labeling diagrams Most labs Most homework Answering text questions Most library research	Concept mapping Writing to learn Group tasks requiring more than factual recall Reading for Understanding Journal writing Representing concepts with pictures and models Explaining diagrams Group work formulating explanations Analysis of peers' work Extended questioning	Searching for applications for science principles at home and outside school Using newspapers as a source of applications Writing about applications Representing applications with pictures and models Group work describing applications Asking "the right question"
Most objective tests	Essay tests	Tests with application items

Figure 6.3. Varied Teaching Strategies for Different Educational Goals (Gallagher, 1992)

In using such tools to make connections between college science and teacher education with teacher education students, perhaps more explicit attention should be drawn to this as a connection. Again, while the Mercedes Model was used in TE401, none of the students mentioned it as a connection between college science and teacher education. The Mercedes Model does offer a different way to delineate the goals of college science and teacher education and through this framework, the goals are somewhat complementary rather than oppositional.

The goals viewed through Gallagher's framework, however do not replace the goals described by Labaree they rather address a different (and equally important) aspect of the course goals. Gallagher's model also reveals the college science classes portrayed in previous chapters as deficient albeit in a more diplomatic fashion.

In spite of science faculty not seeing their courses as weed out courses, when students identify them as such they fulfill the role of social sorting. As noted in Chapter 1, early science courses tend to sort and select whereas teacher education programs tend not to do so until late in the program if at all.

> "...consumers demand a *stratified structure of opportunities within each institution,* which offers each child the chance to become clearly distinguished from his or her fellow students. This means they want the school to have reading groups (high, medium and low), pull-out programs for both high-achievers (gifted and talented programs) and low achievers (special education), high school tracks offering parallel courses in individual subjects at a variety of levels (advanced placement, college, general, vocational remedial), letter grades (rather than vague verbal descriptions of progress), comprehensive standardized testing (to establish differences in achievement), and differentiated diplomas endorsed or not endorsed, Regents or regular). ((Labaree, 1997) p. 53)

These contrasts drawn by Labaree from (add his citations, p. 53) map onto contrast between science and education coursework remarkably well. College science classes include remedial courses to bring at-risk students up to speed, courses for non-majors, majors' courses (for the 'regular' science students), honors courses (or honors options) and special programs for the most advanced like NSF's Research Experiences for Undergraduates (REU) Program. Education courses follow a single track for undergraduates (though a small number may pursue an honors option).

Further, the assessments described previously follow the same divide. In science classes, letter (or numeric) grades distinguish science students one from another. Qualitative descriptions of teacher candidate progress in teacher education courses and the internship are the norm. In teacher education courses, 4.0s are common and in the fifth year, fully half of the credit hours are taken pass/fail (and virtually everyone passes!) For the courses of the internship year, 3.0s are a minority and grades below 3.0 are truly rare. The College of Education, like colleges and departments of education elsewhere, awards grades that are among the highest on campus and is actively discouraged by university administrators from doing so.

The goals for students from the two cultures are at odds. This creates a tension stretching the future teacher in opposite directions. According to Labaree, social mobility and democratic equality are educational goals in opposition: "Whereas social mobility shares with its partner in the progressive agenda a concern for equal access, it stands in opposition to the notion of equal treatment, and it works directly counter to the ideal of civic virtue." (Labaree, 1997) p. 65.

In the dysfunctional relationship, the offspring are the students who plan to go on to teach. Mom the educator pulls them toward the goals in alignment with public goods while Dad the scientist pulls the students toward the private good of social mobility.

Seymour and Hewitt found that the only science students typically encouraged toward teaching by science faculty were women and minorities. Good science students were often actively discouraged from teaching (Seymour & Hewitt, 1997). As noted in Chapter 1, this may be a result of racism or it may be driven by a desire to provide good role models for K-12 students.

Cultural Dissonance

Chapter 1 describes the gulf between the two cultures. From that description we see that the culture of college science evolved as universities evolved and the culture of teacher education evolved as normal schools evolved into universities. The nature in which faculty in science speak to their students and with each other is significantly different than the ways in which faculty in education speak with their student and with each other. It is as if, in Gray's words, they are from different planets.[59]

Individuals within each culture expect those in the other to think and speak the way they do and they become frustrated when this is not the case. Likewise, individuals become frustrated when something that seems obvious to one culture is completely misunderstood by the other. Lisa Delpit, talking about a very different set of cultures, put it this way:

> "In my work within and between cultures, I have come to conclude that members of any culture transmit information implicitly to co-members. However, when implicit codes are attempted across cultures, communication frequently breaks down. Each culture is left saying, 'Why don't those people say what they mean?' as well as, 'What's wrong with them, don't they understand?'" ((Delpit, 1988) p. 283)

[59] I paint with a broad brush here. There are, of course, many exceptions to the generalities described.

Perhaps the most important area of cross-cultural conflict is conceptions of good teaching. On the first day of BS111, Peters said the following:

> "I *do* think by being here you get a lot more out of the lecture. The way I emphasize things, the way I point to things, the things I write on the overhead are all part of the learning experience. So I do believe if you come to lecture you get a lot more out of it."
>
> Jon Peters, 8/31/98, during the first lecture

It is interesting to consider why Jon Peters thinks students should be in class – not for what the students will do, but rather for what will be done in front of them. For him, good pedagogy seems to be in no small part about pointing things out and emphasis. Arguably, Peters's lectures offer a model of the thinking process in science, but the rest of the cycle – both the step before modeling, establishing the problem, and the steps following modeling; coaching, fading and reinforcement are left for the students to do largely without guidance from the instructor.

Teaching, in the college science paradigm, is telling. In teacher education, as one of the Salish participants said, teaching is, "I would say a little bit of everything besides lecture."

The conflict, of course, runs deeper than just the nature of teaching. The nature of content is portrayed in vastly different ways in the two settings. Facts and the need to memorize them are stressed in the science classes described in Chapter 3. In the view of Brad, in teacher education "There really weren't any facts." Assessment reflects the nature of teaching and the nature of what was taught. Reproduce the ideas from the lecture on objective tests in science and in Bill's words for papers in teacher education, "As long as you're thinking critically about something, you're right." This set of conflicts was discussed much further in Chapter 1.

So, what should be done to address problems stemming from the cultural divide? Recognizing that most of those involved in the preparation of future science teachers, whether they are faculty in education or faculty in education, genuinely want to prepare good teachers is a good place to start. Trying to understand the differing worldviews held by others is also helpful. Taking these steps will help alleviate the unproductive blaming.

Another piece of the solution is the funding of projects that bring scientists and educators together for program development and/or reform. There are numerous grant programs that do just this, NSF's Systemic Initiatives, grants for improving biology instruction from Howard Hughes Medical Institute and NASA's NOVA grant program just to name a few. The existence of these programs are further evidence that the separation of science and education is problematic.

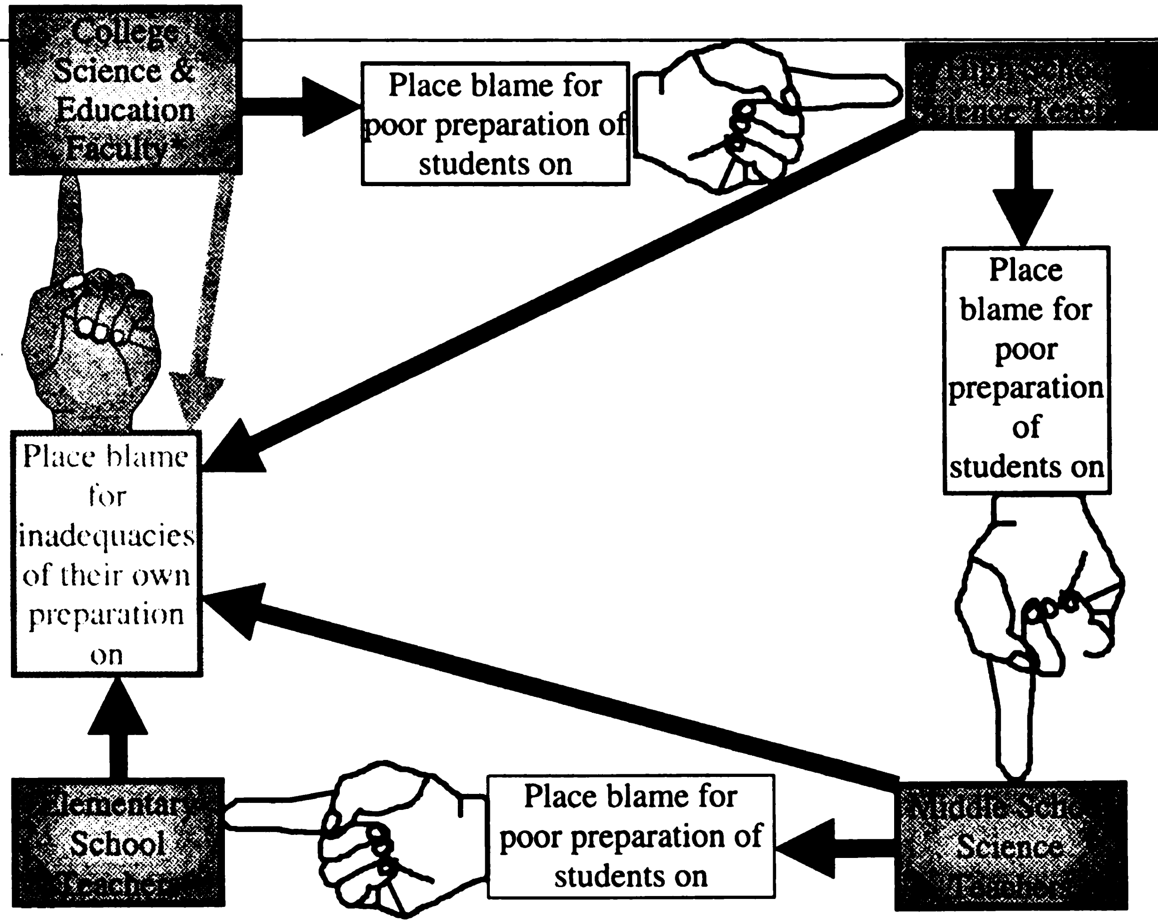
The Centrality of Blame in Dysfunctional Relationships

The issue raised by Delpit of not understanding other cultures' internal cues, leads to the placing of blame. Blame is also, unfortunately, deserved. Educators tend to see science courses as abysmally taught and rightly so. See (Seymour & Hewitt, 1997) or (NSF, 1996) for some of the reasons behind this placing of blame. Scientists often see education courses and education research as "touchy-feely," as Jon Peters, one of the introductory biology professors in this study said. They too have justification for their criticism. Wideen et. al. draw attention to the fact that teacher preparation has consistently failed to prepare teachers to meet the demands of the first year of teaching. Hargreaves & Jacka (1995) cite Lacey's (1977) conclusion that teacher education provides "a stressful but ineffective interlude in the shift from being a moderately successful and generally conformist student, to being an institutionally compliant and pedagogically conservative teacher" (p. 42 as cited on page 159 of Wideen et. al. (1998).

It is generally accepted that science education K-16 has serious problems in this country. Blame can be placed in a variety of settings and when these arguments are viewed collectively, the 'blame path' is circular. College faculty despair about the quality of the pre-college preparation of their students (Seymour & Hewitt, 1997). High school teachers blame middle school teachers; middle school teachers blame elementary school teachers and elementary school teachers blame poor teaching in college for their lack of content knowledge (McDermott, 1990). In addition to these links, all of the individuals included have been trained in college or university to do their current work, so blame may be pointed to college science preparation from anywhere within the cycle. This includes the college science professors themselves who have generally not seen consistently good models of teaching in their own professional preparation and who have had little or no pedagogical preparation. (See Figure 6.2.)

Figure 6.2 shows one possible "cycle of blame" for the problems of science teaching at many levels. The gray line (and finger) from college faculty back to college faculty is perhaps the least obvious and most important. Through this reflective loop real change may be generated. Indeed, what happens inside this box is a key idea of this dissertation. A glaring example of this finger pointing is the Stan Metzenberg congressional testimony discussed at one of the BBLs. Metzenberg places the blame for problems in American science education squarely on the shoulders of science educators (Metzenberg, 1998b). This testimony has been widely disseminated by the organization, *Mathematically Correct* and it is posted on their website, http://www.mathematicallycorrect.com, along with similar examples of vitriolic blaming of science and mathematics educators. Vitriolic blame has power. This is what allowed Metzenberg to testify before the United States Congress.

Figure 6.2: Cycle of Blame



*There is plenty of finger pointing within this box in addition to pointing outside of it!

(Duggan-Haas et al., 1999)

This cycle is, of course, a simplified model. Both larger and smaller contexts are ignored. What is the role of family? Of culture?[60]

Most salient to members of the SMEC collaborative, and to scientists and educators more generally, is the finger-pointing within the box in the upper left hand corner of Figure 6.2 (this is not pictured). In other words, the most important finger pointing is between science faculty and education faculty. There is a fair amount of blame being assigned by both sets of academics both nationally and at Midwestern. For example, blaming was too often a central part of our BBLs. This tendency to accuse others is perhaps the greatest obstacle we face.

