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YOVITA NETSAI GWEKWERERE

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RESPONSE TO SCIENCE EDUCATION REFORMS: THE CASE OF THREE SCIENCE EDUCATION DOCTORAL PROGRAMS IN THE UNITED STATES

By

Yovita Netsai Gwekwerere

A DISSERTATION

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ABSTRACT

RESPONSE TO SCIENCE EDUCATION REFORMS: THE CASE OF THREE SCIENCE EDUCATION DOCTORAL PROGRAMS IN THE UNITED STATES

By

Yovita Netsai Gwekwerere

Doctoral programs play a significant role in preparing future leaders. Science Education doctoral programs play an even more significant role preparing leaders in a field that is critical to maintaining national viability in the face of global competition. The current science education reforms have the goal of achieving science literacy for all students and for this national goal to be achieved; we need strong leadership in the field of science education. This qualitative study investigated how doctoral programs are preparing their graduates for leadership in supporting teachers to achieve the national goal of science literacy for all.

A case study design was used to investigate how science education faculty interpreted the national reform goal of science literacy for all and how they reformed their doctoral courses and research programs to address this goal. Faculty, graduate students and recent graduates of three science education doctoral programs participated in the study. Data collection took place through surveys, interviews and analysis of course documents. Two faculty members, three doctoral candidates and three recent graduates were interviewed from each of the programs. Data analysis involved an interpretive approach. The National Research Council Framework for Investigating Influence of the National Standards on student learning (2002) was used to analyze interview data.

Findings show that the current reforms occupy a significant part of the doctoral coursework and research in these three science education doctoral programs. The extent to which the reforms are incorporated in the courses and the way they are addressed depends on how the faculty members interpret the reforms and what they consider to be important in achieving the goal of science literacy for all. Whereas some faculty members take a simplistic critical view of the reform goals as a call to achieve excellence in science teaching; others take a more complex critical view where they question who 'all students' refers to and what science literacy means for learners with diverse cultural, linguistic or economic backgrounds.

Faculty members' views significantly influence the nature and content of the courses as well as the program focus. It was also shown that a relationship exists between faculty views and the views of their doctoral students and recent graduates. In general, faculty exhibited narrower and more in-depth views about issues they consider being important in the field of science education, than doctoral students and recent graduates. External funding is critical in doctoral studies as it enables faculty to enact their visions of achieving science literacy for all.

The study provides some implications for practice, policy and research. In order to achieve both equity and excellence in science teaching, there is need for dialogue among science educators to enable them to address issues of equity more effectively than at present. If doctoral programs are to continue preparing graduates who can address important issues in the field, there is need for external funding for specific research programs.

Dedicated:

In memory of my father Stanislous Kaseke for the great dreams he had for me

To My Mother Elizabeth Kaseke for her unwavering support

To my husband Bernard for being there as I pursued my dreams

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Getting to this point has been a long journey. Mentioning all the people who have made this journey successful would fill a substantial volume. All I can say is that I am grateful to have had the support of my family, mentors and friends who walked with me throughout this journey. First of all I would like to thank the Lord for the wonderful gift of life, for good health, and strength that enabled me to get through the program. Coming to America to for PhD studies was made possible by generous support from the Fulbright fellowship in August of 2000. I would not have managed to complete my studies without the generous financial support I got from the Teacher Education Department at Michigan State University, for the past four years.

I first met my academic advisor Dr. James Gallagher in 1998 when I came to Michigan State University as a visiting scholar. I thank him for encouraging me to apply to the Teacher Education doctoral program. Since I came to the United States, Dr. Gallagher has been a constant source of support, encouragement and hope. The most important gift I got from working with Dr. Gallagher is that he believed in me, and this is what got me through the program. He has been my mentor, anchor and source of encouragement. During times when I was overwhelmed with work and when I had lost hope for going on, he encouraged me to stay on course. It was a great honor to have opportunity to work with him on the Leadership Development Study---it was a defining moment in my academic career. He has been a fine academic example.

My academic and dissertation committee members, Dr. Avner Segall, Dr. Edward Smith and Dr. John Metzler provided valuable guidance, shaping my program of study and my dissertation research ideas. I feel honored to have worked alongside such great

scholars. I am also greatly thankful for the valuable experiences and lessons I learned from several faculty members in the Teacher Education program at Michigan State University.

As a mid-career changer, I am greatly indebted to all the teacher educators who have supported me as I navigated the field of education. Through their unwavering support I have become an accomplished scholar in the field. Dr. Suzanne Wilson deserves mention as my first teacher educator; she taught me the art of scholarly writing. Dr. Avner Segall taught me to look at education from different viewing points, something that has helped me to define my true passion in the field of science education.
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I have learned so much from my interviewees, both from my dissertation study and from the Leadership Development Study. I am greatly indebted to the science education professors, students and recent graduates who agreed to participate in my study. I appreciate their valuable time and sharing their views and ideas with me. As I come to finishing the dissertation, I realize it was time well spent. Although I take full responsibility for this work, it does not solely belong to me, it belongs to all of us who put our time into it.

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Most of all I need to acknowledge the immense debt I owe to my mother Elizabeth Kaseke—the most loving woman I know. She has endured my long absences on journeys across the world and still wonders whether she will ever see her grandchildren again. Her love and support has kept me going. I am glad, especially for her, that the longest and hopefully the last of my journeys is coming to an end.

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CHAPTER 1

SITUATING THE STUDY

Introduction

In this study I set out to investigate how three science education doctoral programs in the United States are interpreting the current reform goal of science literacy for all and how they are enacting the reforms in their programs as they prepare future leaders in the field. I am interested in this study because it has been more than a decade since the current science education reform documents, namely; a) Science Literacy for All Americans (Rutherford & Ahlgren, 1989), b) Benchmarks for Scientific Literacy (AAAS, 1993) and c) the National Science Education Standards (NRC, 1996) were published, and yet the problems that confronted the science education community in the eighties still remain.

The two major problems in education that triggered the current reforms in the early eighties are: a) America's failure to educate students to a level that is comparable to other developed countries as shown by international studies (TIMSS, 1998), and b) The achievement gap that has existed between poor urban schools and rich suburban schools (Barton, 2003; Lee, 2003; & Brickhouse, 2001). High school students still graduate unprepared for the demands of today's job demands and urban and minority students in urban schools are still not getting the same quality of science education as their counterparts in suburban schools.

Findings from the most recent survey conducted by the Education Testing Services in May 2006 show that the American public is still worried about the failure by schools to prepare young people in Mathematics, Science and Technology, which they identified as critical to maintaining the country's competitiveness in the global economy, and college professors viewed the public schools more negatively than did Americans in general (*Luesdorf, 2006)* as shown in the following quotation:

> Americans are increasingly worried about the quality of elementary and secondary schools and students' preparedness to compete in the global economy, and college faculty members are among the public-education system's greatest critics, according to findings released on Wednesday from the latest in a series of annual surveys. (p.1)

Why should college professors care so much about the quality and outcomes of K-12 science learning? There are several reasons why, but most importantly, science education professors are either directly or indirectly involved with supporting science teachers to reform their teaching in three different ways: a) through preparing teachers and teacher educators, b) through working directly or indirectly on professional development projects to bring reforms to the classrooms, and c) some science education faculty were significantly involved in writing the reforms; hence they have invested interest to see these reforms work.

Science education faculty have been actively involved in reforming science teaching through teacher preparation programs and professional development efforts (Hug, Krajcic & Marx, 2005). These efforts have been manifested in professional conference presentations at the National Association for Research in Science Teaching and the American Educational Research Association for the past five years. Most of the research presented focuses on innovations to improve teaching and learning. As a result, college faculty have been blamed for failing to be efficient in bringing reforms to the schools mainly because they talk to each other and fail to communicate their research to practitioners (Gallagher et. al., 2003). College professors also talk to each other mostly about the practice of teachers and in a few cases about their own innovations in teacher education courses, but they rarely talk about their practice in preparing doctoral students.

There are two major areas that have not received much attention from science education faculty: a) there is limited literature that tells us how science education faculty are interpreting the science education reform goal of science literacy for all and how they are enacting the reforms through their doctoral programs as they prepare future leaders in the field; b) and there also is limited literature on the practice of college faculty compared to the abundance of literature on practice of teachers. The following quotation from Segall (2002) shows concern for the limited amount of critical examination and discussions about what is happening in teacher education:

> Contrary to public schools, which have, for some time been the subject of critical investigation by external researchers, teacher education programs-and for that matter colleges of Education (and faculty in) education in general –have maintained their extraterritorial status, remaining free from such investigation. In other words, --- university classrooms have remained under lock and key. Teacher educators, as educational researchers, tend to investigate their own practices or those of others; they are not, by and large, the subjects of (external) investigation themselves. Not surprisingly then, there is relatively little that critically describes or assesses teacher education programs or provides a critical examination of the teaching/learning interactions that take place in them. *(p. 5)*

In this study I bring together two strands of scholarship: science education reforms and doctoral preparation. The intention of this study is neither to assess nor judge the performance of doctoral programs or the work of faculty. However, it provides recommendations to science education faculty on the need to find ways to address both excellence and equity in doctoral preparation. My major goal is to stimulate discussion among science education faculty about their practice in doctoral studies. I believe that such a discussion brings hope to finding solutions to the growing problems in the education system. By science education reforms I am referring to the K-12 curriculum reforms, specifically the Benchmarks for Scientific Literacy and the National Science Education Standards. I will not be focusing on the No Child Left Behind Policy due to time and space limitation

The science education reforms have been interpreted in different ways (Oakes and Rogers, 2005). As mentioned earlier, the reform goal is to achieve science literacy for all. Research studies and literature has shown that research addressing the reform goals either focuses on science literacy only, equity issues only or both (Oakes and Rogers, 2005;). I believe this is the case because the reform goal as stated in the reform documents is to achieve '*science literacy for all.*' The National Science Education Standards went on to state that the standards "encompass both *equity* and *excellence*". In order to fully achieve the reform goal both intentions of the reforms must be achieved. My hypothesis in this study is that the way reforms are interpreted and enacted in doctoral programs will greatly influence how future science educators are going to think about and enact the reforms in the future. By reform interpretation I am referring to whether the science educators' research and teaching focus on achieving excellence in science pedagogy and learning; or whether they focus on achieving equity in science teaching or whether they focus on both.

A survey of science education faculty's views about challenges confronting their field showed that they considered addressing the current reforms in science education to be a major challenge in the field (Gallagher & Gwekwerere, 2003). There is need to look at how different college professors are interpreting and enacting the reforms in order to ascertain the nature of the challenge. Gaining such knowledge will be an important resource for college faculty as they seek to improve their practice in preparing future leaders in the field. In the rest of this chapter I will provide a detailed description of the current science education reforms, the status of reform outcomes as shown by the Leadership Development Study and why it is important to study science education doctoral programs.

Current Reforms in Science Education

The history of reforms in science education can be traced back to 1957 when Russia launched Sputnik (Dickson, 2003), a spaceship that silently revolved around the earth every 90 minutes (Gallagher, 2006). This event raised several questions of why the United States was behind Russia in technology (Gallagher, 2006). Federal funding was provided to reform the science curriculum, which led to production of the Biological Sciences Curriculum Study the Physical Science Study Committee and the Chemical Broad Approach (DeBoer, 1991). These reform efforts of the 1960s were geared towards providing curriculum materials with deep content knowledge that teachers would readily use, and the belief at the time was that all teachers needed to be effective was a good curriculum.

With change in administration, financial support was eliminated (Gallagher, 2006) and this led to a marked decline in student achievement. Reports of an ailing economy in a document entitled 'A Nation at Risk' (National Commission on Excellence in Science, 1983) detailed how schools were failing to prepare students adequately in science and mathematics in secondary schools at levels that are comparable to programs in other developed nations. The American Association for the Advancement in Science (AAAS) pioneered the current reforms by bringing together specialists in science, mathematics and education, in order to come up with ideas on what should constitute scientific literacy and how it can be achieved. This led to publication of Science for all Americans by Rutherford and Ahlgren, (1989).

This book describes what constitutes literacy in science, mathematics and technology and it highlights the steps that are needed to achieving it. It also included a broader view of science than was found in most school programs by adding features such as emphasis on nature of science, and how science integrates with mathematics and technology (Gallagher, 2006). In addition to providing a broader view of science, this book also highlights he need to teach science to all young people regardless of their social circumstances and career aspirations. "In particular, the recommendations pertain to those who in the past have largely been bypassed in science and mathematics education: ethnic and language minorities and girls" (Rutherford & Ahlgren, 1989 *p.x).* In addition, this reform document called for teaching science for understanding, which is opposed to rote memorization. Teaching for understanding places emphasis on less but relevant science content in more depth and helping students to make connections between science ideas and the real world.

The Benchmarks for Science Literacy (AAAS, 1993) was the second reforms document that was designed to highlight the kind of curriculum described by Rutherford and Ahlgren, (1989). This reform document contains a coherent set of specific learning goals at 4 levels. Similar to Rutherford and Ahlgren's book, the Benchmarks for Science Literacy were set to achieve the goal of achieving scientific literacy for all by the 21st century (AAAS, 1993). The Benchmarks were a precursor for the National Science Education Standards (NSES), published by the National Research Council in 1996. This document laid out standards for science content, teaching, teacher professional development, and assessment to be included in the school curriculum. It also laid out standards for programs and the education systems to guide the national and state leaders. The National Science Education Standards complement the two earlier documents by detailing what students should know and be able to do in eight content dimensions namely, unifying concepts and processes, science as inquiry, physical science, life science, earth and space science; science and technology, science in personal and social perspectives, and history and nature of science.

Both documents present a broader view of science curricular content than was previously commonplace. What makes the standards different from the Benchmarks is its emphasis on teaching science through inquiry. The NSES, the Benchmarks for science literacy and Science for All Americans share the same goal of achieving science literacy for all. The NSES clearly articulate this goal in the document overview: "The intent of the standards can be expressed in a single phrase: Science standards for all students. The phrase embodies both excellence and equity. The standards apply to all students, regardless of age, gender, cultural or ethnic background, disabilities, aspirations, or interest and motivation in science" (NRC, 1996. p 2).

The reforms are premised on a conviction that all students deserve and must have the opportunity to become scientifically literate (NRC, 1996). The NSES for example, call for more than "science as process," in which students learn such skills as observing, inferring, and experimenting; they specify that science is something that students should do and that science is not something done to them.

Although the National Science Education Standards and the Benchmarks for Science Literacy clearly articulate how excellence in science should be articulated by describing what students should know and be able to do, what teachers should know in order to teach science and what teacher education programs should do in order to prepare teachers who can do their job, they do not specify what can be done to achieve equity in science teaching. Rodriguez (2005) argues that the standards make ethnicity invisible, and that this invisibility contradicts one of the standards main goals – to make science accessible to all students. These documents for example do not advise teachers on how to help students with different learning needs to achieve at the same level as their peers. By students with different learning abilities I mean intellectual, physical and linguistic abilities.

The reform documents are also silent on how students in resource poor schools can have access to resources that can help them do science and not have science told to them. Lack of resources such as books and supplies for conducting science inquiry makes it impossible for the teachers to meet the goal of the science teaching standards that require teachers to plan and teach inquiry. This also makes it impossible to achieve the content standards goal that requires that all students should learn science through inquiry.

The silence by the reforms on issues of teaching science to diverse learners and teaching science in resource poor schools means the reform documents failed to articulate how equity can be achieved. The reform documents therefore contradict the claim that the reform goals embody both equity and excellence. In order to achieve equity in science teaching teachers in resource poor schools need resources that support them to achieve the goal of scientific literacy for all. They also need help on how to teach linguistically diverse students as well as students with learning disabilities.

The issues of inequity in public schools have been well documented in literature. Kozol (1992) for instance, highlighted the plight of poor urban schools in three major U.S. urban areas. He specifically showed the disparities in funding between schools in wealthier districts compared to the ones in poorer districts in Chicago, Boston and New York. In his later work, Kozol (2005) showed that these disparities in school funding and resources are still there today. I have also noticed the disparities in science classrooms and the quality of science taught to students when I visited interns teaching science in different high schools in Lansing, Michigan.

In this study I decided to investigate how science education faculty address the current reform issues in their doctoral program and in their research in order to see how they are interpreting the reform goal of science literacy for all. One of the specific questions that will guide this study is: 'How are science education doctoral program interpreting and enacting the reform goals through their coursework and research?' Answering this question will enable us to see whether the science educators' interpretation of the reform goals embody both equity and excellence or not. I am also interested to know whether the science educators' interpretations are translated into action as they prepare future teacher educators.

I decided to investigate how science educators are responding to the reforms as a follow up to the Leadership Development Study that I participated in as a research assistant from 2001 to 2003. The Leadership Development study was an NSF funded study of how present leaders in Science and Mathematics were developed and what led to their success. Studies of Science and Mathematics education doctoral programs were also studied as channels through which leaders in the field are developed.

In the next section I will describe the constraints to implementing reforms that were identified by deans and science education faculty. I will also describe how science education doctoral programs are addressing these challenges. At the end of the section I will show how the present study grew out of the questions raised in the Leadership Development Study (Gallagher et. al., 2003).

Constraints Implementation of the Reforms:

Findings from the Leadership Development Study

Problems of implementing reforms have been reported (Horizon, 2002). Even where reforms are being implemented, there remain problems of low academic achievement in science and failure to recruit teachers who have good science content background (Gallagher & Gwekwerere, 2003). In order to better understand why these challenges remain despite the reforms efforts, it is imperative that we take a holistic look at the education system, especially at science teaching as well as teacher education. A holistic look at teacher education includes preservice teacher preparation, teacher professional development, and doctoral preparation of teacher educators. A recent study of science education doctoral programs provided insight into the nature of science education doctoral programs and how they are addressing issues related to national issues (Gallagher et. al., 2003).

Findings from the 2001-2003 Leadership Development Study revealed some challenges that confront the field of Science Education and are posing a challenge to implementation of the current reforms. Deans and faculty who were interviewed for that study identified the following as challenges: a) the tension between educational policies and academic work; b) teacher quality, teacher recruitment and equity; and finally c) diversity, equity and teaching science to all students. It is clear that these challenges are either directly or indirectly related to improving science teaching, which is in line with implementation of science education reforms.

The deans and faculty highlighted the existence of a conflict between educational policies and academic interests of professors as a challenge to reform implementation efforts. One specific area where policies conflict with academic work is when state or federal policies conflict with faculty interests. One example of this is in California where the California State Board of Education established curriculum standards that have a *"back to the basics"* mentality, which is incompatible with the national science, and mathematics education communities who are more focused on understanding the nature of science and mathematics in a holistic way. The back to basics mentality contradicts reforms efforts that emphasize inquiry. One dean from a University in California saw the conflict between political and academic interests as a challenge to the science education community since faculty efforts are normally overlooked by the legislature.

In keeping with the previous dean's concerns, a faculty member from a University in a southwestern state also sees a problem with too much politics in education as a challenge to the field, and she went on to say; *"Everyone thinks they know how to teach and how students should learn. There is a lack of respect for expertise in the field."* The deans were highlighting how policies are getting in the way of reforms. Such policies have led to a tension for example the No Child Left behind Policy that emphasizes Math and Reading, leading to marginalization of subjects such as Science and Social studies. Responding to standards and educational policies that affect teaching and learning of science therefore becomes a constraint to the science educators. Such concerns from the deans and faculty could be an indication of why the science education community is failing to achieve the national goal of achieving science literacy for all despite the educators' advocacy for reform-based teaching. Whereas academics see themselves as committed to facilitating achievement of the national goal, they see external policies interfering with their work and hindering their efforts.

The deans and science education faculty also viewed issue of standards and testing as highly contentious. A faculty member from a university on the east coast specifically pointed out that policies such as "No Child left behind" emphasize testing at the expense of teaching for understanding, something that faculty have invested in for a long time. This policy impacts student graduation and teacher evaluation, which poses a challenge to educators as teachers are forced to teach to the test as opposed to teaching for understanding. Again, the most recent policies are seen as hindrances to any progress that academics have achieved.

Related to these issues, a faculty member from a Midwestern university mentioned that government prescription of how research should be conducted, or *"the battle of research methods"*, as he called it, restricts the type of research that can produce useful information in education. The federal government is investing more money into experimental methodology, which may not necessarily yield the best results needed to improve science literacy for all. This poses a challenge for educators because they have to choose between what one really wants to do and what gets funded. This is making it hard to secure funding for research as well as getting research findings implemented in the schools. Faculty from different institutions shared similar concerns that they may have good ideas of how to improve science teaching and learning but these may never be investigated due to restrictions on funding.

A faculty member from a southern university also felt that, even when faculty get to do research, the biggest challenge is that '*the pipeline gets stuck*', meaning that it is hard to have research ideas implemented in schools. Resistance to change at different levels ranging from stakeholders to academics and practitioners was mentioned as a constraint by a faculty member from a midwestern university. These constraints have worked against some university faculty's efforts to bring reforms to the schools. Many ideas have come from research on the best practices in education but they have not been implemented in schools.

Teacher Quality, Diversity and Equity in Science Education

Several deans and faculty members identified getting scientifically literate teachers in the schools as a constraint to achieving the goal of science literacy for all. There was a general feeling among the interviewees that the science education community is failing to recruit people with a deep understanding of science. One reason why it is hard to recruit people with strong content knowledge is because teachers are not as well paid compared to other science related professions. A faculty member from a midwestern university stated: *"Teachers are not well paid and yet they are the ones who are training scientists. As a result, there is a supply gap of science educators at all levels from K-12 to university."*

Similarly graduate schools are failing to recruit science education doctoral students, and this is evidenced by a shortage of science educators graduating from doctoral programs. According to a dean from a Southern University, there are other more lucrative opportunities for science graduates than teaching. The challenge being faced by schools of education is how to recruit people into graduate school where the allowances are low. A dean from a Western University gave an example of how their state has not been friendly to the salary of faculty nor is it friendly to graduate education. Candidates for graduate school have to give up their secure and well-paying jobs to join graduate school, a risk that many are not willing to take. This challenge has led to the problem of a shortage of science teachers especially in the urban areas where the need for science literacy is high and where lack of equity continuous to widen the achievement gap.

Several faculty mentioned content preparation of science teachers especially at the elementary level as a major concern. Lanier and Little (1986) have outlined reasons why the field has continued to have this problem and one of the reasons is that the field of education is looked down on by bench scientists. Students who are good at science are therefore encouraged to go into science professional fields like medicine and engineering that have attractive remuneration. Lack of collaboration between natural sciences and schools of education also contributes to the problem of not producing enough teachers who have deep understanding of science content. This lack of collaboration leads to *"weak programs, or programs that are not respected on campus and/or not well situated to influence reforms in schools" (Dean from a Southern University).* Similarly *"Bench scientists are seen as more superior to the educators which leads to science education being viewed as an inferior subject" (Dean from a Midwestern University).*

A number of recent graduates who were interviewed for this study shared similar sentiments about the way faculty in the natural sciences perceive science education faculty. The recent graduates confirmed that good science students are discouraged from becoming teachers. According to one dean from a Midwestern University, there is need to integrate education and the natural sciences courses in order to address the challenge of scientific literacy among teachers. Agreeing with this idea, a dean from a North-Western University said, *There is need to build bridges between science education and the colleges of science."*

Teachers' pedagogical content knowledge influences the way students learn science (Shulman, 1987). University science teaching promotes memorization, which has contributed to production of teachers who are under-prepared to teach science, and this is a big challenge for science educators. The other challenge constraining science teachers' practice is a lack of understanding of the nature of science. According to a faculty member from a Southern University, *"Teachers do not possess a clear understanding of the nature of science because it is not dealt with in detail."* This shows that there is the challenge of figuring out how to improve the quality of teacher preparation. For teachers who are already in schools, there is need for professional development in this area. According to a faculty member from a Midwestern University this brings up another challenge of funding: *"Huge quantities of money are being spent on curriculum development and professional development of teachers who are mediocre to poor and educators must figure out how to do these things better."* Several colleges of education cannot fund professional development initiatives; hence this has negatively impacted faculty efforts to address the reform goals of helping teachers to achieve 'science literacy for all'.

Professors of science education therefore feel that no matter how hard they are working to produce good teachers, it is hard for them to do this because of other external factors such as attraction of good science students to more prestigious and better paying professions. This tension that exists in teacher preparation is also reflected in doctoral preparation where some good teachers of science prefer to get PhDs in the sciences. Teachers who have deeper understanding of science normally also end up teaching in suburban schools that are better equipped, leaving urban schools with less qualified teachers. Urban schools fail to attract good teachers and yet they are the ones that need them most in order to close the achievement gap. Lack of equity in the schools has led to lack of good teacher and makes it harder to close the achievement gap. The most recent No Child Left Behind reform tries to address this issue by requiring that all teachers be highly qualified, but from what has been discussed earlier, it is hard to achieve this if the teachers do not have deep understanding of science. As long as there is no collaboration between the sciences and education departments, preparing teachers with a deep understanding of science content will remain a challenge.

Science education faculty mentioned under-representation of minorities in science education as a big issue that is posing a challenge to the science education community. This issue has been a cause for concern among deans and faculty at different institutions. The dean at a Southeastern University saw this as a crisis in the making as shown in the quotation below:

> According to the current demographic shift, by 2050 there is going to be 50% minority and 50% white and this will lead to a crisis in science and math personnel. One reason why schools are failing to produce more minority science educators is because schools in urban areas do not have good facilities and they do not have the best teachers.

Inequity in the K-12 education system has resulted in a lack of good teachers and lack of resources in urban schools. This has resulted in fewer minority graduates who specialize in science, and this has led to fewer role models for minority students. This leads to a situation where fewer minority students become interested in science hence a vicious cycle results where fewer minority students are attracted to science subjects (Russel & Atwater, 2005; Lewis & Collins, 2001). This makes it difficult to achieve scientific literacy for all students. If some students continue to be deprived of resources that enable them to learn the same quality of science as their counterparts in richer schools, the goal of 'science for all' will never be achieved.

The challenges confronting the field of science education as highlighted above are multi-faceted and have been seen by science education faculty as constraints to achieving the national goal of 'science literacy for all'. In order to address these challenges, there is need to include policymakers, academicians, education administrators, educators, parents as well as the general community. The deans and science education faculty mentioned that educators alone couldn't address these challenges because; socioeconomic and cultural factors also work to create inequity resulting in achievement gap among students.

Analysis of findings from this study shows that doctoral programs are failing to respond decisively to issues highlighted in the reforms. According to Gallagher and Gwekwerere (2003) the field of science education risks becoming obsolete by failing to respond decisively to such issues as diversity and technology. Minority under-representation in science is also of major concern, considering the diverse student body in the US schools. The fact that there are fewer minority role models in science education could be a contributory factor. One other reason for minority under representation in sciences is lack of equity in the education system. Urban schools where most minority students live do not have resources and the poor school districts cannot attract good science teachers, hence these populations end up being marginalized.

Although doctoral programs are making changes in order to address these challenges in the field of science education, the deans at the different institutions that were studied were more concerned about addressing policy issues than issues that are related to equity and diversity. Issues that are critical to the field of science education were not on the deans' radar screens. Since this study was a survey of ten doctoral programs, it did not go into depth looking at how each of the doctoral programs are interpreting the current reforms in science and how they are addressing the reforms in the coursework and research. Therefore, this current study is a follow up investigation of three of those doctoral programs. I take an in-depth study of the three programs and the views of faculty, doctoral students and recent graduates. An interpretive theoretical approach was used to infer how the three doctoral programs are interpreting the current reforms from analysis of the course documents and interview data.

Why Study Doctoral Programs

Doctoral programs play a significant role in preparing future leaders. Science Education doctoral programs play an even more significant role preparing leaders in a field that is critical to maintaining superiority in the face of global competition. Doctoral graduates therefore find themselves confronted with the reform issues in several areas of their jobs, for example: a) preparing teachers for reform-based teaching, b) research on reform-based best practices; c) teacher professional development related to reform-based teaching; and d) research related to curriculum development. By choosing to teach other students following graduation, doctoral graduates can make a contribution to future generations by participating in this form of knowledge transfer. Doctoral graduates also go on to become researchers, curriculum developers and K-12 science education administration and teaching. All these areas are directly or indirectly related to K-12 science teaching. Doctoral programs in science education therefore play a significant role in knowledge creation as well as addressing the challenges facing K-12 science education, especially those related to the current reforms.

The scarcity of research on the work of teacher educators at universities gives the impression that their work does not warrant studying like that of schoolteachers. However, it is Russell and Korthagen's (1995) view that teacher educators at universities have lived too long in a world that pretends they are not teachers when contrasting themselves with those whom the term teacher most readily suggests. Education faculty are teachers and are often expected to be "super-teachers", because they have risen into the academic world to a School or Faculty of Education (Russell & Korthagen, 1995). In this work, I therefore view science educators as teachers whose practice needs to be understood through research, just like the practice of schoolteachers is studied and understood. According to Project 2061 (2006) science educators need to be knowledgeable about science content and how to teach it well before they can help teachers to practice reform-based teaching:

> Support continues to grow for the science literacy goals in Project 2061's *Science for all Americans* and *Benchmarks for Science Literacy* and the National Research Council's *National Science Education Standards*. Yet much remains to be done before teachers and students across the country can reach those goals. For example, educators must themselves be literate in science, mathematics, technology, and their interconnections. They must know how to teach in ways that will help students understand and retain the most important concepts. And they must be able to select curriculum materials that meet benchmarks and standards.
>
> *Project 2061 website*

This clearly shows that there is need for research that focuses on understanding and improving the work of teacher educators and preparation of doctorates.