So, what should be done in response to the issue of blame? Teachers at all levels must not simply respond to problems in teaching with statements beginning, "If only…" but must instead think in terms of, "If I…" or "If we…" (Fullan 1991). In other words, faculty must assume responsibility rather than place blame. Our SMEC discussions, particularly those in the Brown Bag Lunch group and in the Steering Committee, have generally moved beyond blaming. Those who are regular participants still engage in heated conversation, but they also recognize that other participants in the conversation have expertise that is valuable to the conversation and that all members of the conversation care deeply about teaching and learning.

Did Mars make the Martians of did the Martians make Mars?

Is all this difference grounded in the apparently administratively imposed restrictions such as class size and the university reward structure? The answer, of course,

[60] These factors complexify this picture substantially and raise questions about the broader system of

is complex. McNair made clear in our initial meeting that he preferred smaller class size and essay exams and he used these approaches in his summer version of the same biochemistry class. Clearly, if classes were smaller and if quality teaching had a more important place in determining tenure and promotion then the situation would be markedly different. But it's not different.

The constraints faced by college science teachers have been researched extensively. Larry Cuban investigates why teaching has taken a backseat to research in his book, *How Scholars Trumped Teachers: Change Without Reform in University Curriculum, Teaching and Research, 1890-1990* (Cuban, 1999). The administrators that together with faculty establish the reward system are themselves primarily former university faculty. Cuban looks at Stanford University as a case study of the interplay of research and teaching in the university setting. Stanford's presidents have offered themselves as models for the faculty on campus, faculty that were, "...hired to do research but paid to teach: then they were retained or fired on the basis of published scholarship" (p. 10). These administrative practices, and the practices within classrooms have remained "largely constant over the last century at Stanford" (pp. 52 – 53).

It is easy to ascribe problems of huge classes and the system that rewards research over teaching to factors external to the scientists who teach but is somewhat disingenuous. The reward system does indeed perpetuate the constraints for the scientists who teach, but the system that creates and perpetuates the constraints is made up in large part by scientists who teach or by administrators that used to teach. Assigning blame here is useful only as a first step to initiate change.

science teacher preparation. The simple models described thus far cannot address the deeper complexities.

There was a time when Midwestern's teacher education program also relied heavily on large lecture hall classes, particularly for the introductory level. The faculty made choices that eliminated such practices from the program. There were clearly costs for such decisions, but the benefits seem to outweigh those costs.

Reform in higher education has typically taken the form of curriculum reform. Unless pedagogical reform accompanies curricular reform student outcomes will likely change little, thus the subtitle of Cuban's book, "Change without reform..." (Cuban, 1999).

Separate from the system-imposed differences described above, scientists tend to have a different approach and philosophy of teaching than teacher educators. Both Peters and McNair stressed the need to memorize as key to success in each of their courses. This was never emphasized in the teacher education courses I observed.

This is a positive feedback loop where the Martians make Mars while Mars makes the Martians. Feedback loops are discussed further in the next chapter.

Conclusion

Counseling can be helpful

Collaborating with others who have different cultural views is a difficult process, but it is central to the preparation of good teachers. It requires a willingness to work together to hammer out common goals, and this may mean "working through the chaos" (Peck, 1998). It may also require a form of counseling. In a sense, this is what Joe was doing when he introduced Peck's model for community building and Peck's rules for discussion to the BBL. See Figure 5.3. Gallagher's Mercedes Model is a tool that might be used in the diplomacy of relationship building. Such relationship counseling is helpful in moving beyond blaming and onto working together toward specific goals.

More important than counseling is recognition that scientists and educators are different from one another. There is a tension here but tension can be productive. Like divorced parents who do not share each other's worldview, there is dire need to cooperate in work toward certain goals. For the good of the future teachers we share responsibility in nurturing, common goals must agreed upon and worked on in complementary ways. This is not the current situation and the lack of agreement on goals is one of the greatest obstacle to improvement of science teacher preparation.

Unfortunately, the relationship model whether the relationship is functional of dysfunctional oversimplifies the realities of science teacher preparation. The relationships involved in science teacher are myriad and complex – not simply the scientist, educator, student portrayed here. Again, the Salish study found more variation in new teacher beliefs and practices within each of the nine science teacher education programs involved than among those nine universities.

Chapter 7

THE ECOSYSTEM OF SCIENCE TEACHER PREPARATION: DECONSTRUCTING THE DYSFUNCTIONAL RELATIONSHIP

> It's fun to learn about human physiology, how the heart works, how the muscles work, how the brain works and all that, but if you don't understand how one cell works, by itself, all the intricate things that it does, you don't really appreciate the whole picture.
>
> Dr. Peters BS111 lecture, 8/31/98

> When we try to pick out anything by itself, we find it hitched to everything else in the universe.
>
> John Muir

This chapter folds together the ideas of the first six into a conceptual model of a Complex Educational System; that is, in this chapter, the system of science teacher preparation at Midwestern University is portrayed as a complex adaptive system. Examples of complex adaptive systems permeate the natural and human-made world. Ecosystems and economies are two examples of complex adaptive systems. They are systems that are complex and evolve as a result of the interplay of a large number of actors following a fairly small number of basic rules or laws. When as few as two components are joined, the characteristics can be beyond those of the constituent parts. "If we are dealing with a system, the whole is *different from,* not *greater than,* the sum of its parts" ((Jervis, 1997) pp. 12 - 13.)

The interplay of multiple actors in large systems makes prediction in such systems very difficult. The system of education is unarguably a complex adaptive system made of many more overlapping complex adaptive systems including the system of science teacher preparation.

In this chapter I will draw from a variety of sources to describe the system of teacher education as a complex adaptive system, or in the language of a recent NSF grant program announcement, a "Complex Educational System" (NSF, 2000). This portrayal will begin with an overview of Complex Adaptive Systems followed by a description of emergent properties and move on to larger and more complex dynamics. The chapter ends by investigating how optimizing one aspect of a system may "pessimize" other aspects of the system or the entire system (Hawken, Lovins, & Lovins, 1999).

What are Complex Adaptive Systems?

First, some definitions:

Complex Adaptive System (CAS): "Within science, complexity is a watchword for a new way of thinking about the collective behavior of many basic but interacting units, be they atoms, molecules, neurons, or bits within a computer. To be more precise, our definition is that complexity is the study of the behavior of macroscopic collections of such units that are endowed with the potential to evolve in time. Their interactions lead to coherent collective phenomena, so-called emergent properties that can be described only at higher levels than those of the individual units. In this sense, the whole is more than the sum of its components...

Peter Coveney and Roger Highfield, Frontiers of Complexity: The Search for Order in a Chaotic World, 1995. (in Sipper, 2000)

emergent evolution: evolution that according to some theories that involves the appearance of new characters and qualities at complex levels of organization (as the cell or organism) which cannot be predicted solely from the study of less complex levels (as the atom or molecule).

Merriam-Webster's Collegiate Dictionary, Electronic Edition (1994)

ecological model of science teacher preparation: the system of science teacher education is a CAS that is an evolving system characterized by punctuated equilibria, chaos, emergent properties and various actors filling various niches.

Alan AtKisson describes systems elegantly and somewhat humorously in "It's the System," Chapter 4 of his book, *Believing Cassandra: An Optimist Looks at a Pessimist's World.* While his work targets environmental rather than educational systems, his description of systems has broad applicability. Figure 7.1 is composed of substantial excerpts from that chapter.

This chapter is designed to release you from the feeling that you are personally to blame for what is happening to Nature and the World, and to explain what is actually to blame.

Unless you are a wildlife poacher who formerly worked for Greenpeace. A corporate executive who has personally enslaved child laborers, or a black-marketeer in the CFC business with a Ph.D. in atmospheric chemistry, what's happening to the planet is not your fault. Even those whose intentions are genuinely evil cannot be blamed for the overall trajectory of history. Immense and impersonal forces are at work that are bigger than any individual actor could possibly command, whatever their motivation. The problem is not you, or "them," or any one of us. The problem is that the World is literally out of control.

In the 1960s in America, a common way to complain about what was "goin' down" with Vietnam, Mother Earth, or the urban ghetto was to say, "It's the system, man." ...

Sixties slang-slingers didn't know exactly what they meant by the phrase, "It's the system" – for them "system" meant something like "the establishment," the power structure – but they were more right than they knew, even when they were stoned. "It's the system" is an accurate identification of the source of our contemporary global problems. A more accurate way to say it would be, "It's the systems, plural." ...

First, let me provide a very brief introduction to the structure of systems – worth reading, because understanding systems will alleviate that nagging feeling of global guilt.

A *system* is a collection of separate elements that are connected together to form a coherent whole. Your body is a system, and it's comprised many smaller systems, all working together: the circulatory system, the digestive system, and so on. The connections between the elements of a system come in two forms: stuff and information. For example you eat food (stuff), and when your belly gets full it sends a signal (information) to your brain telling you to stop eating.

The science of system dynamics uses a lingo, and it is easy to learn. In the example above, the food moving through your gullet would be called a *flow*. Your belly, filling up from the flow of food, would be called a *stock*. And the signal sent to your brain, indicating whether the stock of food in your belly has reached that comforting level known as "full" is called *feedback*.

The feedback from your belly has an impact on your eating behavior, which in turn causes more feedback from the belly. All that circling around of stuff and information, which controls (or should control) how much you eat is called a *feedback loop.* This feedback loop, like most others, operates in two directions: it tells you to stop eating when you are full, and it starts your search for food again when your belly is not full. Feedback loops essentially give one or two messages to the system" "do more" or "do less."

...

A critical point to remember: *Delays in feedback slow down response.* You can't react to changes you don't know about. And when you *do* know about changes, you may not have enough time to respond. We will return to this point, because it is the crux of the problem.

Here are two more important systems concepts: *sources* and *sinks.* Sources are where stuff comes from; sinks are where stuff ends up. Farmlands and oceans are the *source* of food you eat. In certain more enlightened societies, farmland is also the *sink* where the compostable residue ends up; for most of us, though, the sink is some local body of water connected with a sewage treatment plant. ... Sometimes even the human body acts as a sink, as when lead builds up in the tissues. The impact of that lead is not felt directly for years, and this is another delay in feedback. By the time you notice the symptoms of lead poisoning, it's too late: you're poisoned, and there is no way to get the poison out fast enough to prevent further damage.

The critical thing to know about sources is that they can run out. As for sinks, they can fill up and spill over, just like the sink in your bathroom. A disappearing source creates a shortage; an overfilled sink creates a mess.

Obviously, the issue of how quickly we get feedback about what's happening in the sources and sinks is extremely important to understanding and managing systems. In the 1972 version of the World3 computer model[61], the attention of the press and the critics was on *sources,* for instance metals and fossil fuels. Given that era's knowledge about current stocks and the growth rates of various flows, certain materials seemed likely to run out, with challenging consequences. But it turns out that the real danger was in the *sinks.* Fueled by runaway growth, they've been filling up and overflowing. "Overloaded sinks" is one way to describe the cause of global warming, chemical pollution, and the rising rates of cancer and genetic abnormalities. Had we been watching the atmospheric sink carefully, had we understood the dynamics of what was happening, and had we gotten more compelling feedback sooner and responded to that feedback in time, we might have turned off the faucet of CO2 and prevented the climate system from going out of balance.

But we didn't. So it went.

Figure 7.1 AtKisson's description of system dynamics. (AtKisson, 1999) pp. 69 –72.

The above description that primarily targets ecological systems maps on to the system of science teacher preparation well. It begins with the important release of blame.

The problems of science teacher education are no one's fault. The problems are grounded in a system that has evolved over centuries. No one designed this. Mostly we fill niches in an existing system and we fill those niches in the way the system evolved to have them filled.

Table 7.1a: Complex Adaptive Systems and Science Teacher Preparation	
In Complex Adaptive Systems...	Example from Science Teacher Preparation...
(1) All CAS consist of large numbers of components, *agents*, that incessantly interact with each other.	This includes students, faculty, family, community and the media among other agents.
(2) It is the concerted behavior of these agents, the *aggregate behavior*, that we must understand, be it an economy's aggregate productivity, or the immune system's aggregate ability to distinguish antigen from self. (3) The interactions that generate this aggregate behavior are nonlinear, so that the aggregate behavior cannot be derived by simply summing up the behaviors of isolated agents.	Studying teacher education classes or college science classes (or the two together) is not sufficient to predict the formation of science teachers' actions and beliefs (Salish, 1997).
(4) The agents in CAS are not only numerous, but also diverse. An ecosystem can contain millions of species melded into a complex web of interactions; the mammalian brain consists of a panoply of neuron morphologies organized into a hierarchy of modules and interconnections; and so on.	At the heart of the system of science teacher preparation is the student. The system of science teacher preparation for biology teachers at Midwestern University also includes scientists who specialize in cell biology, biochemistry, genetics, physics and more. It also includes educators who specialize in multiculturalism, content area literacy, science education, computer technology, and again, more. Also part of the system are families, teachers in schools, both before coming to university and as part of the formal teacher education program. The list goes on.
(5) The diversity of CAS agents is not just a kaleidoscope of accidental patterns; remove one of the agent types and the system reorganizes itself with a cascade of changes, usually "filling the hole" in the process.	Different actors within the system fulfill different niches. The technology specialist who worked with movie and filmstrip projectors is a thing of the past.
(6) The diversity evolves, with new niches for interaction emerging, and new kinds of agents filling them. As a result the, the aggregate behavior, instead of settling down, exhibits a perpetual novelty, an aspect that bodes ill for standard mathematical approaches.	The current technology specialists work with computers, graphing calculators and all sorts of emerging technologies like Geographic Information Systems, the global positioning systems and more.
(7) CAS agents employ *internal models* to direct their behavior, an almost diagnostic character. An internal model can be thought of, roughly, as a set of rules that enables an agent to anticipate the consequences of its actions.	Jason's internal model included the use of study groups and direct interaction with science faculty. Other seniors' internal models typically did not. McNair's and Peter's internal models included the use of standardized tests.
	(Adapted from Holland, 1995)

[61] This refers to the World3 computer model described in *The Limits to Growth* (Meadows, Meadows, Randers, & III, 1974) which AtKisson describes elsewhere in the text.

John H. Holland summarizes the common characteristics of all CASs in his essay, "Can There Be a Unified Theory of Complex Adaptive Systems?" Table 7.1a uses Holland's descriptors of CAS characteristics and compares complex adaptive systems to science teacher preparation. The numbered text (1 - 7) in the left column is Holland's (pp. 46 - 47). Table 7.1b includes other descriptors of CASs and examples.

Table 7.1b: Complex Adaptive Systems and Science Teacher Preparation

Delayed feedback complicates understanding and managing system dynamics.	The overwhelming nature of the first years of teaching may conceal impacts of teacher education programs – i.e. Salish showed more differences in teacher actions and stated philosophies within than between programs for beginning teachers. Even without this delay, the measure of what teachers do and believe typically does not flow in any direct way back to the teacher education programs they graduated from (Salish, 1997).
Outcomes are sensitive to initial conditions	The most effective teacher education programs are those that take into account teacher candidates' initial conceptions of the teaching and learning process (Wideen et al., 1998)
The system evolves with occasional periods of rapid change.	There was a time when education courses at Midwestern were taught in large lecture halls and the program was completed in four years. Substantial reform of the teacher education program eliminated the lecture hall classes and moved the program from four to five years in duration.

Emergent Properties

> "Water is H_20, hydrogen two parts, oxygen one. But there is also a third thing that makes it water and nobody knows what that is."
>
> D. H. Lawrence

A product with "characteristics beyond those of its combined elements" is said to have emergent properties (Campbell, 1996)[62]. Repeatedly throughout the dissertation I have used the useful simplification that treats college science and teacher education as

[62] This definition and Figure 7.2 are taken from the BS111 text.

two monolithic bodies alternately working with future science teachers. Future science teachers at Midwestern and across the country are left to their own devices to integrate the two program components into a coherent whole (Wideen et al., 1998)[63]. How these disparate pieces are typically summed together has contributed to a K-12 educational system that is nearly universally recognized as deeply troubled.

In any complex system, properties emerge which cannot be predicted solely from the study of less complex levels within the system. While it is useful to study college science teaching and teacher education in and of themselves, this kind of study can never reveal the actual workings of the total system. See the quote from Peters that opens this chapter. The emergent properties of the combination of the parallel systems of science education and teacher education do not fulfill the goals of either program component, of either science or education.

FIGURE 2.2
The emergent properties of a compound. The metal sodium combines with the poisonous gas chlorine to form the edible compound sodium chloride or table salt.

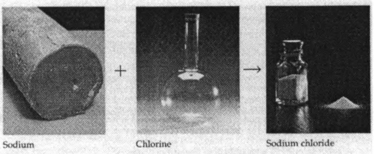


Figure 7.2: The illustration for emergent properties used in the BS111 text (Campbell, 1996) **p. 26.**

Seymour and Hewitt found no reliable predictor for determining whether or not college science students changed their major away from the sciences (Seymour & Hewitt, 1997). The Salish Project found that the teacher education program completed by a new

---

[63] Again, there are hints of making these connections with the teacher candidates in TE401, but the teacher candidates themselves do not report this connection.

science teacher was not a good predictor of either how the new teacher taught or what the beliefs the new teacher espoused (Salish, 1997). Viewing these findings together indicates that studying either students (as Seymour and Hewitt did) or studying teacher education programs (as Salish did) is insufficient to understand the attitudes, beliefs, and practices of new teachers. I conclude that the system must be viewed as a whole.

The Ecology of Science Teacher Education

A future teacher, of course, is not simply the product of college science and teacher education. If they were, each university's graduates would be identical. The Salish study showed that there is more variation within each of the nine programs involved in the study than there was between those institutions. One example of what that means is that a better predictor than the certifying institution for new teacher beliefs about the nature of teaching and the nature of science was whether or not the new teacher had been engaged in meaningful scientific research (Salish, 1997).

This variation implies that there are more important factors involved in the shaping of new science teachers' beliefs and practices than teacher education programs as currently configured. Those factors are myriad and interact in complex ways, like the factors that determine the nature of ecosystems.

The dysfunctional relationship model is, like the Two Cultures model, incomplete. Both models fail to account for the larger context. Important issues in science teacher preparation, like family and community, are neglected[64]. The place of the

[64] I neglect them as well. One of the greatest problems with viewing teacher education as a complex system is that it precludes comprehensive study.

schools and required fieldwork in those schools does not fit easily in either representation. Teacher educators and educational researchers must be attentive to the fact that future teachers are learning to teach all of the time, not simply when they are working on the requirements of course work and field work. *All the time.* Likewise, scientists should recognize that their students are learning things that impact their scientific understandings *all the time,* not just during class time or when doing homework. An important piece of this is the recognition that future teachers are learning to teach from the scientists who teach them and they are also (often) learning science from the science educators teaching them to teach.

Both of the models described in the previous chapters are vast oversimplifications. This does not mean they are without utility. Karl Popper said, "Science may be described as the art of systematic over-simplification" (Andrews, 1993). Over-simplification of complex systems is essential to making progress toward understanding those systems, but it also essential to remember that these are simplifications. The third model I employ, that of the Ecosystem of Science Teacher Education, is the most complex and most accurate depiction of the system of science teacher education. This more accurate model is, naturally, orders of magnitude more complex. It is, therefore, the most difficult to understand and least developed of the models. Cronbach (1988) reviewed James Gleick's *Chaos* (1987) in *Educational Researcher*, with an audience of educational researchers and other social scientists in mind. In that review, Cronbach notes that the ideas expressed in *Chaos* have important implications for educational research, but he predicts that these models will necessarily use metaphorical descriptions and not use the complex mathematical modeling involved in chaotic mathematics. I will not prove Cronbach wrong with this chapter.

The genesis for this model is also more complex – at least four books helped form this thinking. As noted in the introduction, they are: Murray Gell-Mann's *The Quark and the Jaguar* (1994), Robert Jervis's *System Effects* (1997), Claudia Pahl-Wostl's *The Dynamic Nature of Ecosystems* (1995), and James C. Scott's *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed* (Scott, 1998). These books helped me better define a long-held personal belief that my role as a science educator must be that of a generalist, in many ways more akin to a naturalist or ecologist than to a bench scientist. The goals of the science educator map onto the relational goals of the ecologist as described by Pahl-Wostl. See Table 7.2.

Table 7.2. Comparison between a mechanistic and a relational approach

	Mechanistic	Relational
Question:	What are the causes for an even [sic] to happen?	What are the characteristics rendering possible a pattern of interactions?
Goal:	Derive causal mechanistic explanations for system dynamics	Find relationships between structural and functional properties
Method:	Identify and isolate entities and processes	Identify patterns of interaction and their requirements
Theory:	Models that predict events Rules how processes act on entities to produce events	Models that make patterns intelligible Rules on how to proceed in detecting and characterizing relational patterns

(Pahl-Wostl, 1995) p. 47

The National Science Teachers' Association Standards for Science Teacher Preparation (CASE Network, 1998) describe ten standards or ten areas of proficiency that science teacher education programs should target. These standards, when viewed collectively, reflect the (eco-) systemic nature of science teacher preparation. Figure 7.3

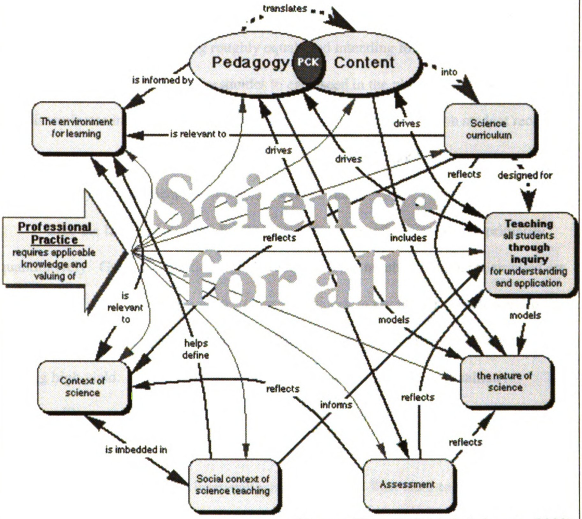
maps some of this complexity. The text in the shaded boxes represents the ten standards for Science Teacher Preparation identified and described by the CASE Network for the NSTA. While the figure is complex, it pales in comparison to the immense complexity of the overall system of science teacher preparation. It should be noted that the connections shown are intended to illustrate some, but by no means all, of the important connections within the system. This work by Enfield, Ashmann, and myself is part of a growing body of work in education that explicitly includes ecological models as central to understanding learning. A recent RFP from the National Science Foundation includes the study of Complex Educational Systems as one of its four key components (NSF, 2000).

In mapping complexity of science teacher education in Figure 7.3 we chose to identify pedagogy and content as the two most important standards and make their overlap evident in the representation. This overlap, pedagogical content knowledge or PCK, is the heart of TE401. Following the bold, dashed arrows around part of the perimeter of Figure 7.3 draws attention to some of the required steps in that process. Beginning with pedagogy, it reads, "Pedagogy translates content into science curriculum designed for teaching all students through inquiry for understanding and application."

Adaptive Systems are highly sensitive to initial conditions.

Sensitivity to initial conditions exists in both biological ecosystems and in human institutions. When teacher education pays attention to the initial understandings of the students enrolled in their programs, they are more likely to be successful (Wideen et al., 1998). It is worth noting that while Wideen, Mayer-Smith and Moon both identify that starting with existing student understanding is a key component of successful programs

Figure 7.3: Mapping some of the complexity of science teacher preparation: The NSTA Standards for Science Teacher Preparation



(Duggan-Haas, Enfield, & Ashmann, 2000)

and conclude by suggesting that ecological models should be explored thoughtfully for better understanding the learning-to-teach process, they do not draw the comparison to the importance of initial conditions to the outcomes of ecological processes. Their work also focuses on understanding future teachers' understanding of the teaching and learning processes.

Midwestern University's Teacher Education coursework seems to consider initial conditions, students' conceptions of teaching and learning, fairly well. The science courses observed, conversely, treat the students as a vast monoculture. See Figure 7.4. Students are planted in rows, all receiving identical treatment like seeds on an industrial farm. Like the farmer providing roughly equal (and intending to provide exactly equal) amounts of water, fertilizer and pesticides to each seed in the plot, the professor comes and disseminates information equally to each student in the room. Each student receives (or is intended to receive) identical treatment. Those who do not blossom as a result of (or in spite of) the treatment are, of course, weeded out[65].

Like the farmer, outcomes for the scientists who teach are measured primarily quantitatively. Grade distributions, grade means and the number of students enrolled are the measures in science course work. Crop yield is key to the farmer. Grade yield is the key to the teaching scientist, although the scientist who teaches may or may not be seeking high yield. Industrial farming arguably causes losses of more qualitative measures like taste and health benefits. It also concentrates environmental impact in generally negative ways – think industrial hog farming. Scott uses scientific forestry as a parable for failed government intervention (Scott, 1998). This work together with David Orr's description of "architecture as crystallized pedagogy" (Orr, 1999) was the inspiration for Figures 7.4 and 7.5.

[65] Although, again, Seymour and Hewitt found that success in science classes was not a predictor of whether or not students switched majors.

Figure 7.4: Two examples of tightly controlled ecosystems that assume a monoculture.

Figure 7.4a Rows of corn outside Parma, Michigan.