Although literature on how teacher educators are addressing issues related to K-12 education is limited, there is evidence that teacher educators have identified three main constrains to preparing teachers and these are well known by those in the profession (Russell and Korthagen, 1995). First, teacher educators face an uphill battle due to tensions that exist between 'theory' and 'practice'. Second, teacher educators also find themselves having too much work to cover over a short period of time that preservice teachers have to complete as coursework. Third, a tension exists between balancing teaching and research especially at large research institutions where tenure and promotions are based more on research than on teaching. Because of these constraints, teacher educators have always struggled to find time to demonstrate the "super skills" that they are expected to exhibit. Although these constraints are known and documented (Gallagher et. al., 2003), their impact on the quality of teachers is not known.

Recent studies have shown that science education doctoral programs do not seem to be responding decisively to the challenges confronting K-12 science education (Gallagher & Gwekwerere, 2003; Jablon, 2003). However, there is no data to show exactly what doctoral programs are doing or not doing to respond to the challenges confronting the field. One well-known factor in academia is that research is valued more than teaching and that the PhD seems to be resistant to change (Russell & Korthagen, 1995). Other factors influencing response to the challenges in the field are related to faculty values, beliefs, knowledge, skills, and inertia, which normally drive the doctoral programs. Interpretation of the reform can also influence how science educators respond to the reforms. Limited resources could also determine level of response to challenges in the field by faculty at different places.

This study will partially fill a gap in literature on preparation of science education doctorates. I also see this study as providing a missing link in the studies that inform us about how excellence in science teaching and learning can be achieved. The challenges confronting K-12 science teaching and learning are complex, and as a result, there is need to conduct studies that provide a holistic picture of how educators are being prepared at all levels. A holistic understanding of the preparation of science educators is a necessary step to addressing the national reform concepts more appropriately. Most importantly, this study served as a reflection for science education faculty who were able to articulate what their programs are doing and are failing to do in response to the current reforms and how they plan to better prepare their graduates.

My interest in studying science education doctoral programs emanated from my experience working on the Leadership Development Project (2003). I had the opportunity of interviewing new science education professors about their experiences during doctoral studies and how they were prepared for their careers. Findings from the study indicated that implementation of current reforms in science education was posing a major challenge to the science education community. Since my goal is to teach graduate courses in science education, I became curious to know what science educators are doing to address the challenges posed by the current reforms and how they are interpreting the goals of the reforms and enacting them as they prepare future leaders through doctoral studies.

This document has 8 chapters. In chapter 2, I provided an analysis of literature that specifically relates to science education reforms and studies of doctoral programs. In the analysis I highlighted the goals of science literacy for all and the emphasis that is placed on research efforts related to the reforms by different authors. I also provided a theoretical framework that is based on literature that focuses on the reforms. In chapter 3, I presented the methodology, study design and methods used in this study. I described the cases in this study and how I am going to use an interpretive approach to analyzing data from each of the cases. In chapters 4, 5, and 6 I provided a description and within case analysis of findings from each of the three institutions. Within each case I compared the views of faculty, doctoral students and recent graduates. In chapter 7, I presented a cross-case analysis of the three cases and I showed the patterns that exist across the three cases. In chapter 8, I provided what I found to be implications for practice, policy, and research. I also presented my plans for future research.

CHAPTER 2

LITERATURE REVIEW

> This Nation has established as a goal that all students should achieve scientific literacy. The National science education standards are designed to enable the nation to achieve that goal. *They spell out a vision of science education that will make scientific literacy for all a reality in the 21st century*
>
> *(National Research Council, 1996 p. ix)*

> Project 2061's benchmarks are statements of what *all students should know or be able to do in science*, mathematics, and technology by the end of grades 2, 5, 8, and 12. *(AAAS, Benchmarks online, 1993)*

> The set of recommendations constitute *a core of learning in science, mathematics and technology for all young people, regardless of their social circumstances, and career aspirations*. In particular, the recommendations pertain to those who in the past have largely been bypassed in science and mathematics education: ethnic and language minorities and girls.
>
> *(Science for All Americans, Rutherford & Ahlgren, 1990)*

These three quotations were taken from the three current science education reform documents to highlight the goals of the reforms. One common feature across the three quotations is the reference to *science literacy* and *all students*. In the case of the National Science Education Standards (NRC, 1996) the goal is that "*All students should achieve scientific literacy by the 21st century.*" Project 2061 (AAAS, 1993) provides benchmarks of what "*All students should know and be able to do*", and Science for All Americans (Rutherford and Ahlgren, 1990) provided recommendations for "*a core of learning for all young people regardless of their social circumstances, and career aspirations*". These reform goals appear to be simple and straightforward because we know that all students refers to all students enrolled in schools. Because schooling is compulsory for all school age young people in the U. S., there is no question about whom the goals refer to.

Although achieving scientific literacy for all students is the major goal of the current reform efforts, there is limited consensus on the meaning of scientific literacy and how it can be achieved or who 'all students' refers to (Malcolm, 2005). According to Galosy (2005), science for all remains relatively unexplored territory and the problem with slogans such as science for all is that they can be taken to mean many different things (Brickhouse, 2005). Since the reform documents do not define the reform goal of science for all in detail, some have viewed science literacy for all as referring to teaching science for understanding to 'everybody' through improving pedagogy and a rigorous curriculum as has been outlined in the reform documents. This way of interpreting 'science for all' has been seen by other science educators as 'one size fits all' (Lemke 2001, Lynch 2001). According to Lynch (2001), this is unlikely to address adequately the diversity of identities among school age children.

Since the reform goals entail both achieving scientific literacy by all children and achieving equity for all children, I will discuss how *scientific literacy* has been defined first, and then I will discuss how science for *all children* has been defined. I have divided the literature into three different ways that science literacy for all and science for all have been defined in the existing literature.

How Science Literacy for all has Been Interpreted in Literature

Achieving Science Literacy for all through Authentic Science Experiences

In the 1950s, scientific literacy was a rallying symbol with no definition and by mid 1963 the term had numerous interpretations (Roberts, 1983). The American Association for the Advancement in Science (1998) defined a scientifically literate person as one who:

a) Is familiar with the natural world
b) Understands some of the key concepts and principles of science

c) Has a capacity for scientific ways of thinking

d) Is aware of some of the important ways in which mathematics, technology, and science depend on one another

e) Knows that science, mathematics, and technology are human enterprises, and what that implies about their strengths and weaknesses

f) Is able to use scientific knowledge and ways of thinking for personal and social purposes

The National Science Education Standard's definition of a scientifically literate person is in agreement with this definition. Similarly, Mitman, Mergendoller, Marchman and Packer (1987) noted that no single definition of scientific literacy prevails, but the many existing definitions share the following several features: a) all the definitions are motivated by the concern that schools prepare all students to function well in an increasingly technologically oriented society, one where they also face important decisions as citizens about use of scientific research and its application; b) all definitions reflect the notion that students should become acquainted with a fundamental set of science facts and concepts for example, this is explicit in the National Science Education Standards (1996) and the Michigan Curriculum Frameworks, 1996; Benchmarks for Scientific Literacy, 1993); c) understanding the importance and meaningfulness of science in connection with other broader contexts of human endeavor reflected by terms such as nature of science, science and society. This is also clearly shown in the benchmarks and the national standards.

Since the 1980s, science educators have advocated for teaching science for understanding and teaching science to all students. By focusing on all students the aim was to move away from the idea that science should only be taught to students who were going to become scientists. Efforts have been made to teach science for understanding and defining what it means to understand science. (Wiggins and McTighe, 1998; Wiske, 1998; White & Gunstone, 1992). Understanding science is different from rote memorization where the focus is on remembering facts that are soon forgotten after a test. In order to prepare all students to become scientifically literate, science educators have researched on and suggested models of teaching science to achieve a deeper understanding of the content. Earlier, conceptual change models were brought forward as a way of helping to address the naïve conceptions or misconceptions that students bring to learning science (Strike & Posner, 1982).

The reforms were built on the ideas of teaching science for understanding and teaching science to all students. Following introduction of the reforms, models of teaching for understanding focused more on engaging students in doing science mostly through inquiry (NRC, 2000; Haury, 2001; and Llewellyn, 2002). The National Science Education Standards (1998) emphasized the importance of inquiry in science teaching as a way of achieving science literacy for all. Martin, Sexton, & Gerlovich, (1998) view inquiry as the cornerstone of the standards for teaching. The National Science Education Standards outline specific teaching standards that are necessary for teachers to produce scientifically literate students. Among the teaching standards (NRC, 2006 p 32), there are several points that encourage teachers to:

- Focus and support inquiries while interacting with students
- Orchestrate discourse among students about scientific ideas
- Challenge students to accept and share responsibility for their own learning

- Recognize and respond to student diversity and encourage all students to participate fully in science learning
- Encourage and model the skills of scientific inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterizes science

Following up on the standards definitions of scientific inquiry, several science educators have come up with instructional models that show how inquiry can be conducted in the classroom. Examples are the 4 Es model (Martin, Sexton, & Gerlovich, (1998), and the 5 Es model (Bybee, 1997) that show the process of doing inquiry step by step. Other models of teaching science inquiry have since been suggested. For example Anderson (personal communication) proposed a model that shows the connections between students' experiences, patterns in their experiences and explanation of the experiences. All these efforts are targeted at producing scientifically literate students. The concept of science inquiry is based on the constructivist theory of learning that view learners as capable of constructing their own understanding and connecting their ideas into a fabric of concepts, attitudes and skills that carries meaning to them personally and academically (Martin, Sexton, & Gerlovich, 1998).

Open-ended inquiry in science has been defined as 'authentic science' (Roth, 1995); or 'real science' (Woolnough, 2000). Authentic science has been seen as a way to engage all students in doing science regardless of their ability. Woolnough, (2000) showed how students' research projects are effective in developing core skills in students, especially problem solving, communication and interpersonal skills that improve students' attitudes towards science. Using his own experience as a graduate student, Roth (1995) showed how exciting it was to see patterns emerging from the data plotted as he read measurements from many hours of experimenting. He therefore viewed going beyond the textbook and doing authentic science the way it was practiced by scientists as a way to motivate all students to learn and understand science. Researchers who are focusing on authentic science and using technology in science teaching are realizing the complexity of learning and instruction (Clarebout & Elen, 2006). Over the past century, researchers have tried to reduce complexity of instructional processes by breaking them down into simpler pieces, which resulted in simplistic solutions for complex instructional processes (Clarebout & Elen, (2006).

Scientific models are essential tools for productive scientific reasoning in children and adults. Science instruction focused around scientific modeling can help learners develop deep understanding of subject matter, powerful scientific skills, and a strong understanding of the nature of science (Carey & Smith, 1993; Feurzeig & Roberts, 1999; Lehrer & Schauble, 2000; NRC, 2000). Scientists and science educators agree that such skills and understanding are essential for all citizens. While inquiry has again become an important focus in the science classroom (NRC, 2000), modeling is not routinely practiced in schools. Perhaps this is due to the nature of the K-12 curriculum that emphasizes complex forms of reasoning only for older and more capable students (Collins, Brown, and Newman, 1989; Schauble, Glaser, Duschl, Schulze, & John, 1995; Bruer, 1993). Schwarz & Gwekwerere, (2006), came up with an instructional model that promotes the use of model-centered scientific inquiry among K-8 preservice teachers.

The literature discussed above shows an effort buy science educators to develop pedagogical methods that focus on ensuring that every child learned science with understanding. Science inquiry, authentic science experiences and model-based reasoning are ways that motivate all students to learn and understand science. These methods are used in an effort to achieve equity in science teaching (NRC, 1986) by engaging all students in doing science, not just those students who are going to become scientists. Students in any school can engage in inquiry, model-based reasoning and different forms of authentic science, provided they have the resources.

Achieving Science Literacy for all Through Equity in Science Teaching

The diverse nature of students in school warrants the efforts being taken to achieve scientific literacy for all to take a more global view that takes the needs of all students into consideration. Researchers who are concerned about this lack of attention on all students in the efforts to achieve scientific literacy have taken a critical approach to defining what science for all means and suggesting how science literacy for all students can be achieved. Using words from Fenshem; Brickhouse (2005) defined science for all as a call to addressing the needs of all children, not just the ones who will become scientists:

> Fenshem has long advocated science for all. His use of this slogan has generally been intended to claim that science classes must address the needs of all students, not just the ones who take up identities as professional scientists...science classes have been too strongly influenced by the needs of few students who will go on to become professionals, qualified scientists. The needs of the majority are largely ignored *(p93)*

This definition of science for all shows that mandating a curriculum or using pedagogy that does not address the needs of all students does not lead to achieving science literacy for all students. Racial/ethnic, cultural, linguistic and socioeconomic variability are factors that have been found to affect science achievement among K-12 students who have traditionally been underserved by the education system (Barton, 2003; Lee, 2005). According to Barton (2003), achievement differences among subgroups of the population have deep roots. These roots are embedded in the social fabric of the nation; "they arrive early and stay late, beginning before the cradle, continuing through to graduation, if that outcome happens (Barton, 2003, p1).

Malcolm, (2003) for example has shown how science for all is contrary to achieving science literacy for some students. He goes on to say that, offering all students narrowly defined programs focused on preparation and selection for tertiary science study is not science for all. According to Malcolm, exclusion occurs through university-required pre-requisites, tracking, stereotyping and counseling in high schools. He therefore defines science for all as a plea to provide access to science for all students. By access he refers both to physical access and access to pedagogy that enables students from different backgrounds to learn science as shown in the quotation below:

- Physical access to teachers, facilities, and courses is a basic requirement. Exclusion occurs through university required pre-requisites, tracking and counseling in high school, stereotyping, curriculum and assessment
- "Science for all" is contrary to "Science for some". Offering all students narrowly defined programs focused on preparation and selection for tertiary science study is not "Science for All"
- Access is partly about pedagogy-enabling different students to learn efficiently taking into account their backgrounds, contexts, learning styles, and aspirations.
- Access is also about outcome. To what should students have access? Access stretches beyond effective learning to meaningful learning, and issues of purpose and content: Which science? Whose science? Why?

Similarly Brickhouse (1994) took a critical look at who has access to science learning and she defined outsiders to science as Blacks, Hispanics, American Indians and girls. In her paper entitled 'Bringing in the Outsider' she showed the need to make science accessible to these groups of students by valuing the knowledge they bring to science learning, hence helping them to identify with science. Although Lee, (1998) acknowledged the value of standards and benchmarks in science as an important first step in articulating what every students should know and be able to do to become scientifically literate and to achieve science literacy for all, she critically analyzed how the standards are not addressing the needs of linguistic minority students. According to Lee (1998), efforts should be focused on how to make reform-based assessments and how to ensure access and achievement for all students. She saw the alignments of assessment with the content standards as well as the attainment of standards by all students as key challenges to standards-based reform and systemic reforms in large education systems.