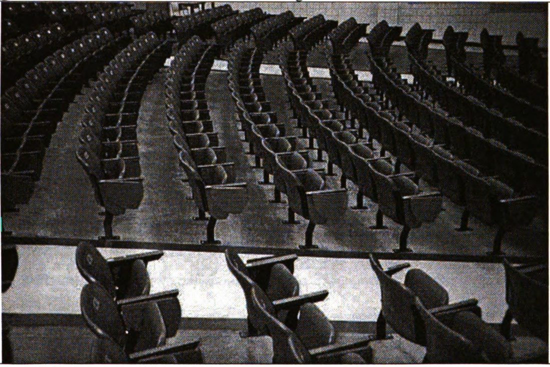


Figure 7.4b Rows of seats in B108 Gilmour Hall, the classroom for BS111.

One might reasonably argue that through the use of monoculture, we feed the world. Here, the metaphor breaks down in an interesting way. If a farmer were to lose as much of the crop as college science does year after year, the farmer would do something to improve the yield. Cuban notes that most of the methods used in college classes today were innovations a hundred or more years ago ((Cuban, 1999) p. 52). The lecture hall itself predates the commonality of books. The high cost of the books at the dawn of the university made the lecture hall a more practical way to disseminate information. How much of the technology used in the typical scientist's research is essentially identical to what was used by predecessors' a hundred years prior?

The use of monocultures in agriculture has served us fairly well for a long time, but it has vulnerability resulting from the monoculture itself – vulnerability to pest and disease. A recent article in the journal *Nature* reports stunning success in battling the major disease of rice, rice blast. In a study involving five townships in 1998 and ten townships in 1999 in China, heterogeneous plantings of disease susceptible varieties along with "resistant varieties had 89% greater yield and blast was 94% less severe than when grown in monoculture" (Zhu et al., 2000). A parallel in the complexity of the World Wide Web is the susceptibility of the various Microsoft monocultures to "viral infections" like the Melissa Virus (Taylor, 1999). I believe the monoculture of the lecture hall is showing its own vulnerability.

Figure 7.5 shows two *apparently* more loosely controlled systems – the education classroom and a wild area that appears to be loosely managed. In both of these less rigidly managed systems, the management is not less but rather *different* in its nature. The control is less centralized and more complex. In both the science classroom and

Figure 7.5: Two examples of apparently loosely controlled ecosystems that assume diversity.

Figure 7.5a A marshy area outside Parma, Michigan. This photo was taken a few hundred yards from Figure 4a.

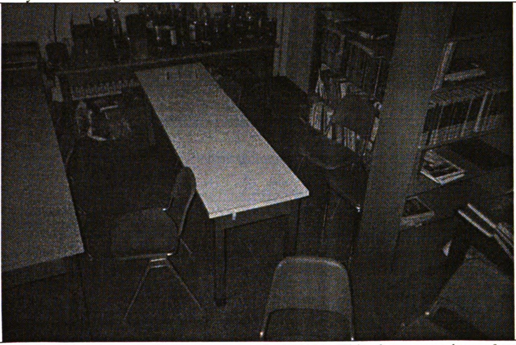


Figure 7.5b 121 Aquino Hall, the classroom for TE401. This photo was taken a few hundred yards from Figure 4b.

managed agriculture, control rests primarily with one individual or one organization. In these more complex systems, the control is quite different – the trees will never grow beyond a certain height and will not grow within the marshy area until the area is no longer marshy. These are very real controls.

What appears controlled in the classroom is perhaps less controlled than what appears uncontrolled. In my classroom observations, I never saw students sleeping in the education classes[66]. I saw sleeping students in nearly every science lecture I observed[67]. The percentage of students in attendance also was far greater in the education classes than in BS111[68]. The nature of the classroom control in the education classes – some kind of active engagement – controlled for sleep and attendance fairly effectively.

Many have compared the educational system to assembly lines and schools as modeled after factories. Chika Hughes's syllabus states, "The evolution of the one-room schools into larger and complex institutions was modeled after industrial models." See Figure 7.7. We can see that in the future teachers moving back and forth between science classrooms where content knowledge is loaded in and education classrooms where pedagogical skills are added. While we have tried to simplify and mechanize the processes of teaching and learning, other factors override these simplifications.

Figure 7.6[69] diagrams how one Chika Hughes physically transformed one type of system into the other. The layout of the room, of course, only tells a small piece of the story, but it is quite revealing. More important than how the seats are arranged is what students do and are expected to do.

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[66] Unfortunately, I can not say the same of every education class I have ever taught!

[67] Every time I remembered to look for people sleeping, I saw them.

[68] The percentage "in attendance" in BCH401 was not measurable as it was broadcast on campus cable, and videotapes were made in the library, but those other ways of "attending" precluded interaction.

Figure 7.6: Reconfiguring a classroom to the suit the needs of one culture

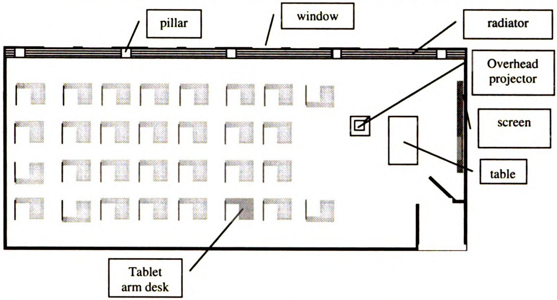


Figure 7.6a 103 Crop & Soil Science Building, before class. TE250. This schematic shows the configuration of the classroom before teacher education students entered and rearranged the room for class. The desks were returned to rows at the end of class.

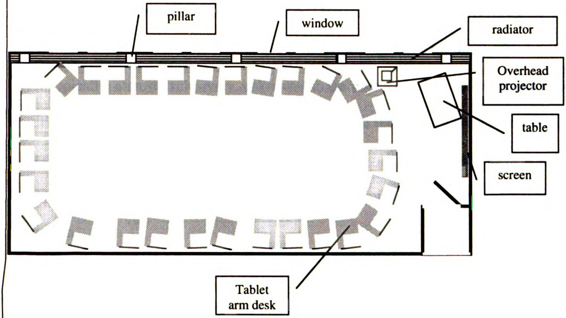


Figure 7.6b 109 Crop & Soil Science Building, during class. TE 250. This schematic shows one common configuration of the classroom during class. Desks were also sometimes gathered into groups of two, three, four or occasionally more. The desks were returned to rows at the end of class.

[69] This same figure is included in chapter 3.

In the science classes, students, with very rare exceptions,[70] sat passively throughout the class period with no interaction with the instructor. In the education classes, very nearly every student spoke in almost every class observed. In both education classes, every single student spoke to the entire class on the first day. In subsequent classes, many students would participate in whole class discussion and virtually all of them would talk in small groups and small groups was a feature of nearly every education class period observed. In these settings, student individuality was treated as an asset. In both education classes, students made name placards with large index cards on the first day. They learned each other's names and were engaged in regular discussions about the subject of the class.

In the science classes, student individuality was treated as if it either did not exist or did not matter. Students rarely spoke, either to each other or to the instructor during class time. They were anonymous, and attendance was sporadic for many. Students were typically, almost exclusively, unknowns to the instructor. The students interviewed, with one exception, did not know many of their science faculty on a one to one basis. In fact, in more than one instance, seniors could not name faculty they had had in at least one science course, including courses taken at the time of the interview, weeks into the semester.

Scientists often groused in the BBLs that educational research often does not apply universal treatments to students. A simple reality is that one of the reasons blanket treatments are not applied is that a good educational researcher recognizes that universal treatments are insensitive to initial conditions and educational outcomes are highly

[70] One student per week asking a question that goes beyond "What's that word?" would be a very generous estimate in classes numbering in the hundreds of students.

sensitive to initial conditions (Wideen et al., 1998). Blanket solutions are often not solutions at all. Of course, sometimes blanket solutions are both effective and necessary.

Scientific forestry – replacing natural forests with monocultures initially increased yield but over the long term, yield decreased and other services provided by forests diminished or disappeared (Scott, 1998). The nature of these problems took more than a generation to present themselves. Monocultures tend to produce well in the short term. On the scale of a few years or a few semesters, productivity can be seen to increase, but over the long haul, both in agriculture (Scott, 1998) and, I suggest, in teaching, monocultures lose their effectiveness and returns diminish. A teacher may be in a classroom for thirty years. In this timeframe problems rooted in the monocultural treatment of students appear.

Niches and System Evolution

In the last chapter, I noted that scientists and educators fulfill different roles within the system of science teacher preparation, that each of the two divorced supervisory entities serve their own purpose in the development of future science teachers, but they are not cooperative in the endeavor. In the managed system of science teacher preparation they appear to be fulfilling mechanistic roles, rather than filling niches.

The reality is, however, that each player is filling a niche and the niche is shaped to the player as the player shapes the niche. Organisms within natural ecosystems do not decide to fill a niche. Systems and species evolve together so that each niche is filled. Scientists, likely without intending to do so, are teaching not only about science but also about teaching. Students, sometimes intentionally and sometimes unintentionally are learning to teach, learning science, and learning about learning all of the time. Educators, likewise, intentionally and unintentionally fill a variety of roles that add up to make a niche.

This increasing specialization raises questions about system stability. Typically, the greater diversity, the greater the stability of an ecosystem. Is the kind of specialization taking place among scientists and educators increasing stability or does it merely increase the polarity of the system and decrease the overall stability? The dissonance between what happens in science and education classrooms is stress on the system. The rate of evolution increases in systems under stress. Which is more important in determining the rate and nature of system evolution, increased diversity through increased specialization or increased stress through increasing dissonance?

The evolutionary process of organisms shaping their niche as their niche shapes the organism in the system of education moves both intentionally and organically. Within the system, there are generalists and specialists. Currently movement in both science and education is generally towards increasing specialization, though there is also a growing specialty area in complexity and chaos that cuts across disciplinary boundaries. The Luce Foundation just awarded Kalamazoo College an endowed professorship for just such work.

The evolutionary process is also uneven. The evolution of the university has generally been slow. One might raise the same kinds of criticisms of the system today as was made decades ago. In 1921, W. J. Osburn reviewed foreign criticism of American higher education from the decades prior to his publication. I echo many of the concerns raised in that those criticisms that date back a century, for example in 1901, Ashley wrote:

> One disadvantage of the American Ph.D. requirements is that they make the doctor's degree almost essential to students who desire an academic post. The best way for a man to become known outside of his university is through the publication of a doctor's thesis. The result is rather to make published work the test of fitness for an academic position, whereas it is not necessarily anything of the kind. The qualities that make a good investigator are not always those which make a good teacher and the two are not always combined. There are many admirable teachers whose published work is quite unimportant.
>
> (Osburn, 1921)

There was a time when universities (and high schools) did not exist and a time when access to them was much more restricted than it is today. Also, of course, there was a time without computers. In spite of these changes, the lecture hall today operates in much the same way it did a century ago.

Chika Hughes's course targeted many of the ideas in the K-12 realm fairly directly. Figure 7.7 is how the most relevant section of the course is described in the syllabus. The evolutionary process is shaped not only by events within the system but also by events that originate outside of the system. Certain changes for certain organisms might be akin to an asteroid strike. Understanding the system should allow for more intention in how the system evolves. We might be able to change the system from one that leans toward Darwinian evolution, random change coupled with survival of changes that best fit, to a system that leans toward Lamarckian evolution where random change is replaced with change to fulfill need. This requires both understanding the constituent parts and the interactions between them. It requires understandings of niches, the actors that fill those niches and how those actors interact.

Figure 7.7 Theme 4 from Chika Hughes's TE250 syllabus.

Theme 4: How are schools organized to deal with individual diversity and how does this organization limit possibilities for change?

Schools are social institutions that by definition were created to impart common values and knowledge to a [sic] increasingly diverse population. As waves of educational reform have swept our schools, recurring concerns with the function and organization of schools and the way they structure inequality have prevailed. A dilemma that schools confront is their need for efficiency (educating large numbers of diverse students within a limited time-frame) while attempting to address the needs of diverse students. The evolution of the one-room schools into larger and complex institutions was modeled after industrial models. The organization of the modern school divided students artificially by grades and other characteristics and exposed them to a pre-designed curriculum expected to address their learning needs. Educational researchers argue that classifying students in this manner is detrimental to student learning and have found that poor students end up receiving watered-down curriculum whereas economically better off students receive better education. At the same time, the complexity of the school organization added to its highly bureaucratic structure has made it difficult for families (one of the equalizing forces in schooling) to intervene and serve as advocates for their children's better access to a quality education.

In this theme we will study the impact of the organization and structure of schooling – such as tracking and ability grouping – on students' learning. Using a case study, we will take an inside look at a school analyzing the limitations encountered by teachers and parents when attempting to gain access to more academic school knowledge for a group of minority students in the school.

Universal Treatments Pessimize the System

The changes that have been made are not, in fact random. The changes may appear random when viewed from outside of the situation where the change originated. *Natural Capitalism,* by Paul Hawken and Amory and Hunter Lovins (1999), identifies many tales where services provided by nature are lost due to economically driven decisions that were short term (or medium term) and neglected services provided by natural ecosystems[71]. Their work has important, though not explicit implications for education. A key idea that pervades the book is "Sometimes single-solution approaches do not work, but often... optimizing one element in isolation pessimizes the entire system. Hidden connections that have not been recognized and turned to advantage will eventually tend to create disadvantage" ((Hawken et al., 1999) p. 285).

The idea of a solution that ends up pessimizing the system is well expressed in the "Guiding Parable" for the Rocky Mountain Institute (RMI)[72], the story of Operation Cat Drop. The story is told in *Natural Capitalism* (pp. 285 – 286) but I have reproduced a shorter version below from RMI's website (http://www.rmi.org/sitepages/art41.asp).

> **Operation Cat Drop**
>
> In the early 1950s, the Dayak people of Borneo suffered from malaria. The World Health Organization had a solution: it sprayed large amounts of DDT to kill the mosquitoes that carried the malaria. The mosquitoes died; the malaria declined; so far, so good. But there were side effects. Among the first was that the roofs of people's houses began to fall down on their heads. It seemed that the DDT was also killing a parasitic wasp that had previously controlled thatch-eating caterpillars. Worse, the DDT-poisoned insects were eaten by geckos, which were eaten by cats. The cats started to die, the rats flourished, and the people were threatened by potential outbreaks of typhus and plague. To cope with these problems, which it had itself created, the World Health Organization was obliged to parachute 14,000 live cats into Borneo.
>
> (RMI, 2000)

How does this manifest itself in education? When we debate whether or not future secondary science teachers should major in education or major in a science, we are making an argument for optimizing one area which results in pessimizing the other.

[71] This book has accomplished the extraordinary feat of being excerpted in the journal *Nature, The Harvard Business Review* and *Mother Jones.*

[72] of which Hunter Lovins is President and Amory Lovins is Director of Research

Textbooks are another example of optimizing one aspect of a system – in this case content concentration is optimized by being placed into a single (often massive) volume. The nature of putting it into textbook format sterilizes the content and forces science into a linear structure. The text loses authenticity when it is placed within the confines of a textbook. The foreign language community has known this for years and has moved toward the use of culturally authentic materials.

> Communicative language teaching also advocates the use of culturally authentic texts written by native speakers for native speakers instead of simplified or edited texts developed expressly for foreign language learners. Effective use of authentic texts includes having the learners perform interesting and level-appropriate tasks after or while seeing, hearing, or viewing culturally authentic materials. For example, it would be inappropriate to give beginning learners a newspaper editorial and ask them to translate or summarize its content. However, even beginning learners can find dates and names of persons or places and can often get the general sense of what is being said.
>
> (Schulz, 1998) p.7

Research on the learning of second languages has shown that language is acquired more effectively through use of materials written for native speakers than in contrived writings for language learners. Logically, the same assumption holds true for the learning of other subject matter. It can be safely assumed that most people who know a subject well did not learn it primarily from either textbooks or lectures. McNair did use some more authentic texts in the first week of class, but that use stopped after the first week.

Peter Senge's *The Fifth Discipline* popularized the search for a trim tab for education (and other institutions). A trim tab is a "rudder on a rudder." To turn large ships, the force to turn a rudder directly is too great, so the rudder on the rudder begins the turning process. This mechanistic description is quite appealing – what's the one thing we can do to begin turning the ship of education in the right direction? It is a search for single optimizing agent or action.

The system of schooling is far more organic than mechanistic and we should learn from natural systems that when one thing triggers change throughout the system the results are generally not only unpredictable but also often catastrophic. We should also learn from past experience. One catalyst for rapid change in education was desegregation. This was intended to address inequities in schooling but instead triggered white flight from city centers and a resurgence of tracking (and its associated problems) in schools. The nature of schools did change, and change remarkably, but not in ways that brought about the intended benefits. Optimizing across the system is more challenging, but we will find no trim tab for the ship of education.

Linearity and Cyclicity

> The researcher presents the work in highly stylized research publications. In those scientific short stories, which use the linear scientific method as plot, ambiguity and error disappear. The publication becomes the discovery. Because the linear model is the primary way in which scientists communicate, the public has come to believe that science works in a linear fashion, a misunderstanding of the nature of science and a source of disappointment when the results of research do not meet expectations. When high-school science teachers spend a summer working in my laboratory, they are amazed at how frequently experiments fail to work out as planned.
>
> (Grinell, 2000)

Science education at all levels between kindergarten and graduate school has a tendency to portray science linearly. The scientific method is portrayed as lock-step linear method without room for the ambiguity that comes with the actual pursuit of science. Scientific knowledge appears to build in a linear fashion.

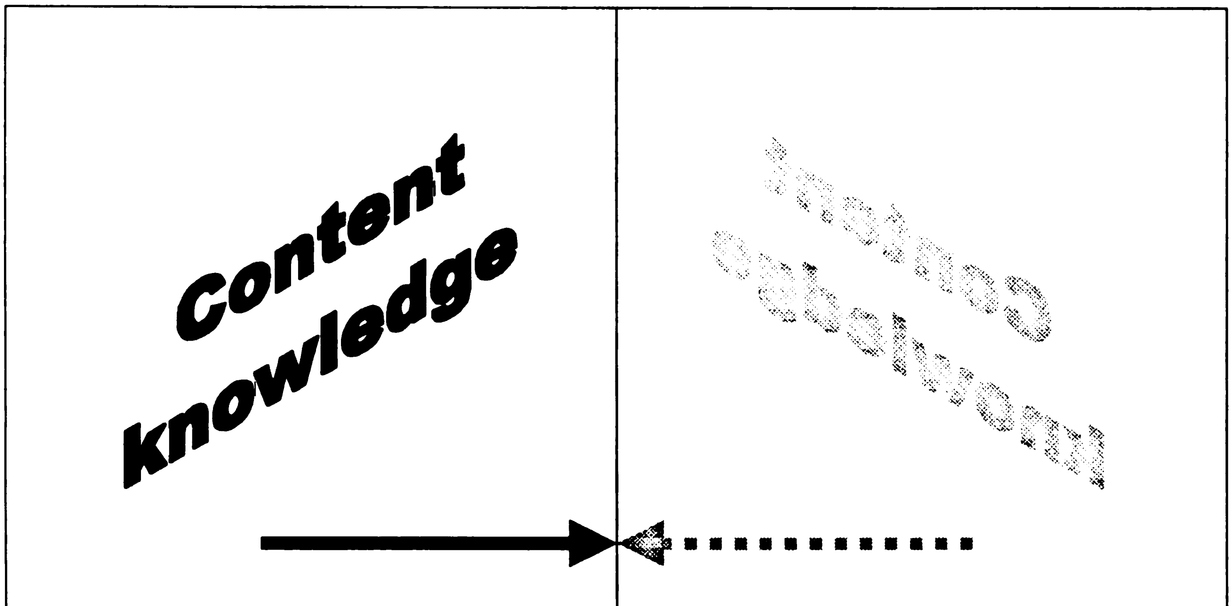
Teaching and learning is also a non-linear process that is often force-fitted to a linear model. One aspect of the teaching and learning process is the flow of information. In the science classes I observed and most of those described by the seniors, the professor and the textbook present the subject matter information in science classes. This information is reflected back to the professor on examinations, as shown in Figure 7.8. Each student's reflection is of the same form, most commonly an objective test, but areas of clarity vary from to student. In the case of BS111, the information from the lecture is quite similar to the information from the text. In BCH401, this is somewhat less true.

Bill described it well:

> Don: How do you learn best?
>
> Bill: It's not just memorizing facts and being able to spit it back out, it's being able to apply something. I know I've learned something when I can use it or I can apply it or I can construct something from the knowledge I've gained. When I can regurgitate the facts and a knowledge of something. I can understand the basic parts of it, I may not be able to construct it or apply it, but I can understand the basics. I kinda take it as knowing and understanding, if you've learned something you'll be able to understand it and you can use it whereas knowing is maybe just having an awareness to something or having an exposure to something but it's not as deep.

Some new teachers in the Salish Project and Bill (quoted above) one of the seniors in this study used the term "regurgitate" to describe the return of information to professors. This sense, in fact, is used as an example in Merriam-Webster's Collegiate Dictionary: "memorize facts to *regurgitate* on the exam" (1997). In some ways, however, it is misleading because regurgitation implies that the information has been chewed on for a while, which would cause it to be returned in somewhat different form.

Again, the science faculty recommended the formation of study groups where this information processing might take place. As noted in the chapter 3, Peters suggested groups of "three or four or five," and to get together once a week and go over the information in the lectures, to ask each other questions, and he noted, "...an easy way to learn something is if you actually have to teach it to somebody else." And again, six of the seven senior teacher candidates interviewed had not heeded this advice. The one who had regularly worked in study groups, Joseph, was not going on teach.



The professor and textbook present science content for the students to absorb and reflect.	The student reflects a fainter version of the content back to the professor through examinations. Each student's reflection is in an identical framework, although the areas of clarity in the reflection vary from student to student.

Figure 7.8 A model of the movement of information in college science courses.

The kind of framework that the Peters suggested students build (with some help from him) outside of class was the kind of framework that the education instructors employed during class time. Figure 7.9 is a simplified model of how information is processed in group work within the teacher education classroom. Here information is not simply bounced backed and forth between instructor and student, but it is worked with by the students during the class time. This work takes primarily the form of discussion with classmates and with the instructor. Embedded within the model are several cycles and feedback loops.

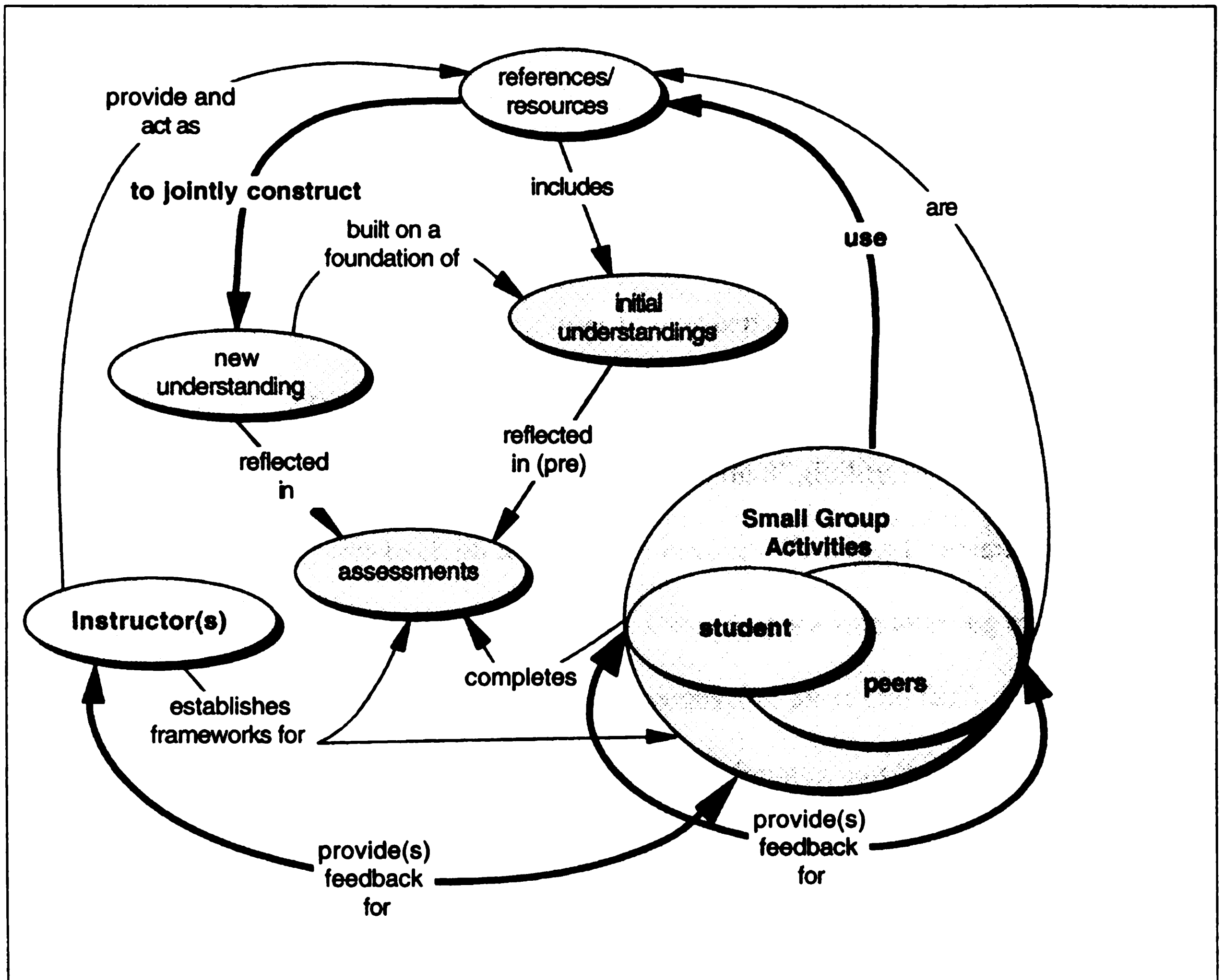


Figure 7.8 A simplified model of group work in teacher education classes.