Several educators share the critical perspective that it is hard to achieve both excellence and equity without making resources available to all students. According to Kahle (1977) and Porter (1995), without resources and opportunities, setting high academic standards may pose additional challenges and learning difficulties to disadvantaged students. Similar efforts to define what constitutes the influence of standards on student achievement showed that it hard to separate the influence of standards from investment in schools (Anderson, 2003). In agreement, Biddle (1997) argued that:

> If you want to know what influences student achievement, don't follow the standards follow the money. Improving achievement is about making resources available to children and to their teachers, not about setting standards. *(p 9)*

Biddle (1997) argued that the influence of standards is insignificant in comparison with variables such as school funding and child poverty. Using evidence from the Third International Mathematics and Science Study, Biddle showed that the United States has greater disparities in school funding and higher levels of child poverty than any other developed countries participating in the study. Anderson (2003) agreed with Biddle's basic premise that factors such as school funding and child poverty do affect student learning and that they will continue to do so whether we have standards or not. Anderson (2003) argued that it is hard to separate the influence of standards from the influence of other factors in a complex system where student learning is affected by many factors". Anderson (2003) goes on to wonder whether the focus on standards is a distraction from the issues that really matter.

Taking a more critical look at the implementation of the reforms, Thomson, Spillane and Cohen, (1994) viewed the standards as demanding and complex and posing challenges for teachers. According to these authors, the current practice of many teachers does not match what is called for in the national standards: "To teach in a manner consistent with the new vision, a teacher would not only have to be extraordinarily knowledgeable, but would also need to have a certain sort of motivation or will." (NRC, 1998, p.27). Hence the teaching and learning envisioned in the national standards would require new resources and long-term support in the form of professional development, new curricula, and new assessment systems. According to Anderson (2003), there is need to ask what will be the payoff for investing in the standards and what effect this investment will have on student learning.

Along the discussion of achieving science literacy for all, some scholars believe that schools have the capacity to close the achievement gap (Thernstron & Thernstron (2003), yet others strongly believe that schools alone cannot close this achievement gap because the gap is widened more by socio-cultural factors (Rothstein, 2004). Rothstein (2004) argues that Schools lack the capacity to reduce the achievement gap and that a range of social policies has more profound effects but these policies cannot gain political support. He believes that achievement gaps between black and white, affluent and poor are deeply rooted in the social realities of race and class and that no evidence suggests that improvements in quality of schooling alone can do much to significantly reduce the achievement gap.

On the other hand Thernstron & Thernstron (2003) argue that racial inequality should be addressed by improving academic performance of black children. They believe that good schools can help close the achievement gap through high expectations, discipline, order, good teaching, and core academic skills. They go on to say that addressing the race gap requires change in behavior of black parents as well as educational policy and practice. They see the social gap as not being caused by socio-economic or social class but by culture, hence according to these authors, given purpose, discipline and support, disadvantaged minority children will commit to their schools.

It is clear from the different views of these authors that reforming science to achieve scientific literacy for all is complex and the issues are multi-faceted. Besides the need to improve pedagogy and make resources and finances available to all schools, there is need to address socio-economic, cultural and racial issues that influence student learning.

Achieving Science Literacy for all Through Teaching Science for Social Justice

Recently, some science educators realized that science literacy for all is a social justice issue. In order to address these issues, some science educators are taking a social justice approach to science teaching. Literature shows that poor children and minority children, mostly African American, and Hispanic who live in urban areas have not received good science education compared to fellow students, mostly white who live in suburban areas (Barton, 2003). The education system has not provided a 'just' science education to all students (Connell, 2003). Achieving science literacy for all students means providing 'just' science education to all students.

However, according to Griffiths (2003), social justice and education are both complex and have many interconnections. No one teacher can claim to know what is going on for mixed-race children, refugees, African Americans and immigrants. Griffiths (2003) went on to advise teachers and other school administrators that they need not worry that they cannot know everything about the learners. He came up with three strategies that can be used to understand the learners in order to serve them better; a) to listen and talk; and then, b) to consult and cooperate; and c) to take action. She came up with a model of action for social justice in education (Figure 2.1) that can be used as a lens for thinking about how social justice can be enacted in education.

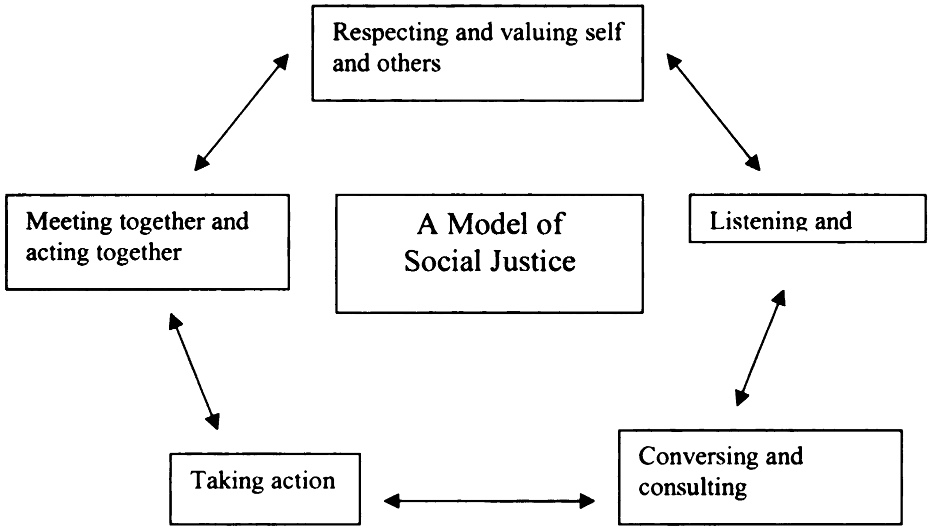

Figure 2. 1: Model of action for social justice in education (Griffiths, 2003)

According to Connell (2003), teaching cannot be separated from social justice because teaching is a moral tool that involves questions about criteria for action, application of resources and responsibility and consequences for action. In agreement with this fact, Griffiths (2003) emphasized the fact that social justice matters for everyone connected with the schools mainly because schools are social institutions and a public asset and it is important to question who gets its benefits (Connell, 1993). Many people view education and social justice as separate entities and this is clearly shown by the separate government departments that oversee these issues (Connell, 1993). By making these departments separate, difficult issues of social justice in education are avoided rather than confronted. This claim has been confirmed by the reform documents' silence on issues of social justice and the emphasis they place on the content that students need to know and be able to do. According to Oakes (2003), learning is a social and cultural activity, and social justice plays a role in multicultural education.

Minorities are not well represented in science and this is mainly because not many minorities specialize in the sciences (Gallagher et. al., 2003). This is mainly because of inequities that exist in the schools as well as failure by minorities to identify with science (Brickhouse, 1994). A science curriculum that only addresses the needs and interests of one group in society is not a just curriculum and according to Brickhouse (1994), science traditionally alienates racial, cultural and linguistic minorities as well as girls. Science knowledge is culturally constructed (Lemke, 2001therefore those who belong to the culture of power (Delpitt, 1998) identify better with science compared to minority students and girls. Curricular justice can only be achieved when the interests of the least advantaged are taken into consideration (Connell, 2003; Brickhouse, 1994).

In order to achieve the goal of 'excellence and equity' in science education, there is need to "think through science experiences from the standpoint of the poor and minorities not the rich, we think through gender from the standpoint of women and we think through race from the standpoint of indigenous and minority groups" (Connell, 2003). Barton (2003) showed how specialists in science education believe that the knowledge students bring is less superior to that of teachers. Using the example of "the picnic table", she showed how the researchers thought the picnic table kits sold at Home Depot would make more stable tables than the ones the students were to make. To their surprise they found that the Home Depot picnic table kits had been discontinued because the tables were falling apart. Offering students the chance to construct their own picnic tables showed the researchers that the students were capable designers and who exhibited science knowledge and skills in the process.

According to Barton, (2003) there is need to move beyond the deficit model that views urban students as having no prior science knowledge or ideas if we are to achieve science literacy for all. Poor urban students bring a wealth of knowledge to learning science. When making a science curriculum that enacts social justice, educators need to ask themselves "what science means to the disadvantaged students in society" and "what science is relevant to students who are less advantaged" (Connell, 2003). A curriculum for social justice therefore entails that the teacher develops an understanding of the urban youth and know what science knowledge they are bringing to the classroom (Burton, 2003). Only by doing so can science literacy for all students be achieved for all students.

Literature shows that science literacy for all should be viewed from a social justice perspective. This is mainly because not all students have had equal access to science education because of inequitable funding in schools. Brickhouse argued that minority students and those from cultural backgrounds that are different from the culture of power have found it difficult to identify with science. Griffiths and Connell argue that education and social justice should not be separated and that in order to achieve curricular justice there is need to think from the viewpoint of the least advantaged in society. The national goal of achieving science literacy for all is therefore a social justice issue.

Studies of Doctoral Programs

> It is imperative to continue evaluating the significance of the Ph.D. Its complex nature defies simple explanation, and its continued value as capstone to American higher education only makes its presence more enigmatic (Buchanan & Herubel, 1995)

Traditionally, research on doctoral programs has focused on ranking them in terms of reputation of the program and its faculty (Hughes, 1925). In 1960, Allan Carter used qualitative judgments such as quality of graduate faculty, effectiveness of doctoral program and the expected change in the next 5-10 years to rank doctoral programs. His study is seen as the pioneer to the modern approaches to assessing doctoral programs. In 1990, the National Research Council conducted a more comprehensive survey that included 41 specific fields in 274 institutions and 3, 634 doctoral programs. The program rankings in this study were based on the names of "star" faculty without considering program quality (Osteriker & Kuh, 2003).

Criticisms have also been leveled against the US News and World Report ratings. For example the 1992 US News and World Report rankings were criticized for their narrow focus that led to bias where bigger programs got better ratings just because they are large, and for perpetuating a mythology about "excellence" that is misleading because they measure the number of stars" on the graduate faculty (Greenberg, Astin, Webster, & Massey, 1992). Jackman and Silverson, (1996) also viewed the 1990 NRC rankings as controversial since some interpret them as an indicator of relative program quality while others view them as a gauge of age and size of a program and yet still others view them simply as a popularity barometer.

These assessments of doctoral programs provided students and the society with information on which doctoral programs were the best, but they only focused on reputation of programs and faculty, and they did not provide information on the quality and nature of the academic and professional courses offered. Neither did these studies consider the outcomes of the doctoral programs. Programs within well-known large universities were rated higher than equivalent programs in lesser-known smaller institutions (Osteriker & Kuh, 2003). These authors went on to show how these ratings did not recognize the excellence or the role each program played within its community and how they overlooked some small programs that may have focused their resources on achieving excellence. These studies also rated scholarly achievement as if it were separate from educational effectiveness, for example by placing emphasis on research productivity and scholarly achievement of faculty without consideration of the program outcomes (Osteriker &Kuh, 2003). These criticisms point to the need for studies of doctoral programs that focus on the nature and quality of doctoral programs, outcomes of doctoral preparation and the role the programs play in their communities.

There have been limited studies of science education doctoral programs. The pioneering research of science education doctoral programs was conducted to determine the extent to which doctoral programs reflected adoption of the guidelines for doctoral studies that were proposed by the Association for Education of Teachers of Science in 1966 and 1974 (Butts, 1977). Studies that followed consisted of surveys of graduate centers (Yager, 1980), and evaluation of educators' perceptions of the graduate preparation programs of science teachers (Butts and Yager (1980). This led to documentation of the following recommendations that science education doctoral programs needed to improve on: a) in-service training of teachers as a key to improving science teaching; b) creation of new curricula in order for science to focus on scientific and technological needs of society; and c) collaboration between science educators and teachers in order to address the problems in science education (Kahle & Yager, 1981).

Earlier studies of science education doctoral programs also showed the trend in enrollments and doctoral production from the 1960s to the 1980s. Yager and Zehr (1981) found that the number of institutions with major science education programs and graduates peaked in 1975 and declined in 1980, reflecting the disappearance of programs at Stanford and Harvard University. They also found that doctoral production increased by a factor of 5 from 1960 to 1970, and decreased between 1970 and 1980, and that staffing declined but program features such as number of semester hours required have remained fairly constant. Other major trends in their findings were that the science education discipline grew swiftly from 1960 to1970 and slowly from 1970 to 1975 in terms of number of institutions, faculty and graduates. This was mainly due to increase in financial support during 1960 to 1970 and a major decline especially with respect to externally funded projects and internal funding for graduate students after 1970. They also found out that little attention was paid to goals of science education; with few attempts at defining science education in any other way other than the science that is taught in schools and the preparation of teachers for such efforts.

Later studies focused on trends in the evolution of doctoral programs. Yager and Butts (1982) described the doctoral programs and contrasted them with those from the past in order to identify relevant directions for future developments. Their comparison reflected several trends: a) a decline in the number of students enrolled in doctoral programs, b) constant faculty numbers, c) flexibility in specific course requirements; courses in general curriculum and instruction remained as required features; d) research design and statistics course requirements increased and research procedures became less traditional and more flexible in nature; e) emphasis in planning projects and writing grant proposals for external funding; f) changes in employment, g) fewer graduates becoming teachers of science, and more graduates returning to K-12 as department chairs, consultants, directors of curriculum, evaluation and leadership roles including general admin. Opportunity for employment as a college or university science educator had declined, however it remained a major area of employment. More graduates were finding employment in industry, health fields, public centers and government.

Yager, Bybee, Gallagher and Renner (1982) reported on the Crises in the Discipline of Science Education, using data from five surveys conducted between 1978 and 1979 to determine perceptions and problems facing science education among science educators representing 28 institutions in the US. Results from this study were in keeping with Yager and Butts (1982) and some of these findings are consistent with the problems faced by the science education community today. There was general lack of agreement concerning goals and objectives that are relevant to contemporary priorities in science, society, and education; lack of vision and leadership in schools and universities; lack of professional identity and legitimacy; and inappropriate testing which resulted in slavish attention to factual recall. Other problems cited included organizational problems both in schools and universities; teacher related problems; the nature of science and its relationship to society; decline in number of students electing for upper level science classes; lack of dialogue between university scientists and science educators and practitioners in the schools; public and parental apathy toward science; impact of government control on schools; and lack of financial support for graduate students and new faculty in science education.

These earlier studies provide a unique opportunity to see the trends in the evolution of science education doctoral programs. Most recently, Jablon (2002) Gallagher et. al., 2003) conducted studies of science education doctoral programs. These studies have provided a better insight into doctoral program structure, how graduates are prepared, and the challenges that programs are faced with as they prepare future leaders. For example, Jablon (2002) focused on the outcomes of the doctoral programs. He conducted a survey eliciting data from 64 science education doctoral programs and interviewed the deans and heads of schools and departments of education about the need for and qualities expected of science education doctoral graduates. Findings from his study showed a need for enrichment in areas of urban science teaching, nature of science, and effective school change strategies in science education. These issues are related to the current reforms in science education and the findings show that doctoral programs were failing to address issues that are pertinent to achieving the reform goal of 'science literacy for all'.

Similarly an NSF funded Leadership development study that was described in the introduction (Gallagher & Gwekwerere, 2003,) showed that science education doctoral programs were failing to decisively respond to issues of national concern such as diversity and technology. Additionally, programs were failing to respond decisively to the reform agenda. The study also reported that there is minority under-representation in science education—a general shortfall in the number of graduate enrollments. These most recent studies of science education doctoral programs show that the programs are not addressing issues that are pertinent to K-12 science education as outlined in the standards.

There is need for research that focuses on how individual doctoral programs in science education are addressing or failing to address issues related to the reform agenda.

This study aims to partially fulfill this need by studying how three science education doctoral programs are responding to the current reforms in science education. Since the ultimate objective of doctoral programs is that of "serving society", failure to respond seriously to the reform agenda could mean that they are failing to achieve their objective.

Theoretical Framework

This study is based on a critical theory framework. Critical thinking has been looked at from different perspectives. In this case I will look at critical thinking from a complex critical thinking perspectives borrowed from Kincheloe & Weil (2004). According to Kincheloe & Weil (2004), simplistic critical thinking looks for a set of solutions to neatly outlined problems where one "enters a virtual world without rough edges, where all relationships are in place and easily discerned and inquiries into the disjunction between the virtual world and complex lived world are ignored" (Kincheloe and Weil, 2004. *P. 3)* In contrast, complex critical thinking takes into account a wide variety of social, cultural, political, cognitive, and pedagogical discourses (Kincheloe and Weil, 2004).

Whereas critical thinking places emphasis on logic, conceptual analysis, and epistemological insight, complex critical thinking goes further to emphasize the existence of unexplored domains of human consciousness and cognition. Kincheloe and Weil's (2004) conception of complex critical thinking therefore emphasizes the need to respectfully understand the thinking of others and to be more hesitant to reject other forms of knowledge production and meaning making. When applied to science education, complex critical thinking includes a closer look at other factors that influence science learning and diversity among learners in terms of social, cultural, linguistic and learning disability. Contextual factors such as policies, funding, business, and the public, just to name a few, influence schools and science learning. Therefore when looking at achieving science literacy for all students, complex critical thinking places emphasis both good pedagogy, diversity among learners and contextual factors that influence students' learning.

I chose to use Kincheloe and Weil's (2004) conception of critical thinking as a framework for my study. This study is an investigation of how science educators are responding to science education reforms as they prepare future leaders in the field. As I read literature around the issues of reforms and teaching science for all, I realized that science educators are taking different stances on how science literacy for all can be achieved, with some focusing on achieving science literacy for all through improving pedagogy and teaching science for understanding. In this case the science educators are responding to the prevailing definition of achieving science literacy for all as outlined in the National Science Education Standards (NRC, 1998) and the Benchmarks for Science Literacy (AAAS, 1993).

Prevailing reform-based science teaching emphasizes the practice of inquiry, model-based reasoning and authentic science experiences as teaching methods that improve science teaching and ensuring that all students gain an understanding of science. This practice of teaching science to all students is a departure from the traditional practice where science was only accessible to a few students who were interested in becoming scientists. Hence the prevailing practice of science ensures equity in science teaching in the sense that everybody now has access to science. In addition to promoting reform-based pedagogy, other science educators are also focusing on finding ways to address inequity in science between affluent suburban schools and other poorly funded schools in cities and rural areas. Hence these science educators are going beyond thinking of improving pedagogy in one classroom to improving pedagogy in multiple settings. The bottom line is that all science educators are involved in the process of critically thinking about how to achieve equity in science teaching and they are thinking about doing this at different levels.

Achieving science literacy for all students is the national goal for the science education reforms. The reform documents show that policy makers have critically looked at the state of science teaching and learning and they have realized that there is need to change the way science has always been taught in order to improve scientific literacy among all students including those who are not going to be scientists. In addition, the way the reforms are neatly laid out into what students should know and be able to do, and what teachers should do to achieve science literacy for all shows critical thinking as defined by Kincheloe (2004):

> Critical thinking in education is an art form and goes beyond a Cartesian notion of reasoned choices among available logical alternatives or a Piagetian notion of formal operations where the linear procedures of the scientific method are followed by individuals seeking higher forms of cognitive activity. It is what we call post formal thinking-a form of cognition that contends that Piaget's Cartesian-based formal stages do not represent the apex of human cognitive ability. (p.7).

In keeping with Kincheloe, the reforms include a broader vision of science than there was before, and they advocate for use of inquiry in science teaching. This is different from the traditional lecture methods where the teacher was seen as the one who possessed knowledge and learners were believed to have no knowledge of science. Science inquiry is also different from the traditional scientific method where students followed a set of directions to find some pre-determined answers. Science inquiry enable students to actively engage in the process of doing science by asking questions, conducting investigations to come up with answers, finding explanations to the answers and applying the knowledge gained to everyday life.

The new paradigm acknowledges the fact that learning is an active process where the learner actively creates his/her own knowledge by making connections between what they know and the new knowledge they learn. Hence the reformers used knowledge from research in different areas such as constructivist theories from cognitive science to emphasize the need to use inquiry in science learning (NRC, 1996).

The simplistic critical thinking perspective can also be referred to as traditional school science teaching and learning approach. From this approach, how teachers teach depends on the knowledge, skills and commitments they bring to their teaching and opportunities they have to continue learning from their practice. The following statement from Feiman-Nemser (2001) emphasizes the critical role that teacher preparation plays in producing powerful student learning:

> If we want schools to produce more powerful learning on the part of students, we have to offer more powerful learning opportunities to teachers…New courses, tests, and curriculum reforms can be important starting points, but they are meaningless if teachers cannot use them productively. (p2).

Consequently, the preparation of prospective teacher educators through doctoral study plays a critical role in producing quality teachers. Therefore, the preparation of doctoral students also impacts the quality of teachers' practice either directly or indirectly through the way the graduates are prepared for their roles as teacher educators, curriculum developers, and researchers. Since the publication of the National Science Education Standards and Benchmarks for Scientific literacy, teachers have been called upon to change their ways of teaching and to teach in new ways (NRC, 1998; AAAS 1996). These reforms are aimed at improving student achievement and ensuring that all students become scientifically literate. Numerous reports of successes at preparing new teachers to teach in reformed ways have been presented at professional meetings such as NARST and AERA.

Across the literature, I showed how science educators and researchers have interpreted the goals of the reforms in different ways. Whereas there is an explicit effort by science educators to teach science for understanding through inquiry, model-based reasoning and authentic experiences, there have also been some efforts to find ways to bring equitable science experiences to minorities, urban students and students with learning disabilities. There have also been some efforts to make connections between education and social justice and teaching science for social justice. Looking at science from a social justice perspective is a radical way of looking at science because science has always been seen as a special and objective body of knowledge. However, viewing science from a social justice perspective shows realization that science should be accessible to all students.

Making science accessible to all students is critical because science exists in our daily lives and to keep science, as a preserve for only a few people who can learn it is to deny the rest of humanity a right to understand their world. Therefore viewing science as a social justice issue shows humility among science educators who empathize with the least served in society (Kincheloe, 2004). Making science available to all students including those who are not going to be scientists is radical indeed. The focus on reaching out to students who have not been equally served previously has led to questioning why schools are failing to address the needs of all students and how all students can get equal access to science education.

From review of literature it can be concluded that that researchers and science educators are all making efforts to address issues of equity in science teaching both at classroom level and at national level. Science educators can therefore flexibly interpret the reforms in ways that best suit their abilities and needs. A critical theory framework will help me to identify the way science educators are interpreting the reform goal of science literacy for all using the definitions of critical thinking described in this section.

CHAPTER 3

STUDYING DOCTORAL PROGRAMS

Methodology

My research question was "How are science education doctoral programs interpreting the current reforms and how are they enacting these reforms as they prepare future leaders in the field?" Three science education doctoral programs were selected for this study. Two faculty members, three doctoral students and three recent graduates from each of the three programs were selected to participate in the study. The faculty members were purposely selected in order to get the views of people who are actively involved in science education doctoral preparation. Data for this study was collected through telephone and face-to-face interviews, surveys (Cohen, Manion & Morrison, 2000) and analysis of course documents (Yin, 2003).

I entered this study with the aim of gaining an in-depth perspective of how a selected set of doctoral programs were preparing their doctoral students for leadership in the field of science education. As a science educator, my study needed to have a focus that relates to issues that are relevant to the field, which is why I chose to investigate how the doctoral programs are responding to current reforms. As an outsider, I was introduced to reforms during my first year of doctoral study in the United States. I found the reforms to be consistent with the way I thought about science teaching and learning. I have come to realize that reform issues occupy a significant part of the research literature in science education. I got exposed to research and literature that showed how the reforms have been addressed and the different ways science educators are trying to address issues of equity in science education. As I analyzed findings from the leadership development study

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study realized that there is not much literature on how science education doctoral programs were addressing issues related to the reforms. I therefore decided to focus my study on finding out how doctoral programs were interpreting the reforms and how they are incorporating them in their programs.

I would like to acknowledge right from the beginning of this study that I am looking at science education doctoral programs in the US as an outsider. However, I am also looking at these programs with an insider perspective. I am not an American citizen, which makes me an outsider to the American education system. However, I have lived in the United States for 6 years and I have knowledge of US science education doctoral programs that I gained as a participant in a doctoral program and in supervising prospective teachers as they worked in American secondary schools. I was also involved in a study of science education doctoral programs as a research assistant for 3 years, which also provided me with a better understanding of the nature and variations among doctoral programs in the US. My role in this study as a research assistant was to collect and analyze data and to write up the manuscript. I conducted interviews with recent graduates and analyzed data from the surveys. The conversations with recent graduates made me aware of issues in doctoral studies that need to be investigated, hence my interest in conducting this study.

As an outsider, I do not claim to have an understanding of the epistemologies and worldviews that shape American science educators' thinking and acting. My cultural and educational background influences my own worldviews and ways of thinking, which are different from that of my subjects. My interpretation of findings from this study is influenced by my own epistemology, which is defined by my cultural background and worldview. Being aware of this helped me to be more conscious as I conducted the interviews. I asked the interviewees to define the meanings of phrases I was not sure we shared common understanding. I also restated some of the responses to ensure that I captured the interviewee's views correctly. My analysis of the findings represents my understanding of the data and what I made of conversations that I had with the participants. As I interpreted the views of my participants, I was acutely aware that how I interpret the data is often at variance with what the interviewees may want or expect (Paine and DeLany, 2000). In order to ensure that I represented the doctoral programs more accurately, I asked the faculty members from each institution to read my transcriptions and descriptions of their programs. This enabled the interviewee to voice their concerns about the way I had represented them. I included their feedback in my final analysis, ensuring a fair representation of the other.

At the time of this study I was a students at one of the doctoral programs in this study. As a doctoral student I have been exposed to multiple perspectives in the field of science teacher education. My own perspectives as well as the perspectives from my doctoral courses have shaped the way I think about issues in science education and as a result influenced the way I interpreted the findings in this study. I therefore came to this study with a set of particular opinions, abilities and objectives, which shaped my ideas. I was aware of having inside perspectives of my own program while being an outsider to the other programs. In order to ensure that I presented a balanced analysis of the programs, I used a framework (NRC, 2002) to analyze the interviews. This helped me to look for similar issues in the interviews and this allowed be to do a cross-case analysis of the programs.

Interpretive Approach

An interpretive research approach (Rowlands, 2005) was used in this study to investigate how science education doctoral programs are interpreting the current reform initiatives and incorporating them in their programs. The goal of the current reform efforts is to achieve science literacy for all students. In my investigation I looked at the focus of science education faculty's research and coursework and how they are addressing the reform goal of science literacy for all and issues of equity in science learning among students in different situations and among students with different learning abilities.

I chose to use the interpretive research method for three main reasons. First, the nature of my research problem and how my interest to work on this study developed influenced my choice of the research approach. An interpretive research approach was appropriate for this study because my research question was broad. My research question was influenced by the way my research interests evolved from the Leadership Development Study mentioned earlier on. Findings from the leadership development study and other recent studies showed that doctoral programs were failing to address national needs such as diversity and technology. I decided to investigate what individual doctoral programs were doing to address the current reforms, how the professors interpreted the reform goals, and how they arrived at decisions on what courses to teach and what to include in the coursework. I did not have any measurable values and what I wanted to learn shaped the research questions (Klein, & Myers, 1999). I conceptualized this study to be exploratory in nature.

Secondly, my choice of interpretive approach was influenced by the assumptions I made about the theoretical lens that emerged (Klein, & Myers, 1999) from literature on how different science educators think about reforms and how to address them. This kind of literature revealed knowledge about how reforms can be addressed in K-12 schools but there is no literature that showed the way science educators think about the reforms and how they enacted them through doctoral study. The interpretive research approach is consistent and compatible with the epistemological and ontological assumption that the world and reality are interpreted by people in the context of historical and social practices (Klein, & Myers, 1999). In this case, the meaning and goals of the reforms is subjective and the way science education Professors think about them can at best be understood in terms of their subjective meanings rather than my objective definitions as a researcher.

Third, I chose the interpretive research approach because of its flexible nature (Klein, & Myers, 1999). Since I was uncertain about the topic, I did not have specific variables that I was measuring. Coupled with this is the fact that there is little prior research done in this area, hence there was need for more participation from the participants in the form of interviews, which necessitated a qualitative study. There is also need to develop theory that explains the science educators' way of thinking about issues in the field, how they interpret these issues and how they enact their interpretations through doctoral programs. An interpretive research approach therefore enabled me to explore the issues of greatest salience within the doctoral programs (Tobin, 2000).

Research Methods

I used a *multi-site instrumental case study* design (Creswell, 1998) in this study. The cases I used were three science education doctoral programs in different parts of the United States. I decided to use three doctoral programs instead of one because I was aware of the variation among science education doctoral programs in the United States. Looking at three doctoral programs enabled me to come up with findings that can be applied to some extend to doctoral program in the US. These cases provided the context for understanding 'how' science education doctoral programs are responding to the current reforms as they prepare their graduates. The doctoral programs provided boundaries for my study and each of the doctoral programs was considered as a self-contained system (Creswell, 1998). The three cases played a supportive role, facilitating my understanding of the how doctoral programs in science education prepare their graduates. Initially I did not want to study my own program because I was afraid that I bring in some bias because of my familiarity with the program. My committee recommended that I study my own program because this would enable me not just to talk about the "other" and what they are doing but also to talk about my own program and what it was doing.

The case study design was suitable for this study because of several reasons. First, the research intended to answer a 'how' question (Yin, 2003), and I did not have any measurable variables, therefore I needed to collect several sources of data from each institution. Second, collecting information about different doctoral programs necessitated a case study. This allowed me to provide holistic and meaningful characteristics of each program and at the same time make a comparison of the different programs.