One loop within the framework begins with the instructor establishing a framework for a group activity where students use resources provided by the instructor and their own existing conceptions to build new understanding. The process is informed by frequent assessments that guide the instructor in reshaping the activities. Such cycles are present throughout the organic process of learning.

The output differs from the input in substantial ways. Rather than a restatement of information presented in the resources (often a variety of genres), the output includes a reframing of the information in a context that is usable in a K-12 classroom.

The entire process of learning is described as cyclic. The Learning Cycle is defined in many ways in educational research[73]. As mentioned in the dissertation overview, the Learning Cycle as defined by Anderson is one of theoretical frameworks informing this dissertation. The Learning Cycle includes the following steps: ① Establishing the problem; ② Modeling; how one works through the problem; ③ Coaching the learner; ④ Fading as the teacher removes him or herself from coaching; and ⑤ Reinforcement (Anderson, 1999). These steps could be folded into Figure 7.9, but it would make it more complex to the point of being unintelligibility.

This process cycles back on itself in part because "In a good curriculum, learning cycles are carefully connected to one another. The fading for one learning cycle helps to establish the problem for others. Maintenance means that ideas and skills from one learning cycle are built into others" (p. 8). These overlapping and interlocking cycles relate back to the notion that future teachers (and everyone else) are learning all the time.

[73] See (Bybee, 1997) for a description of the "Five E" (engagement, exploration, explanation, elaboration and evaluation) model. . This model, and variations of it, has been commonly used for decades to guide science teaching at the pre-college level.

Conclusion

> The World consists of systems within systems within systems. It also includes such wild-card elements as political scandals, breakthrough inventions, and renegade dictators. The World includes the beauty of Mozart and fine architecture and the Bolshoi Ballet, as well as the tawdriness of Atlantic City on a slow Monday night. The World is more than just people, culture, machinery, and the movements of capital, though it includes all of those, together with human qualities like courage and vanity and greed. The World, to dig deeply into it origins in Old English, is "the age of man." Or, since "man" is thought to be an old word for "consciousness," the World is "the age of consciousness." No one could presume to build a model of *that.*
>
> (AtKisson, 1999) pp. 6 - 7

In early chapters I alluded to the ecosystem of science teacher preparation in using a common expression for describing introductory science courses. Students refer to them as "weed out" courses, though Peters emphatically stated it was not. The reference implies some students are weeds and that others will flower and bear the kinds of fruit we desire. This metaphor has great potential – the flowers have been pollinated by generalists and specialists throughout their college experience and, very importantly before and aside from that.

Niels Bohr said, "The task of science is both to extend our experience and reduce it to order." The business of universities is to manage that ecosystem as best they can, to manage for knowledge production in a variety of ways. The logical route in the undergraduate science classroom seems to be to simplify the system and bring it to order. Simplification and order is brought about by planting the students in rows, apply universal treatments and regularly measure student growth using simple instruments.

These seemingly simple solutions designed to optimize efficiency pessimize the system in many ways – high attrition rates in science and a cycle that regenerates bad teaching in generation after generation. An important point raised earlier about the cycle of blame shown in Figure 6.2 is that the placing of blame is justified. Through a systemic lens, the usefulness of this placing of blame disintegrates. Blame cannot be fairly leveled on an individual or class of individuals as I had attempted to do in much of the earlier part of this dissertation. As AtKisson notes, “It’s the system, man.” Individuals working within the system are filling the niches that have evolved for them within the system.

At Midwestern University, the nature of the teacher education niche yields a very different approach to managing the ecosystem. For example, teacher educators, in this study and in the programs well-regarded in Wideen et. al’s. meta-analysis recognize that the output of a complex system is highly sensitive to initial conditions, and they take great pains to understand those initial conditions. This is just one of the ways in which the teacher educators seem to be in harmony with natural learning environments.

Science teacher candidates move back and forth between these differently managed systems on a daily basis. They experience dissonance that is perhaps growing as teaching in teacher education programs evolves at a faster rate than science programs. As noted earlier, this stresses the overall system that encompasses both the science and education classrooms. Will this stress act as a catalyst for evolution in the larger system or will increased specialization increase stability of the system?

Chapter 8

SO WHAT?
IMPLICATIONS FOR ADMINISTRATORS, POLICY MAKERS, SCIENCE AND EDUCATION FACULTY

> It is possible, in other words, to practice chemistry as if evolution, ecology, and ethics do not matter, but it is not possible for them not to matter.
>
> (Orr, 1999) (p. 229)

> The first day or two, we all pointed to our countries. The third or fourth day, we were pointing to our continents. By the fifth day, we were aware of only one Earth.
>
> Prince Sultan Bin Salmon Al-Saud,
> Saudi Arabian astronanut
> As quoted in (Sagan, 1997) (p. 136)

This dissertation begins and ends by drawing attention to the fact that college science and teacher education courses are taught differently. Hardly, it seems, a news flash. I can easily imagine John Dewey's students navigating a similar cultural divide a century or so ago. I knew before I began this work that college science classes are taught not only differently than teacher education classes but different in ways that are in direct opposition to the goals of teacher education. I knew before I began that scientists and educators do not often see eye to eye, that the relationships oftentimes are dysfunctional. I also knew that factors beyond teacher education programs shape the way new teachers teach in important ways. Doubtless most of the people that read this dissertation know all these things too. What then, is the point?

We know that there are problems in science education from kindergarten through college. In the introduction, I ascribe the problem simply to the failure of integration of science content and pedagogy. Does the integration fail because teachers don't understand the science they are expected to teach (in the way the current standards movement says they should)? Or is it because teachers don't understand the pedagogy to teach in that way? Or is it because science content and pedagogical ability are taught separately and the teacher is left to put these complex pieces together on their own? In a word, yes. Problems with any and all of the pieces cause problems of the complete complex picture.

In the dissertation I develop three models to describe the formal system of science teacher education: Two Cultures, The Dysfunctional Relationship, and The Ecosystem of Science Teacher Preparation. Each model builds on the one before it but the utility of the first goes beyond building to the second and the utility the second goes beyond building the third. What are the implications for each model? What difference does this make?

Ok, Science education programs are really two distinct programs that have separate agendas. So what?

The most important lesson learned here is not that the scientists are different from educators and that the two groups teach in fundamentally different ways, but that we leave the teacher candidate to navigate the gulf between these two cultures almost completely on their own. It is a problem that these produce disparate experiences for the teacher candidate. It is a bigger problem that the gulf is largely unaddressed, or addressed in a way that fails to register with the students or when it is addressed it is done in a derogatory way.[74]

The two cultures can learn from each other, but not until they want to. Seymour & Hewitt conclude that the area in greatest need of reform (to reduce attrition from S.M.E. programs) is college science teaching, not curriculum, which is the most common target of reform. I agree. The following are suggested pre-requisites to improving college teaching.

What the Two Cultures model says we need to do:

1. Pay attention to the difference in cultures! This step is listed first not because it is most important, but rather because it is simplest and it is a prerequisite to other changes. This important step could be completely contained within colleges of education. Ideally, faculty in S.M.E. would pay attention in ways that lead to the second step.
2. Recognize that all science teachers are educated by university faculty and that scientists are, therefore, teacher educators. If they believe that new science teachers are ill prepared, they must share some of the blame and they must be responsible for helping to improve the situation.
3. Stop discouraging interested S.M.E. majors from pre-college teaching and start encouraging them into the world of teaching. Again, this is a logical pre-requisite to what follows and is technologically simple. It also would bring along with it a recognition that teaching is worthwhile.

The second and third conceptual models support these implications as well.

[74] Remember, the students typically reported the only connection came through the NSC401 course and that comments like that in Table 1.1 "I would say a little bit of everything beside lecture," to describe teaching in education classes was typical. It could hardly be construed as complimentary when contrasted with the comments about science teaching.

Ok, the relationship between the two cultures that make up science teacher education programs is dysfunctional. So what?

Scientists and educators work on the same problem, science teacher preparation, yet they do not truly work together on the problem. They are critical of each other, and the criticism is often not terribly constructive. Their practices differ, like parents with fundamental differences in their beliefs about the nature of parenting. Part of the difference stems from goals that not only differ, but also oppose one another.

Scientists and educators must answer the question, what kinds of science teachers should we prepare? This requires genuine collaboration, not simply doling out one set of tasks to scientists who teach and another set of tasks to teacher educators. Solid progress has been made here. Documents like NSF's *Shaping the Future* and NRC's *National Science Education Standards* were authored and endorsed by preeminent scientists. They have failed to be widely implemented in any meaningful way, however, and many scientists are openly hostile to their recommendations. Reaching consensus here will be difficult, like the work of keeping a marriage functional. Also like the hard work of a successful marriage, it might benefit from counseling, or at least thoughtful reflection on the nature and dynamics of the relationship.

The science education community has an image of what good teaching looks like, as expressed in *The National Science Education Standards,* the various publications from Project 2061 and countless other documents. Some scientists, like the group of Nobel laureates who blocked the California science standards that were derived from national standards, also hold clear conceptions of what science teaching should look like.

Whether or not scientists and educators can reach consensus on such a contentious issue seems unlikely. Biologist Stan Metzenberg's testimony before Congress was a topic of discussion in one of the BBLs. His anti-reform rhetoric should not be dismissed casually. It is a glaring example of the just how dysfunctional the relationship is and just how far apart some scientists and educators are. This testimony has been widely distributed by the group Mathematically Correct and is posted on their website in the context of much more like-minded opinion (Metzenberg, 1998b).

What the Dysfunctional Relationship model says we need to do:

1. Build genuine collaborations between scientists and educators. When scientists and educators actually listen to one another, they can use each others' strengths to improve science teaching at all levels. This may require counseling the relationships or a process of analysis that has the same net result, but less of, in Jon Peters words, "touchy-feely" stuff.
2. Improve the sharing of understanding within teacher education and between teacher education and science faculty. Teacher education could learn from science about the sharing and development of ideas about teaching. Both science and teaching are processes that have developed substantial and interconnected bodies of knowledge. The culture of science does a far better job of sharing this knowledge with people within the culture than does the culture of teaching.

Meeting these objectives may prove ultimately to not be the course to take. The relationship may prove so dysfunctional as to be irreparable and a true divorce, due to irreconcilable differences, may be appropriate. What then? In some ways, a return to normal schools seems logical. Future teachers would be taught science courses specifically for future teachers that not only help the future teacher to understand the content s/he will eventually teach, but also to model best educational practices. This solution, however, would almost certainly never fly as many would claim that science courses designed specifically for teachers would be "watered down" in the eyes of too many (regardless of the courses' actual merit). Therefore, future science teachers belong in the ranks of science majors.

Ok, the system of science teacher education operates like a poorly managed ecosystem. So what?

> It's fun to learn about human physiology, how the heart works, how the muscles work, how the brain works and all that, but if you don't understand how one cell works, by itself, all the intricate things that it does, you don't really appreciate the whole picture.
>
> Dr. Peters BS111 lecture, 8/31/98

The problem of the functional solution of preparing science teachers separately from science majors being untenable is a result of science teacher preparation being part of a larger, more complex system – a complex adaptive system – like an ecosystem or the human body.

The formal, programmatic part of science teacher education is roughly two (or three) parts science and one part education, but it, like water, is something more than its constituent parts and nobody knows what exactly that something else is (though we are getting closer). The frameworks developed here explore both formal pieces and the properties that emerge when these disparate entities are joined to form new science teachers.

Currently, scientists and educators both work to prepare future science teachers, but the work tends to be in an assembly line fashion that does not work terribly well with real human beings. The idea that one set of individuals loads in the scientific knowledge and another set of individuals loads in the skills of how to teach that knowledge has never worked very well (Shulman, 1986, 1987). I argue that a key reason that this assembly line approach has not worked is that while it appears logical to simplify complex systems, like education, in mechanistic ways, that simplification is ineffective and does not yield the intended result.

The simplifications are attempts to optimize parts of the system, and in many cases they do optimize things typically related to certain definitions of efficiency. If efficiency is defined as putting large numbers of students through courses with a minimum of faculty resources, then the system is efficient. If we include in the definition of efficiency more of the unintended consequences (offputs) then the system is horribly inefficient. The most obvious outcome of this is that majors in science change their major more than in most other disciplines (Seymour & Hewitt, 1997).

A less obvious but equally important offput is the teaching skills learned from these science classes by future teachers. Again and again in my work with future and practicing teachers, I hear that students need to be taught certain material, and taught it in certain ways, to prepare the kids for college. This argument includes the need to lecture – both to convey the amount of information deemed necessary and to prepare the students to be lectured to in college. I crudely simplify the argument to "We must teach them badly to prepare them for bad teaching."