This study is an instrumental case study (Creswell, 1998) because the focus was on the issue of how science education doctoral programs responding to the current reform initiatives. Tellis (1997) describes a case study as instrumental when the case is used to understand more than what is obvious to the observer. Creswell (1998) also classified cases according to their focus. If the focus is on an issue with the case used instrumentally to illustrate the issue, it is referred to as an *instrumental case study*. The instrumental case study was appropriate in this case because, although literature supports the fact that teacher educators are promoting standards-based science teaching among teacher candidates, there exists some skepticism among educators on whether the current reforms in science education will lead to the goal of achieving 'scientific literacy for all'. Much still needs to be known about what different science educators' views, ideas or doubts are about the current reform initiatives. An instrumental case study will be useful in understanding what science educators think about the reforms and how this is manifested in preparing their graduates.

Study Sites

In order to get a good representation of ideas about the content of doctoral preparation, I chose doctoral programs that I knew were producing a sizeable number of doctorates. My choice of doctoral programs was influenced by my experience working on the Leadership Development Study. I selected three out of the ten-science education programs previously studied in the 2001-2003 Leadership Development Study in Science and Mathematics Education (Gallagher et. al., 2003) so that I could do an in-depth study of these programs. My decision to choose some programs and leave out others influences the findings I got. Whereas there are many other science education doctoral programs that are the same size as the ones I chose, my intentions and objectives played a significant role in the choices I made. Since I already had demographic data and information pertaining to the general features of these programs from the previous study, I did not need to commit a lot of resources and time collecting this data. This allowed me time to focus more on open-ended interviews and analyzing course documents.

The doctoral programs that I selected for the study had some features in common, but they also had some distinguishing characteristics, which made them unique. These programs represented the range of science education doctoral programs in the U.S. in terms of size, geographic location, funding, and location within the university. In this study selected 3 of the medium to large programs. I selected the science education doctoral programs located in different geographic regions of the United States. One of the programs is at City Ville University, which is located in a large city in the East coast. The second program is at Midwestern University, which in the Midwestern part of the United States. The third program is Southern Valley University, which is located in the Southwestern part of the United States.

I purposely selected programs that are actively producing about 2-3 or more doctorates per year. I used data from the Leadership Development Study (Gallagher et. al., 2003) to select the doctoral programs for this study. The science education program at Midwestern University is part of the Curriculum, Teaching and Educational Policy department and between 1990 and 2000 it produced 2-3 graduates a year. The science education doctoral program at Southern Valley University is part of the Teaching, Learning and Culture department and it produced about 1-2 doctorates a year between 1990 and 2000. Finally, the science education doctoral program at City Ville University is within the Science, Mathematics and Technology Education department and it produced about 3-4 doctorates per year between 1990 and 2000.

Other considerations I made were the program focus and funding availability for doctoral programs. Again I used information from the Leadership Development Study (Gallagher, Floden, Ferini-Mundi & Anderson, 2003) that provided information about program focus and funding structure. Whereas the science education doctoral programs at Southern Valley University and Midwestern University are publicly funded, the program at City Ville University is privately funded. The programs at Midwestern and Southern Valley have Teaching and Learning centers that are substantially funded by the National Science Foundation. On the other hand, the program at City Ville University has an Urban Science Education Center that is funded by several private foundations. A comparison with a privately funded program was meant to see if funding is a factor in the way doctoral programs prepare future leaders. It is important to highlight the fact that the Center for Learning and Teaching at Midwestern and Southern Valley are not a permanent feature of the programs and have a 5-year term. Similarly Urban Science Education Center at City Ville is also not permanent and funding from various foundations runs for specific limited time. Therefore all the Centers run by the three science education programs are temporary features, but nonetheless important to consider because the funding plays a significant role in what a program can and cannot do. However, the temporary nature of the Center for Learning and Teaching means that the data pertaining to the centers will only be a short-term feature of the programs. Besides the limited generalizability of the data from the Centers, the findings will serve a critical role of showing the role of funding in improving doctoral programs.

In selecting the three programs, I also considered where the graduates go to work on completion of their programs. Data collected from the [2001-03] Leadership development study provided a better understanding of these programs. Findings from a survey of recent graduates showed that the program at Midwestern University is preparing its graduates for jobs at both teaching and research universities. Graduates from City Ville also go on to find jobs both at research and teaching universities but a majority of the Southern Valley graduates go on to find different jobs within their state either at the university or school district level. Finally, I considered the representation of the programs in terms of geographic and physical location. Whereas City Ville University is located in a large city, Midwestern University is located in a medium size suburban area, and Southern Valley University is located in a rural setting. These were important considerations in selecting these programs, and they ensured collection of data that would be representative of different science education doctoral programs.

Because I wanted to have a representation of doctoral programs in different parts of the country, this meant that two of the sites I chose to study were far away from where I was located and only one of the sites was in close proximity. Because of financial constraints, I could not physically go to the other two institutions to collect data; thus I communicated with the participants via email. I conducted telephone interviews with faculty, doctoral students, and recent graduates from the three institutions. I was aware of the differences in the data I was going to collect among the three programs due to the differences in proximity. To avoid a big difference between the data collected from Midwestern and the other two institutions, I used the same protocol for collecting program documents and for interviewing.

The study Participants

In order to find out how the selected doctoral programs in science education are responding to the current reform initiatives as they prepare their graduates, I interviewed faculty, graduate students and recent graduates and I also analyzed course documents from these programs. I contacted senior faculty members from the three programs and asked them for names and contact information of other faculty members who I could interview. Since I had no access to students and recent graduates, I also asked the faculty leaders from the three programs to provide the names of advanced doctoral students in their 4^{th} or 5^{th} year and recent graduates from the past 5 years who could be contacted to participate in this study.

I purposefully selected the faculty members on the following basis: they were either coordinating the science education doctoral programs, a senior member who had been on the institution for more than 10 years and a junior faculty who was actively involved in teaching or mentoring doctoral students. For example, at Midwestern I selected a senior faculty and a junior faculty who are both actively involved in teaching and mentoring doctoral students. At Southern Valley I selected two senior faculty members who are both actively involved in teaching and mentoring doctoral students. At City Ville I selected two senior faculty members who are both actively involved in teaching and mentoring doctoral students. I randomly selected three doctoral candidates and three recent graduates from the lists provided by the faculty. A total of 6 faculty members, 9 doctoral students and 9 recent graduates participated in the study.

Data Collection

Yin (2003) recommended six types of information to be collected in a case study, namely: documentation, archival records, interviews, direct observations, participant observations and physical artifacts. In this study I collected data through; a) faculty surveys (Appendix A), b) telephone interviews with faculty (Appendix B), c) telephone interviews with doctoral candidates (Appendix C) and d) interviews with recent graduates (Appendix D). I also conducted extra interviews with faculty who are principal investigators in the Centers for Learning and Teaching at Midwestern and Southern Valley and the Urban Science Center at City Ville (Appendix E). I collected and analyzed program documents such as course syllabi and course descriptions. These multiple sources of data were used to get a better understanding of 'how' science educators are interpreting the reforms and 'how' they are preparing their graduates in response to the reforms.

All communication with the participants was done through email. Initially I sent letters inviting the senior faculty (Appendix F) to participate in the study. The invitation letter contained a detailed description of the study and a consent form (Appendix G). After the senior faculty agreed to participate in the study and gave their consent I emailed requests for names of other faculty members I could interview. I selected the second faculty member based on their experiences on the doctoral program. I then emailed them invitation letters and consent forms. At the beginning of the study I sent questionnaires (appendix A) to senior faculty members at each of the three programs and asked them to complete the questionnaire. In the questionnaire I requested for names of 5 doctoral candidates who have passed their candidacy examinations as well as names of 5 recent graduates who graduated from their programs within the past 5 years. I also requested for program documents such as course syllabi, program descriptions, program requirements and reading lists. I emailed all the participants requesting for their curriculum vita. I also requested for program plans, dissertation topics and completions dates from recent graduates.

After I got back all the information from faculty I emailed them to schedule a time for a telephone interview for those who I could not interview face to face. I also sent invitation letters and consent forms to recent graduates and doctoral candidates (Appendices H & J). After I got their consent, I emailed them to schedule a time for a telephone interview for those I could not interview face to face. For the telephone interviews I initiated the telephone call and for face-to-face interviews I arranged a quiet venue for the interview. All interviews were audio recorded using a manual tape recorder and each interview lasted about forty-five to sixty minutes.

One other advantage of the case study design is that it enabled flexibility in the choice of interviewees. Although I had initially planned to interview only two faculty members at each of the institutions, I chose to interview one more faculty member from Midwestern University. The reason why I decided to interview an extra faculty member is because as I made progress with my data collection, I realized that at least one of the faculty members I had interviewed at the other two institutions was either a principal investigator (PI) or co-PI in the Centers for Learning and Teaching). They provided detailed information about the science education centers and how they were mentoring doctoral students. This detailed information was missing from Midwestern, therefore I decided to interview the Science Education Center co-PI. This enabled me to compare the roles of the Science Education Centers at the three institutions.

As I made this change, I was aware of the fact that I needed to balance adaptive ness with rigor. I had to modify the interview protocol in order to ask questions about the role of the Science Education Centers at the other two institutions. The interview protocol I used for the additional faculty member only focused on the Science Education Center. I added these same questions to my original protocol and requested a second interview with the other two faculty members who worked with the Science Education Centers in order to get comparable in-depth information. Table 3.1 shows the different types of research that were asked and how the data was collected.

Table 3.1: Research questions and how data was collected

Research Question	Data to be collected
1. How are science education doctoral programs responding to current reforms in science education in their coursework and other mentoring experiences offered to doctoral students?	a) Analysis of program documents b) Interviews with faculty (appendix I), doctoral students and recent graduates (appendices ii, iii and iv)
2. What are the perceptions of science education faculty, recent graduates and doctoral candidates, about the challenges confronting K-12 science education and how are these challenges related to the way the programs are preparing their graduates?	Interviews with faculty, doctoral students and recent graduates (Appendices…)
3 What are the perceptions of doctoral candidates and recent graduates about their preparation in relation to challenges in the field?	a) Interviews with doctoral candidates and recent graduates

The Interview Process

I designed three sets of parallel questions that I asked faculty members, doctoral candidates and recent graduates (Appendices B, C, D). These questions were reminders regarding the information I needed to collect and why (Yin, 2003). The questions were also meant to serve as prompts in asking questions during the interview, but mostly they helped to keep me on track as data collection proceeded (Yin, 2003). Having parallel sets of questions for the three groups of interviewees on each program enabled me to collect data that I could use to do within case as well as cross-case analysis.

At the beginning of each interview I asked the interviewee for personal information if I did not receive it prior to the interview. I then started the interview by asking the first question: "What are your views about the most important issues in the last 5 years." This was an open ended question that was meant to get individual views from science educators and what issues they strongly felt about. I decided to ask what the science educators and doctoral students thought instead of asking them what they think about particular issues because gathering information on the issues they think are important was one of the goals of this study. Since there is limited literature on what science educators think about issues in their field, asking an open-ended question was meant to collect data that would contribute to literature in this area. I also used this type of question to avoid bias that I already have about issues in the field, hence I this allowed me to hear some issues I may not have thought of as important. After the respondents talked about their views, the next question asked them to provide more details on each of the issues mentioned. As the interviewees talked about their views, I asked follow-up questions and clarifications if I sensed that there was some useful information between the lines (Yin, 2003).

The type of questions in interview protocol were asking interviewees about their views about different issues such as leadership in the field of science education, reforms in science education and how science should best be taught in K-12. I also asked questions related to the doctoral programs such as how doctoral students are mentored, how reforms are incorporated into the framework of the courses and how doctoral programs can be improved. The questions were therefore meant to gather peoples' views as well as facts about the doctoral program. One of my goals was to investigate the intersection of science educator's views and actions. For example, a) "Do faculty's views influence the content and nature of doctoral programs?" b) "Do faculty's views influence those of recent graduates and doctoral candidates or vice-versa?" c) "Does the way faculty interpret the reforms reflected in the way they incorporate them in the coursework?"

As I asked the questions during telephone phone interviews, I was aware of the physical distance between the interviewee and interviewer and that this would have an influence on how much information the interviewee was willing to give. To reduce the distance between the interviewee and interviewer I was also actively involved in the interview process by volunteering my own experiences and gave examples, which helped to create a more interactive environment. I also created a situation where the interviewees found it easier to speak freely and more in-depth by affirming their responses to show that I was actively listening. I also followed up on what they had said in order to get clarification and more information. All this helped create a rich dialogue (Yin 2003).

As I moved from one question to another, I made sure that I connected to what they had said in relationship to that question. This helped to reduce repetition of responses. In some instances, a number of the questions were answered during the first open-ended first question since one question led on to a host of other questions; hence I did not repeated questions that were already answered.

Data Analysis

An embedded analysis of the cases was conducted, starting with a within-case analysis followed by a thematic analysis across the cases (Creswell, 1997). In the process, I established patterns, and looked for a correspondence between two or more categories. In this case, faculty, doctoral students and recent graduates were considered as different categories. In the end I presented the lessons learned from the cases. From the emerging patterns I provided a detailed description of the cases both within the programs and across the categories.

By situating the current science education reforms within the doctoral programs and in the science education field as a whole, my goal was to provide a rich context for understanding how science educators think about and interpret the reforms and how this gets translated into their doctoral programs. Basically I expected three stories to emerge from each of the interviewees, that is; a) a story about their views of issues in Science Education; b) a story about how their doctoral programs are preparing leaders for the broader view of science teaching and learning; and c) a story about how science educators are interpreting the current reform initiatives in the field of science education.

As planned this study, I was aware that the story that will finally be told would depend on a number of factors: a) What I would choose to include and what I would choose to leave out would be mostly influenced by my own perspective, knowledge and experience in the field. Issues that I would consider being more important than others would find their way into to the story and those I consider to be trivial could be left out. This does not mean that the latter are less important in reality, but in terms of my priorities and biases. In the analysis, I decided to include what I thought was necessary to understand the case. The story that emerged was the case's own story but I as the researcher was responsible for dressing the story (Stake, 1995). Dressing the case cannot be seen as necessarily bad because knowledge is socially constructed and by choosing what goes into the story, thus shaping it, I assisted the reader in the construction of knowledge. Although I entered the study expecting or even knowing that certain events, problems, or relationships were important, the real case content evolved in the act of writing itself (Stake, 1995).

I analyzed two sets of data; namely program documents and interview data. In both cases, I interpreted the data to show how the science educators interpreted the reforms, how they viewed the reforms and how these are enacted in the doctoral programs. I analyzed each case separately first, then I did a cross case analysis in the final chapter. In each case I analyzed course documents and interview data separately.