Intentionally and unintentionally the system of science teacher education prepares future teachers to do just this. Most institutions require future secondary teachers to either major in a science discipline or major in science education with requirements similar to that of science majors. If the science courses are taught in the traditional lecture format, then the future teacher sees more models of the kind of teaching that colleges and education departments (rightly) criticize than of the kind they support.

The system is rife with cycles – some feedback loops that are helpful in the preparation of future teachers and others that serve to reproduce the system and its problems from generation to generation. Feedback in those loops is often slow to result in change because the feedback is often slow to register. The feedback is slow because indicators are not clearly identified or, perhaps, do not exist.

In chapter 7, a pair of important questions was raised:

- Is the kind of specialization taking place among scientists and educators increasing stability or does it merely increase the polarity of the system and decrease the overall stability?
- Which is more important in determining the rate and nature of system evolution: increased diversity through increased specialization or increased stress through increasing dissonance?

The increased specialization seems to lean toward the research these individuals are doing rather than impacting very directly the nature of their teaching. Therefore, I suspect that the increasing specialization of college and university faculty does not strengthen the system of science teacher preparation. In fact, the work of the educator destabilizes the system by pushing the education classes to increasingly differ from the science classes. Many scientists, of course, do show an interest in the careful study of teaching and learning and use educational research to shape their teaching practice. Oh the complexity!

While I am optimistic that the cultural dissonance will act as a catalyst for positive change, that is purely speculation. It requires that the dissonance (feedback) is detected – that is, it requires that the indicators be recognized and listened to. I fear that the tide of religious conservatism that removed Darwinian evolution from the Kansas science standards will continue to cause a variety of problems for science education.[75] This is a different sort of stress on the system that has the potential to draw scientists and educators together. Indeed, it is already doing that. This stress may have potential in fostering some kind of change, but the nature of the change is unpredictable. Unfortunately, the system dynamics make accurate prediction difficult. As noted by Pahl-Wostl, models derived from ecosystems make patterns intelligible, they do not make future occurrences predictable (Pahl-Wostl, 1995).

What the Ecosystem model says we need to do:

1. Improve college science teaching. This is clearly the most difficult as well as the most pressing of the tasks. It is unlikely that teaching will improve until it is more widely recognized as a problem. We must begin by making the goal of college science teaching "education," not "selection." Improving assessment in college science courses is a big part of improving teaching and learning by allowing scientists to gain first hand knowledge of students' poorly formed and weakly integrated understanding of science knowledge.
2. Engage scientists in the study of teaching and learning. Encourage the exploration of multiple hypotheses for results of objective tests and the development and use of new instrumentation for gauging student understanding. This could be seen as a part of number 1 above, but it deserves to stand alone.
3. Recognize and use to advantage the fact that future teachers are learning to teach all the time. Learning science and learning to teach science are not separate activities.
4. Planfully engage in the evolution of the system. This includes seeking out and identifying indicators and where they can not be found developing new indicators.

What would be the consequences of improved college science teaching?

[75] Happily, shortly before the submission of the final draft of this dissertation, the Kansas School Board composition was changed by an election.

Not only will improving college science teaching reduce attrition in science programs, but it has great potential for improving the quality of pre-college science teaching. If college science teaching is improved substantially, students would not change their majors due to disappointment with teaching. They would be less likely to lose interest in science. Remember, the three most important factors in the decision to change majors are loss of interest in science, better educational opportunities exist in other disciplines and poor teaching in science classes (see Chapter 1.) Precollege teachers would also *understand* science. Currently, they know a lot (that is, they have factual knowledge) but understand little (that is, they have poorly integrated conceptual knowledge and are even weaker in process knowledge) (Gallagher, 1993).

Currently, the keepers of the culture of college science classrooms not only disparage teacher education and actively and effectively discourage their best students from pre-college teaching, they also disparage the pre-college preparation of their students. In other words, professors of science criticize pre-college science teaching and actively oppose its improvement by preventing the best students from pursuing a career in teaching! If science professors became more interested in improving their own teaching, it follows that they would be interested in promoting good teaching and in respecting the profession more broadly. Again, college science professors must recognize and address their role in the problem.

Improving college science teaching would bring need for other changes within programs. The nature of these changes is far beyond the scope of this first model, however I can briefly comment on the implications. Admission to programs would need to be more selective or the resources for upper level courses would be overwhelmed and the surplus of scientists and mathematicians would increase. Some of this surplus, however, would be redirected to the classroom. The problems oft cited by Darling-Hammond and many others (National Commission on Teaching & America's Future, 1996) of under-qualified and unqualified science and mathematics teacher would gradually diminish.

Back to where we began

The introduction includes the primary goal stated NSF's *Shaping the Future* Document. In closing, it is appropriate to echo two of the recommendations for institutions of higher education from that report:

- *SME&T faculty:* Believe and affirm that every student can learn, and model good practices that increase learning; start with the student's experience, but have high expectations within a supportive climate; and build inquiry, a sense of wonder and the excitement of discovery, plus communication and teamwork, critical thinking, and life-long learning skills into learning experiences.
- *SME&T departments:* Set departmental goals and accept responsibility for undergraduate learning, with measurable expectations for all students; offer a curriculum engaging the broadest spectrum of students; use technology effectively to enhance learning; work collaboratively with departments of education, the K-12 sector and the business world to improve preparation of K-12 teachers (and principals); and provide, for graduate students intending to become faculty members, opportunities for developing pedagogical skills.

(NSF, 1996) p. iv.

Positive Offputs

An additional pair of implications for this dissertation is that by using the ecosystem as metaphor, perhaps some scientists' understandings of the system of science teacher preparation will be enriched more so than if they were to read educational research that relies more heavily on the common language of educational research. Of course, they may also identify holes in my reasoning... The companion positive offput is that educators may gain a deeper understanding of complex systems including the environment in which we live.

What can scientists and educators do?

Organizations like Midwestern's Science & Mathematics Education Collaborative bring scientists and educators together. Such collaborations are not unique to Midwestern University and those interested in improving the relationship between scientists and educators on their own campus might benefit from the investigation of such collaborations. As a member of the Association for the Education of Teachers of Science (AETS) Committee on Scientist/Science Educator Collaboratives, I have gathered descriptions of and links to such collaboratives and posted it on my website. The text of the web page is included as Appendix C and it is found on the web at: http://cc.kzoo.edu/~dhaas/ScienceEdCollab.htm. Several of the organizations listed describe their beginnings on their web pages. These may serve as useful models. Also included is a link to NASA's NOVA grant program which offers grants of up to $30,000 to institutions for collaborative course development that involve scientists and educators working together.

Some Resources for Doing What Needs to be Done

In addition to the resources in Appendix C, countless other institutions are engaged in appropriate reform of their undergraduate science coursework, not simply through reforming curriculum but also through supporting pedagogy. The University of Delaware's Institute for Transforming Undergraduate Education offers good examples of course structures that appear to facilitate meaningful learning. Their web site, http://www.udel.edu/inst/, has links to course syllabi that not only offer an out line of the content to be taught, but also information about what learning looks like in classrooms of the Institute's Fellows.

For example, Linda K. Dion's Introductory Biology I syllabus describes the course structure as follows:

> Half of BISC207 "lecture" will be devoted to problem-based group learning and half will be devoted to more traditional lecturing and evaluation of your progress. Class activities are roughly apportioned in the following way: on Tuesdays there will be a lecture on the material and sometimes a quiz; on Thursdays you will work with your group on a problem which applies to the topic of the week.
>
> (Dion, 2000)

Susan E. Groh's Honors General Chemistry starts the description of the class format as follows:

> "At times I felt the professor's notes became my notes without passing through either of our minds." - P.A. Metz
>
> The traditional lecture approach to teaching is an excellent way to transfer information from one notebook to another; unfortunately, it's not necessarily an excellent way to develop a real understanding of chemistry. You don't learn how to ride a bike or speak French by listening to someone explain how to do it - you've got to try it yourself. To learn any subject well, including chemistry, you have to become actively involved in the learning process. The format of this course is designed to encourage that involvement; in addition to lectures, you can expect to encounter both individual and group activities (problem-solving, brain-storming, discussion, feedback, etc.) during class.
>
> (Groh, 1999)

There are links to dozens of such syllabi.

The site also includes links to and descriptions of research coming out of the Institute's work: http://www.udel.edu/pbl/articles.html. This includes both research articles and books and text that might be described more as "how to." The central focus of this work is employing Problem Based Learning across the college curriculum. (University of Delaware, 1999)

Conclusion

This study makes the argument that deficits exist in teacher preparation because the interconnections of pedagogy and content necessary to develop strong and applicable pedagogical content knowledge were severed as the gulf between the cultures of college science and teacher education increased in size. The dysfunctional relationship between those two cultures and dynamics of the larger system of science teacher preparation may further confound success in teacher preparation. Understanding the nature of the dynamics involved can help us to better fill our niches within the ecosystem of science teacher preparation. That understanding may also guide us in planful system evolution, but the likelihood of those plans going off without a deviating from the plan is nearly nil.

As Dr. Peters noted on the first day of Biological Sciences 111, we need to understand the components of a system to understand the system. The reverse is also true. To understand the components of a system, we need to also understand the entirety of the system. The current system of higher education tends to work very hard at the former and virtually ignore the latter!

The first model, Two Programs, Two Cultures, helps develop the understanding of the nature of components within science teacher preparation. In large part this comes from seeing the sharp contrast between the way individuals operate within each seemingly separate piece. This framework is the foundation for the second, The Dysfunctional Relationship. We can better understand the relationship if we understand those who are involved. This framework indicates that there exists need for relationship counselors within the dynamic system.

Both of the first two models are vast simplifications of the complex realities of the complex educational system of science teacher education. These simplifications are bridges to understanding the more complex system with its diversity and the strengths derived from that diversity that are damaged by treating classes as monocultures. Ecological models of learning to teach have great promise for deepening understanding, not only for educational researchers but also, and more importantly, for the "hard" scientists who teach.

A key idea is, as noted in Chapter 7 and again earlier in this chapter, is that future teachers are learning to teach all the time, not simply when someone thinks they are teaching them how to teach. In my current work as the Director of Teaching Internships at a small private elite liberal arts college, I occasionally place student teachers at small private elite secondary schools. In an attempt to place an art teaching intern at such an institution I spoke with the art department head. The department head told me that most of the teachers are MFAs and are not certified to teach. They are "artists who happen to teach." It occurred to me that artists are taught their craft almost exclusively by *doing it.* How much different could the practice of science be from the lecture hall?

Teacher education is a system in operation over an individual's entire life. Often times, the different actors within the system are poorly coordinated, or not coordinated at all. The fundamental core of science teacher preparation should be model teaching of science, that is when these teacher candidates are taught science (from kindergarten through graduate school) it should be taught in such a way that it can be used as a model of good teaching by the teacher candidate. This rarely happens, not because teachers and professors are not thoughtful and hard working, but because they are working in a system that encourages them to do the wrong thing. Two examples reinforce my point: preparing high school students for college by lecturing to them because that is the way they will likely be taught in college, or working to improve one's lectures when it may make more sense to figure out what to replace those lectures with.

Taking a great leap beyond the data, I have come to understand that the structure of college science as currently configured will prove to be an "evolutionary dead-end." This is not to say that lecture does not have a place in education. It does, but it does not deserve a central place in any part of the educational system. It is not, as Stephen Arch claims in the Journal *Nature*, "It just may be that counterrevolutionary, old-time lecture hall education is still with us after all these centuries because -- although everyone agrees it is a terrible way for students to learn -- it's still the best thing anyone has yet invented (Arch, 1998)." Better methods are known and understood, but not by the broad community.