Analysis of Course Documents

Although I did not have a specific framework or strategy for analyzing the course documents, I analyzed the course documents using the theoretical proposition that I described in the first chapter. For each program the purpose of the case study was to show how faculty interpreted the science education reforms and how this influenced doctoral preparation. This framework helped me to focus attention on certain data and ignore other data (Yin, 2003). I chose to do an in-depth analysis of courses whose content either implicitly or explicitly addressed the science education reforms and I ignored courses that did not specifically address the reforms. For example I focused on courses such as 'Curriculum and instruction' or 'Exploring scientific literacy', and ignored such courses as 'Research methods' or 'Philosophy of Science'.

As a way of identifying how the reforms were incorporated in each of the selected courses, I examined the course outline, course goals and reading lists. However, I did not read through the course literature, hence I did not include it in my bibliography. I used passages from the course documents to justify my claims about how the reforms were addressed in each of the courses. I also used quotations from interviews with faculty, doctoral students and recent graduates about how the reforms were incorporated in the course. I then used the theoretical framework to identify which of the following approaches defined the way faculty are interpreting the reforms: a) science literacy for all as Plea for Achieving Excellence in Science Teaching and Learning: A Simplistic Critical Thinking Perspective; b) science literacy for all as a plea for Equity and Social Justice: A Complex Critical Perspective. Using both the course content analysis and interview data I developed a description of how each program is incorporating the reforms in its courses, how the faculty are interpreting the reforms and how the reforms are enacted in the doctoral program through coursework and research.

Analysis Interview Data

For the analysis of interviews I used the framework for investigating the Influence of the Nationally Developed Standards for Mathematics, Science and Technology (NRC, 2002) shown in Fig. 1. The National Research Council's framework identifies "three channels of influence" that influence the practice of teaching and learning outcomes in schools, namely: 1) teacher development, 2) the curriculum, and 3) assessment and accountability. Besides these factors, it also identifies contextual factors such as politicians, the public, business and industry and professional organizations. I chose to use this framework because it helped me identify issues that were considered to be most important in the field by the interviewees. Identifying the issues that were considered most important by interviewees helped me to match the faculty's views with the nature of the program. In other words I was looking to see whether faculty's views and interests influenced doctoral preparation. Using the NRC framework also enabled me to do a more in-depth within case analysis. I compared the views of the faculty, doctoral students and recent graduates.

In order to classify the views of interviewees into the different orientations identified in the NRC framework, I entered the transcribed data for each applicant into a matrix as shown below:

Question	Response from interviewee 1	Response from Interviewee 2	Response from interviewee 3

I had three different matrices, one for faculty, one for recent graduates and one for doctoral students. For each of these groups I entered the interviewees' responses to each of the interview questions. I then read each of the transcribed data to see whether their views were related to teaching, teacher development, curriculum, assessment and accountability or to contextual factors. I used different color highlights to indicate these categories. For categories that did not neatly fit into these categories I decide which category best fits. For example issues of teacher shortage, lack of resources, issues of equity etc, are more of contextual than any of the other categories so I grouped them under contextual factors. I then counted the number of respondents who emphasized each of these categories in response to the different questions.

I used excel spreadsheet to graph the number of responses and this way I was able to see which category was emphasized by most respondents as an important issue in the field. Although the different categories were not used directly to describe the nature of the program, they helped me to find patterns of how science educators think about issues in science education within cases and across cases. The categories also helped me to define the contextual factors that were emphasized by the interviewees. Below is a description of the National research council with a detailed description of each of the categories I used.

The NRC Framework

The National Research Council's framework for Investigating Influence of the Nationally Developed Standards for Mathematics, Science and Technology (2002), shown in Fig. 1 as a lens for analyzing the content and intentions of Science Education doctoral preparation. This framework was developed to provide guidance to answering questions related to how the education system has responded to the introduction of the nationally developed standards their consequences for student learning? The National Research Council's framework identifies channels through which nationally developed standards may influence teaching practice and learning outcomes. According to the NRC (2002), the argument implied by the framework can be summarized in these interrelated propositions:

- Nationally developed standards in Mathematics Science, and technology represent a set of fundamental changes in the way these subjects have traditionally been taught, placing new demands on teachers and students.
- The influence of the nationally developed standards on teaching practice and student learning is likely to be: a) direct taking place through proximate effects on other parts of the education system; b) entangled (and sometimes confused) with other influential forces and conditions, such as broader state standards-based reforms; and c) slowly realized and long term.
- Three core channels exist within the education system through which nationally developed standards can influence teaching and learning; these channels of influence are complex, interactive, and differ across subject-matter communities.
- Variability within the education system implies that students and teachers are likely to experience different influences, depending on locality, resources, participant background, and other factors.
- Nationally developed standards will eventually be judged effective if resources, requirements, and practices throughout the system align with the standards and if students in standards-based classrooms demonstrate high achievement in knowledge and skills deemed important.

The NRC framework offers four key questions to guide inquiry into the influence of standards on various parts of the education system: a) How are nationally developed standards being received and interpreted? b) What actions have been taken? c) What has changed as a result? And d) Who has been affected and how? (NRC, 2002). The following sections provide a detailed description of each of the identified channels through which reform ideas may flow to influence students learning:

Curriculum

The influence of the standards is filtered through the forces and conditions that determine the curriculum and instructional materials. What is taught in the classroom is influenced by decisions made at the National, State District and classroom levels. What is taught in the classroom is influenced by certain policy decisions that affect curriculum materials and other resources, the developing of curriculum materials and the processes and criteria for selecting curriculum materials which determines what students learn in any one classroom. The nationally developed standards provide a comprehensive picture of what students should know and be able to do, which can influence the development and adoption of curriculum materials that embody the standards vision. State content standards are increasingly aligned with the national content standards; textbooks reflect the content standards and teachers have resources for teaching standards-based lessons.

Teacher Development

The National Research Council's framework is based on the idea that, what teachers know and can do makes the crucial difference in what they can accomplish (The National Commission on Teaching and America's future; In Feiman-Nemser, 1996). However, what and how teachers teach depends on the knowledge, skills and commitments they bring to their teaching and opportunities they have to continue learning from their practice. Teacher preparation and development within the education system provide channels through which the nationally developed standards might influence how the teacher learns to teach initially and throughout their careers. The policies and programs at national, state and federal levels determine investments made in teaching prospective teachers and mold the way they continue to develop as classroom practitioners. Teachers' pedagogical and content knowledge is influenced by the way the subjects are taught both prior to and during the certification programs. Teachers' professional development is determined by the policies and resources available in the school district and within the school they teach. If nationally developed standards are influencing the preparation of new teachers, would require prospective teachers to gain knowledge and skills needed to help students meet standards based learning. Postsecondary institutions would create systems that would enable teachers to practice standards-based teaching.

Assessment and Accountability

Assessment and accountability constitute the third channel through which reform might flow. As the standards movement gains momentum, assessment and accountability are being used to realize the standards. Assessments are a way of showing students, teachers, parents and the general public how students are performing. Accountability mechanisms linked to assessment provides incentives to make changes. Assessments are a vital component of the standards as they specify expectations of the knowledge students need to have and what they should be able to do. The developments of assessments to support instruction, to drive educational improvement and to support accountability are possible influences attributable to the national standards. If nationally developed standards are influencing assessment policies and practices, assessments would be aligned with learning outcomes embodied in the national standards. Accountability policies would support schools and teachers by providing professional development opportunities, instructional materials, and appropriate resources to enhance their efforts to raise performance levels of their students.

Contextual Forces as a Source of Influence

Decision making in education is a political process, involving legislators, government officials, and citizen groups, in addition to educators. Educational concerns may lead different groups to lobby for certain decisions and educational policy decisions may be influenced by the media. If standards are influencing groups external to the education system, decisions made by elected officials should support policies that enhance standards- based teaching and learning. On the other hand standards may generate resistance and opposition from people within and outside the system. In this case, opponents to the standards would work to affect the decisions and actions within the education system. Opponents would support decisions that work against funding of programs that are related to the national standards.

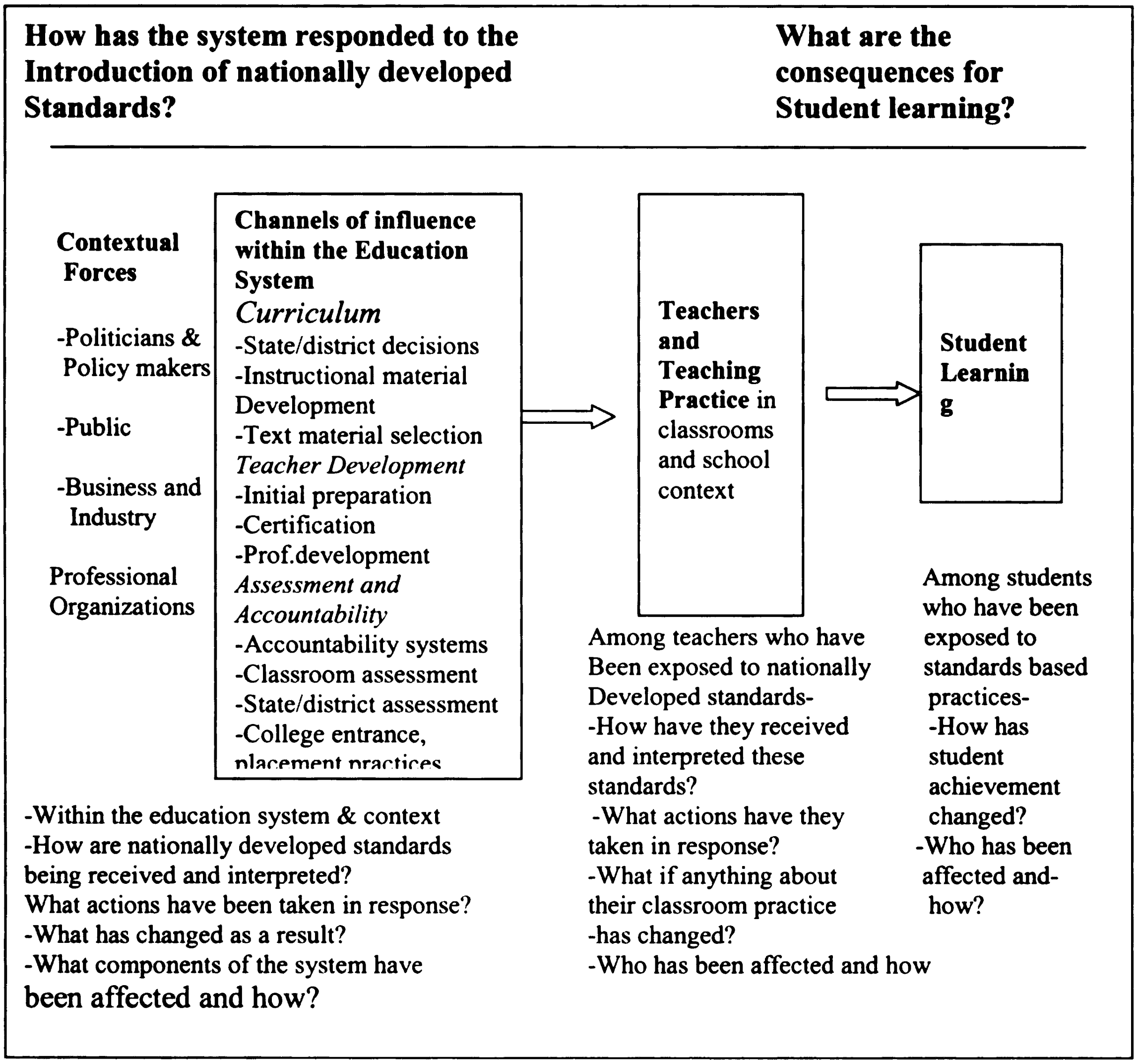

Figure 3. 1 Framework for Investigating Influence of the Nationally Developed Standards for Mathematics, Science and Technology (NRC, 2002 p. 114)

Problems encountered

I did not manage to interview one recent graduate from Southern Valley University because she backed out of the study at the last minute. I also had problems with data from one of the faculty members from Southern Valley who was busy during the time I collected data and I only managed to interview her for a short time. Hence I do not have as much data from her as the other professor as you will see in chapter 6.

CHAPTER 4

THE STORY OF CITY VILLE SCIENCE EDUCATION DOCTORAL PROGRAM

Introduction

> *Even in the welter of alarm and misjudgment, malice and racial spite, cultural obtuse-ness and official coldness of heart, all is not lost. The battle, though already joined, is far from over.* Ayers & Ford (1996)

In the introduction I described how the leadership development study I worked with as a graduate assistant influenced my interest to conduct an in-depth investigation of science education doctoral programs. The most surprising finding from the Leadership Development Study was the variation that exists among science education doctoral programs. I kept wondering how the different professors at the different institutions make decisions on choosing to focus on certain courses and areas of research and not others and why they mentor their students the way they do. I also wondered whether doctoral graduates from the different doctoral programs had similar experiences. I asked myself the following question several times, "If I had all this knowledge about science education doctoral programs before coming to US, would it have influenced my choice of institution to pursue my studies? Probably I would have ended up at City Ville, an institution that is located in a large city in the United States, but most probably I would have ended up at Southern Valley located in the warmer southern part of the US. If I had chosen City Ville a large metropolitan urban area of more than 8 million people, what kind of experiences would I have had? Would the experiences be different from the experiences I got from a Midwestern University in a small town of about 50 000 people? This and the next two chapters partly answered these questions.

This chapter specifically focused on the science education doctoral program at City Ville. I provided a description the science education doctoral program and the mentoring that doctoral students receive. Alongside the description of courses and research programs, I provided an analysis of the course documents, providing my interpretation of how the courses address the current reform goals of science literacy for all. The findings discussed in this chapter aimed to answer the following question, "How are science education doctoral programs interpreting the current reforms and how are they enacting them in preparing future leaders in the field?"

The following specific research questions will be addressed.

1. How are science education doctoral programs responding to current reforms in science education in their coursework and other mentoring experiences offered to doctoral students?
2. What are the perceptions of science education faculty, recent graduates and doctoral candidates, about the challenges confronting K-12 science education and how are these challenges related to the way the programs are preparing their graduates?
3. What are the perceptions of doctoral candidates and recent graduates about their preparation in relation to challenges in the field?

In this chapter I presented a description and analysis of findings from the Science Education doctoral program at City Ville. I interviewed two faculty members, three recent graduates and three doctoral candidates. I also analyzed program documents such as syllabi and course descriptions as well as program descriptions in order to get a better understanding of the program and how it is preparing its graduates. In my analysis I looked for evidence of how the courses and other experiences as well as faculty dispositions are addressing the reform goals of "Science literacy for all" as they prepare future leaders in the field. I used an interpretive approach that enabled me to assign meaning both to written and verbal text.