APPENDICES

APPENDIX A

TEACHER CERTIFICATION REQUIREMENTS

Table 2.1 Requirements for the Bachelor of Science Degree in Biological Science -- Interdepartmental		
5. The University requirements for bachelor's degrees as described in the Undergraduate Education section of this catalog: 120 credits, including general elective credits, are required for the Bachelor of Science degree in Biological Science – Interdisciplinary. The University's Tier II writing requirement for the Biological Science – Interdepartmental major is met by completing NSC401. That course is referenced in item 3.a. below. Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1 under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3 below may be used to satisfy the alternative track.		
6. The requirements of the College of Natural Science for the Bachelor of Science degree. The credits earned in certain courses referenced in the requirement 3. below may be counted toward College requirements as appropriate.		
7. The following requirements for the major:		CREDITS
a. All of the following courses:		38
BS 110 Organisms and Populations	4	
BS 111 Cells and Molecules	3	
BS 111L Cells and Molecular Biology Laboratory	2	
CEM 251 Organic Chemistry I	3	
CEM 252 Organic Chemistry II	3	
CEM 255 Organic Chemistry Laboratory	2	
CEM 262 Quantitative Analysis	2	
NSC401 Science Laboratory for Secondary Schools	4	
PSL 250 Introductory Physiology	4	
ZOL 341 Fundamental Genetics	4	
ZOL 355 Ecology	3	
ZOL 355L Ecology Laboratory	1	
ZOL 445 Evolution	3	
b. One of the following groups of courses		9 to 12
(1) CEM 141 General Chemistry	4	
CEM 142 General and Inorganic Chemistry	3	
CEM 161 Chemistry Laboratory I	1	
CEM 162 Chemistry Laboratory II	1	
(2) CEM 151 General and Descriptive Chemistry	4	
CEM 152 Principles of Chemistry	3	

	CEM 161 Chemistry Laboratory I	1	
	CEM 162 Chemistry Laboratory II	1	
(3)	CEM 181H Honors Chemistry I	4	
	CEM 182H Honors Chemistry II	4	
	CEM 185H Honors Chemistry Laboratory I	2	
	CEM 186H Honors Chemistry Laboratory II	2	
c. One of the following pairs of courses			6 or 7
(1)	MTH 132 Calculus I	3	
	MTH 133 Calculus II	4	
(2)	MTH 132 Calculus I	3	
	STT 201 Statistical Methods	4	
(3)	MTH 124 Survey of Calculus with Applications I	3	
	MTH 124 Survey of Calculus with Applications II	3	
(4)	MTH 124 Survey of Calculus with Applications I	3	
	STT 201 Statistical Methods	4	
(5)	MTH 152H Honors Calculus I	3	
	MTH 153H Honors Calculus II	3	
d. One of the following pairs of courses			6 or 8
(1)	PHY 183 Physics for Scientists and Engineers I	4	
	PHY 184 Physics for Scientists and Engineers II	4	
(2)	PHY193H Honors Physics I – Mechanics	3	
	PHY193H Honors Physics II – Electromagnetism	3	
(3)	PHY 231 Introductory Physics I	3	
	PHY 232 Introductory Physics II	3	
e. One of the following pairs of courses			2
(1)	PHY 191 Physics Laboratory for Scientists, I	1	
	PHY 184 Physics Laboratory for Scientists, II	4	
(2)	PHY 251 Introductory Physics Laboratory I	1	
	PHY 252 Introductory Physics Laboratory II	1	
f. Two of the following courses			8
	BCH 401 Basic Biochemistry	4	
	ZOL 350 Histology	4	
	ZOL 482 Cytochemistry	4	
g. One of the following courses			3 or 4
	BOT 301 Introductory Plant Physiology	3	
	BOT 405 Introductory Plant Pathology	4	
	BOT 418 Plant Systemics	3	
	BOT 434 Plant Structure and Function	4	

Midwestern University's Writing Requirements:

The University catalog describes the Writing Requirements as follows:

Each student must complete the University's writing program requirements[76] as follows:

1. The Tier I writing requirement that consists of either:
   (a) One 4-credit Tier I writing course[77] during the first year or
   (b) The developmental writing courses (American Thought and Language 0102 and 1004)[78] and one 4-credit Tier I writing course during the first year.

A student who completes the Tier I writing course with a grade of 0.0 must repeat the course. A student who completes the Tier I writing course with a grade of 1.0 or 1.5 must enroll in the 2-credit writing tutorial course (AL201) concurrently with IAH201.

2. The Tier II writing requirement for the student's academic major and degree program. This requirement involves writing in the student's discipline and is met by completing either:
   (a) One or more 300-400 level Tier II writing courses as specified for the student's academic major and degree program, or
   (b) a cluster of 300-400 level courses that involve writing experiences and that are approved as the Tier II writing requirements for the student's academic major and degree program.

These footnotes are quoted from the original document.

[76] New freshmen who have taken the College Board Advanced Placement Examination in English should consult the statement on Academic Placement Tests. Transfer students should consult the statement on Transfer Student Admission.

[77] For students who are enrolled in the College of Business, the completion of Business College 111 and 112 satisfies the University Tier I writing requirement. For students enrolled in the DaVinci School, completion of DaVinci School 133 satisfies the University Tier I writing requirement. The other Tier I writing courses are listed below: American Thought and Language: 110, 115, 120, 125, 130, 140, 145, 150, 195H.
Arts and Latter 192 and 192H.

[78] Based on the English placement mechanism, a student may be required to complete the developmental writing course prior to enrolling in a Tier I writing course. The developmental writing courses are administered by the Department of American Thought and Language. For additional information, refere to the statement on Academic Placement Tests.

APPENDIX B

NEW TEACHER PRESERVICE PROGRAM INTERVIEW

Q1: how would you describe your typical science course? Include types of objectives, instructional strategies, resources used including lab, text, computer use...

~

Q2: how were you typically evaluated in the science courses? Describe nature of tests, graded labs, papers and homework assignments, computer graded work and any other graded work.

~

Q3: how often were cooperative learning techniques used in your science courses? Distinguish, if possible, between group work and cooperative learning.

~

Q4: did you take science courses different from those taken by students not preparing to teach?

~

Q5: how often did you work on actual research projects or in actual research facilities as part of your science program? Briefly describe the research (if applicable). If you completed research that was not part of your program, please describe that.

~

Q6: which science course experiences stand out in your mind as particularly important to you and why?

~

Q7: how would you describe the student-faculty relationship in your science program? Did you have direct interactions with faculty? If so, describe.

~

Q8: were you a member of a student cohort (or team) when studying science? That is, did you take most of your classes with the same set of students as you went through?

~

Q9: what was the purpose of your science study? Did it include teaching as a career? Did you start out as a freshman wanting to be a biology teacher?

~

Teacher education courses.....

Q10: how would you describe your typical teacher education course? Include types of objectives, instructional strategies, resources used including lab, text, computer use...

~

Q11: how were you typically evaluated in teacher education courses? Describe nature of tests, graded labs, papers and homework assignments, computer graded work and any other graded work.

~

Q12: how often were cooperative learning techniques used in your teacher education courses? Distinguish, if possible, between group work and cooperative learning.

~

Q13: okay. How would you describe your field experiences (work in schools)?

~

Q14: which courses or experiences in teacher education stand out in your mind as particularly important to you and why?

~

Q15: what was the relationship between what you learned in science courses and what you learned in teacher education courses including you methods courses?

~

Q16: how would you describe the student-faculty relationship in your teacher education program? Did you have direct interactions with faculty? If so, describe.

~

Q17: were you a member of a student cohort (or team) in your teacher education program?

~

Q18: what was the philosophy of your teacher education program related to science education and related to science teaching?

~

Career experience prior to entering program -- only answer these questions if you are returning to msu for teacher certification after completing your bachelors' degree. (These questions did not apply to any of the seniors interviewed in 1999).

Q19: please describe briefly your professional career between when you obtained your undergraduate degree and when you returned to obtain your teaching certificate.

~

Q20:

How has your prior professional experience contributed to your ability to secondary science?

APPENDIX C

Scientist/Science Educator Collaboratives Webpage

Contents of this page...

Introduction

This page includes links to organizations within institutions of higher education where scientists and science educators are working together to improve specific aspects of science education.

Requesting information on your collaborative...

We would like to know if you are involved in a collaboration involving scientists and/or mathematicians and educators. If the collaborative has a web page that you would like included here, please send the information to Don Duggan-Haas at dhaas@kzoo.edu . Send a brief description (fewer than 100 words, please) along with the URL. The description should be sent as an attached document, either in Microsoft Word format or as an RTF file.

Look for symposiums on these collaboratives at the AETS meeting in January 2000.

The Center for Learning Technologies

The Center for Learning Technologies is a collaboration between Northwestern University, The University of Michigan, and the Chicago and Detroit Public Schools. The Center's goal is to support urban school systems in taking a leadership role in educational reform. In the center, teachers, administrators, and university researchers are working together to develop strategies for embedding and sustaining the use of computing and communications technologies in inquiry-based science curricula. Leveraging these technologies in support of inquiry-based curriculum can provide the critical support needed by students to engage in the serious, intellectual learning called for by new national, state and local standards.

The URL is http://www.letus.nwu.edu/

Center for Science and Mathematics Education at the University of Southern Mississippi

The Center for Science and Mathematics Education is dedicated to preparing science and mathematics teachers capable of providing the high-quality instruction that will better enable students to understand themselves and the world around them.

The Center works with the departments to coordinate programs in teacher education offered by the College of Science and Technology (CoST), and provides, in cooperation with the Department of Curriculum and Instruction, a curriculum in the sciences for prospective elementary schoolteachers. In addition to providing programs in secondary education and for advanced degrees, the Center works with the public schools to improve science and mathematics curriculum and works to utilize educational technology in personal development.

The Center also conducts a variety of workshops to enhance the skills of in-service teachers and contributes to the science and mathematics preparation of candidates for initial certification. Learn more about these and other educational activities in the discussion on Outreach.

The URL is http://www.csme.usm.edu/

The Collaborative Vision for Science & Mathematics Education at Michigan State University

The Collaborative Vision for Science & Mathematics Education at Michigan State University is the original host of this website. CVSME is a collaborative effort involving science and mathematics educators, and scientists and mathematicians who are interested in improving math and science teaching and learning from before kindergarten through school completion and beyond.

The URL for the CVSME homepage is http://ed-web3.educ.msu.edu/cvsme/

The NOVA Project at Fort Hays State University

Fort Hays State University, Hays, Kansas has been engaged in a collaborative reform effort to improve the science and mathematics preparation of preservice K-9 teachers. Faculty in physics, mathematics, and education have met, planned, and implemented changes in the teaching and assessment strategies used in Physical Science and Elements of Statistics. The purpose of the project is to provide students with a common set of learning experiences based on an inquiry-based learning model as a foundation for the development of their praxis.

Further information is available at http://www.physics.fhsu.edu/~nova/.

Greater Wichita Area Mathematics and Science Education Collaborative

The Greater Wichita Area Mathematics and Science Education Collaborative (GWAMSE Collaborative) was formed for the purpose of improving the mathematics, science and technology skills of our present and future citizens by enriching the preparation and professional development of science and mathematics teachers in grades K-16.

Further information is available at http://web.physics.twsu.edu/gwamse/gwamse.htm.

The IUP Teacher Education Center for Science, Math, and Technology

This website is constantly being updated to reflect collaborations, services, and resources available to teachers.

The URL is http://www.iup.edu/smetc

You can also go directly to the website for IUP's Eisenhower summer institute program.

That URL is http://www.iup.edu/smetc/SPIRAL

Oswego State University

This web site describes an inservice project supported by Eisenhower funds since 1988 which involves A&S and school of education faculty in efforts to improve K-8 science, math and tech instruction in Central New York.

The URL is http://www.oswego.edu/~sueweber

Toledo Area Partnership in Education: Support Teachers as Resources to Improve Elementary Science (TAPESTRIES)

The web site is for an NSF funded LSC project. In the project, scientists and science educators collaborate to provide professional development. The purpose of this five-year project is to develop comprehensive school science programs through the sustained professional development of all K-6 teachers in the Toledo Public Schools and Springfield Local Schools. Teacher-based leadership and other support structures will be implemented as teachers use inquiry-based science curriculum and instructional strategies. Teachers will be involved in long-term professional development activities during Summer Institutes and academic year sessions.
TAPESTRIES is funded by the National Science Foundation in cooperation with the University of Toledo, Bowling Green State University, Toledo Public Schools, and Springfield Local Schools.

The URL is http://www.tapestries.ut-bgsu.utoledo.edu/

Wisconsin Teacher Enhancement Program in Biology (WisTEB)

The Wisconsin Teacher Enhancement Program in Biology (WisTEB) is a 15 yr old program that has provided a spectrum of professional development opportunities for some 3000 K-14 science teachers from around the U.S. and abroad (but with the majority being in Wisconsin and the Upper Midwest). The two components are an annual Summer Institute, consisting of 30-40 1-3 week intensive courses over a wide spectrum of content areas in the biological and physical sciences, and an academic year outreach and support program.

The WisTEB staff is composed entirely of scientists with a great deal of bench experience who have elected to devote the rest of their career to science education. There is a close working relation with the Department of Curriculum and Instruction in the UW-Madison School of Education. Since the inception of the program, over 200 faculty and staff researchers on campus have donated over 2500 hours in both the summer and academic year program. A few years ago, WisTEB began a program that allows young scientists (advanced level grad students and post docs) to participate in the program. All participating scientists are asked to share their excitement and expertise as a mentor and partner rather than as a purveyor of facts and/or pontificator. In return, they often gain fresh insight in approaches to teaching as well as a profound understanding of what goes into precollege science education. During the academic year, WisTEB has hosted brown bag seminars that bring scientists and science educators and teachers together to chew over different issues in science education.

Further details can be found on the WisTEB web site: http://www.wisc.edu/wisteb/

Resources for collaboratives:

NASA's Project NOVA

Project NOVA is a NASA funded project involving several colleges and universities throughout the US. For more information on the work being done around the country, see the NOVA website at http://www.eng.ua.edu/~nova.

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