I used the National Research Council's Framework for assessing the influence of standards in Mathematics, Science, and Technology Education that I described in chapter 3 as a framework for analyzing data from the telephone interviews. Key features of this framework include channels through which policies and reform impact student learning in K-12 education. The channels include: 1) teacher development, 2) teaching, 3) assessment and accountability, 4) curriculum, and 5) contextual factors such as politicians, the public, business and industry and professional organizations. In my analysis I also coded issues related to student learning such as school funding, school administration and teacher salaries as contextual factors. I used the channels of influence described above to identify aspects of the K-12 education system that the Science Education doctoral program in this study mostly focuses on. I used this lens to make connections between the doctoral programs' interpretation of the reform goals and how they are preparing their graduates to address these challenges.

This chapter is made up of 4 sections. In the first section I presented background information that provided a context for understanding the nature of the Science Education doctoral program at City Ville. In the second section I provided a description and analysis of courses offered, program focus, faculty research, and mentoring provided to doctoral students. I used examples to show how the course content implicitly or explicitly addresses the current science education reforms. In the third section I presented the views and perceptions of the program's faculty, recent graduates, and advanced doctoral candidates and compared their perceptions about reforms in science education and doctoral preparation. Finally, in the conclusion, I provided a summary of the patterns that exist and what implications this has for Science Education doctoral programs.

Geographic Location

City Ville University is a large research intensive university located in the heart of one of the largest cities in the United States. The city has a very diverse population both culturally and socio-economically and has a population of about 8 million. The City Ville graduate school was established more than 100 years ago with the mission of preparing professional educators and leaders in the field of education. City Ville is a privately funded university and it serves students from diverse backgrounds both from the city, state, national and international populations. The Science Education Doctoral program at City Ville is housed in the Department of Mathematics, Science and Technology. Most of City Ville's doctoral students are self-funded hence a majority of them study part-time and continue to teach full time in the schools. The students who manage to study full time at City Ville are funded either through fellowships, teaching or research assistantships, or the university employs them either as adjunct faculty or instructors.

Program Description

The Science Education doctoral program at City Ville offers both Ed.D. and PhD. degrees. The Ed.D places emphasis on breath of professional education coursework with a focus on educational practice. On the other hand, the PhD degree program places emphasis on advanced preparation in science to develop both breadth and depth in science subject matter background and research expertise. According to the program website, candidates are required to "be competent in both quantitative and qualitative research methodology and to have knowledge of the epistemology of science and of psychology sufficient to be an informed scholar practitioner".

The science education doctoral program at City Ville produced at least 30 doctoral graduates in the last five years. The department has 5 faculty members and an enrollment of about eighty students. Half of the students are female and 75% are part-time. About one quarter of the students are white Caucasian and approximately one third of the student population is international. Minority racial groups such as African Americans, Asian Americans, Hispanics and Native Americans have limited representation in City Ville's science education doctoral program. This reflects the situation at several other science education doctoral programs in the US (according to findings from the Leadership Development Study, 2003).

Participant Profiles

Professors

The two professors who were interviewed from City Ville have been at this institution for at least 5 years and they have been science educators for at least 10 years. They have held leadership positions in science education professional organizations and have published widely in professional journals. Both professors teach science education courses but they are engaged in different types of research.

Professor Luke Macarthur

Professor Luke Macarthur has been a professor of science and education at City Ville University for about 39 years, and he will be retiring within the next 5 years. Professor Macarthur's scholarly interests are in the areas of knowledge acquisition in science learning and physiological studies of Eukaryotic micro biota. Professor Macarthur has published widely in the areas of teaching and learning of Biology, Comparative Zoology, and Neuro-cognitive Models. He has held leadership positions in several national organizations, and he has been a consultant to numerous science and education organizations and projects. Professor Macarthur has a doctorate in Biology and education and he has a joint appointment in the Departments of Natural Science and Science Education. Currently he is teaching courses in microbial ecology, guided study in science education and research and independent study in science education.

Professor Marilyn Gordon

Professor Marilyn Gordon is an associate professor of science education and has been a science educator for more than 10 years. She has a bachelor's degree in chemistry and a doctorate in science education. Her research interests are in the areas of urban science education, feminist and critical theories, and science education. Professor Gordon has published widely in the areas of teaching science for social justice, critical pedagogy and urban science education. She has served on several university committees. Professor Gordon runs the Urban Science Education Center at City Ville that is funded by grant money from several corporations. She currently teaches the following Science Education courses: Teaching and Learning Science in Urban Settings, Science Professional Seminar, and the Dissertation Seminar.

Recent Graduates

Three recent graduates who were interviewed for this study graduated had been at City Ville for at least two years or more. One of the recent graduates, Michael was an international student, Courtney is an American citizen and Kathy is an American permanent resident who is originally from Malaysia. All three recent graduates were full time students, Michael and Courtney had funding from the Urban Science Education Center as well as teaching assistantships, and Kathy paid her own tuition with help from her parents-in-law.

Michael

Michael is an international graduate of 2002 and graduated with PhD in Science Education. He has since gone back to his home country where he is Assistant professor of Science Education. Upon graduation from City Ville, Michael got a job as assistant professor at a research university in the United States where he worked for 8 months before going back to his home country. During his tenure as doctoral student, Michael worked at City Ville as an adjunct faculty teaching physics education and environmental education. He also worked as a research assistant with the Urban Science Center. Michael has a bachelor's degree in Physics and a teaching qualification. He did not have extensive teaching experience when he started the PhD program but had taught as part of undergraduate teacher education for 2 years both at primary and secondary levels. His dissertation investigated the effects of computer-based interactive simulations prior to performing a laboratory-based inquiry experiment on science teachers' conceptual understanding of physics.

Kathy

Kathy graduated from City Ville in 1999 with an Ed.D. in Science Education. She is currently employed as a part time instructor of science education at a research University in the Southern part of the United States. Upon graduation Kathy worked two years as assistant professor at a research University in the United States. Kathy completed her doctoral program in two years. During her doctoral program tenure Kathy studied full time and her family paid her college tuition. She taught elementary science methods courses and supervised lab instructors and teachers in schools for a required graduate course. Kathy taught high school science for 7 years before starting her doctoral program. Her dissertation was an ethnographic Study of the Construction of Science on Television.

Courtney

Courtney graduated from City Ville in 2004 with an Ed.D. Currently she is a post doctoral fellow at a Center for Learning and Teaching the United States. During her doctoral study, Courtney focused on higher education. She is planning to move into teaching non-majors chemistry courses and chemistry for pre-service teachers on a faculty level. During her tenure as doctoral student, Courtney co-instructed Chemistry content and methods classes, taught organic chemistry labs and worked as a research assistant on several research projects. She did not have extensive K-12 teaching experience before her doctoral studies.

Doctoral Candidates

The doctoral students interviewed for this study are either in their fourth or fifth year. They are all at the dissertation writing stage. Two of the doctoral candidates worked as teaching and research assistants and assistants. One doctoral candidate taught in the city schools and is planning to continue teaching.

Amanda

Amanda is a fifth year doctoral candidate and she is at the dissertation writing stage. Amanda worked as adjunct instructor teaching graduate courses in physics and chemistry content and pedagogical strategies. She also worked as a graduate research assistant on several projects. Amanda is a licensed physical science teacher but she did not have teaching experience when she started on program. She taught high school for 4 years during her doctoral studies.

June

June is a fourth year doctoral candidate and she is at the dissertation writing stage. Her dissertation research is entitled Understanding How Low-Income, Minority Students Express Agency in a 9th Grade Physics Classroom Developed with Expectations of Curricular Rigor and Student Engagement." During her doctoral program June has been teaching science in the city schools and is working towards licensure for teaching in the city.

Pamela

Pamela is a fifth year doctoral candidate and she is at the dissertation stage. She is an international student who also got her masters degree from City Ville. During her doctoral studies, she co-taught science methods classes with her advisor and with other doctoral students. She did not have teaching experience when she started her doctoral studies and she does not wish to go into college teaching. She wants to work for non-profit organizations that work with children or educating the public.

The Urban Science Education Center

Professor Gordon runs the Urban Science Education Center at City Ville together with one other science education professor. The center is funded through several grants that were obtained by the two faculty members after they wrote a proposal to start the center. The goal of the Urban Science Education Center is to promote provision of equal opportunities in science learning to students in urban schools. The following goal of the center can be clearly seen in the mission statement on the center's website:

> All urban students ought to have equitable and just opportunities to develop the kinds of literacies (knowledges, skills, ways of knowing, and discursive practices) necessary to make informed decisions about the science, mathematics, and technology related matters that they encounter in their daily lives.

To achieve this goal, the Urban Science Education Center conducts research in four main areas namely: a) Developing deep understanding of empowering practices in K-12 science, mathematics, and technology education, especially for students from linguistic and racial/ethnic minority backgrounds and students living in poverty; b) Preservice teacher education and the preparation and on-going professional development of Science, Mathematics, and Technology teachers in urban school systems; c) Understanding & actualizing relationships between urban communities, schools, and universities, and d) Equity issues surrounding science education in urban areas.

Professor Gordon and a colleague wrote grant proposals to start the urban science education center in response to the problems faced by youth in urban youth. Urban science teaching and learning is in jeopardy due to poor funding, lack of resources and high staff turnover. The science educators at City Ville saw it as their duty to develop a center whose mission was to support teachers as well as prepare doctorates who will become urban science educators and researchers. There was need to provide fellowships to doctoral students so that they could spend more time in schools and have more extensive teacher education experiences. The job of the Urban Science Education Center is therefore that of helping teachers to understand urban youth and to connect the curriculum to them and understanding how urban school systems work. The Urban Science Education Center also help teachers procure some resources that they can use in their teaching and also help them identify resources available in the city that they can utilize for science teaching. The urban science education center currently works with eight partner schools, and the partner schools range in size from 200 students to 1200 students. The number of teachers in a school can also range from 1 teacher who is doing all the science to 6. The center has 10 fellows that are a combination of 7 masters and 3 doctoral students and the fellows work with the teachers in the partner schools to do participatory action research throughout the school year.

Findings

This section answers the following research questions: "How are science education doctoral programs responding to current reforms in science education in their coursework and other mentoring experiences offered to doctoral students?"

Courses Offered

The course requirements for Science Education doctoral students at City Ville are listed in table 4.1 below: PhD students are required to take a minimum of 75 points (credits) in the following areas: disciplinary courses, science education courses, specialization electives, technology, core professional courses, research methodologies, non-specialization electives, and dissertation study.

Table 4.1: Selective and elective courses offered at City Ville

Course	Required Points
Disciplinary	15 points
Science Education Courses	18
Specialization Electives	17
Technology	3
[subtotal=area of specialization]	*50*
Core Professional Concerns	12
Research Methodologies	9
Electives (Non-Specialization)	3-6

Dissertation Study	6
TOTAL	*75 points*

The disciplinary courses include Nature and Practice of Science, PCK course, and Science, Technology and Society course (Table 4.2). The PhD students are also required to take five Science Education courses listed on the right hand column in Table 4.2 below:

Table 4.2: Disciplinary courses and science education courses offered at City Ville

Disciplinary Courses	*Points*	*Science Education Courses*	*Points*
PCK Course	3	History of Science Education	3
Science, Technology and Society	3	Curriculum and Pedagogy in Science Education	3
Nature and Practice of Science	3	Science Teacher Education	3
		Urban Science Education OR a class in equity/science education	3
		Science Professional Seminar (1 point course taken 3 times)	1 (x3)

Doctoral candidates are required to take a minimum of 15 points in science content courses, 15 points in core science education courses, 12 points in professional education courses, 12 points in research methodology, 3-6 points in methodology, and 6 dissertation points. This leaves 12-15 points of optional studies to be determined in consultation with the advisor. Students are required to take three points of each of the following core professional courses that are offered outside their department: History and Philosophy of Education, Sociology, Cultural Dimensions, Policy and Organization of Education; Cognition and Psychological Foundations of Education; Curriculum, Instruction and Teacher Education. Students also take a total of nine points of qualitative and quantitative research methods courses and a minimum of six dissertation seminar points with no specified maximum. Students must complete 55-65 points or complete five science education courses to qualify for certification examinations. A maximum of 30 graduate level credits may be transferred to meet the degree requirements in the following areas: disciplinary courses, technology, core professional concerns, research methodologies, and electives.

According to the faculty members at City Ville, the university as a whole has an emphasis in Urban Science Education. They offer multicultural courses, develop teachers for urban schools, and develop doctoral graduates to do research in urban areas as well as prepare teachers for urban schools. The Science Education courses cover themes such as Urban Science Education, Curriculum and Pedagogy in Science Education, History of Science Education and Science Teacher Education. I chose three courses that I analyzed to show how the coursework addresses some of the issues that are pertinent in the current reform efforts and how the program is interpreting the national goals of 'teaching science for understanding' and science literacy for all. From the analysis of course materials and interviews, it became apparent that the science education doctoral program at City Ville interprets the goals of science literacy for all as referring to providing access to all students including racial/ethnic minorities and students living in poverty. I will give examples from courses, research and some interview data to support this claim in the following sections.

One of the science education courses that all doctoral students are required to take is entitled: "Teaching and Learning Science in Urban Settings". My reading of the course description showed that it focuses on issues of science for all in terms of addressing equity issues, teaching science for social justice, and curricular and pedagogical issues in urban settings. Below is a quotation from the syllabus which shows how the course focuses on what science educators should know and be able to do in order to achieve the 'Egalitarian ideal' of science literacy for all, which is outlined as the national goal in the reform documents (NRC, 1998; Benchmarks for Scientific Literacy, 1996):

> ..... but many of us chose education because we wished to help it fulfill its egalitarian promise. This course is meant to support you in enacting this ideal. We will look into what is going on in terms of "science for all" in this City, as well as think about and, importantly, act upon our ideas concerning what urban science educators can do to make science education in urban settings, places rich with opportunity for city kids.

From the above quotation, it is clear that this course explicitly incorporates the reform agenda of achieving science literacy for all. However, the course probes into how science educators can provide opportunities for city kids specifically in order to achieve the goal of science literacy for all. This way of looking at the reform goals is evidence that the program at City Ville interprets the national reforms goal to be a plea for access to science education by all students. In this case 'all students' means paying more attention to those students who do not have equal access to science education as a way of equalizing opportunities.

The course engages students in discussions of scholarship in the area of urban education through reading books such as: "*Improving urban science education*" by Ken Tobin, "*Teaching science for social justice*" by Angela Calabrese Barton, "*Connecting School and Community with Science Learning*" *by* Bouillon and Gomez, and "*Science Education as a Civil Right*" by W. Tate among other authors. Group assignment themes such as "*Developing an Anti-deficit perspective*", and "*City as Laboratory*" clearly show that the intent of the course is also to engage students in a discourse that helps them change their way of thinking about urban teaching and learning from the long accepted deficit model that pre-determines failure of city youth who live in poverty and attend poor schools to a social justice approach that emphasizes what ideas students from different socio-cultural backgrounds bring to learning science and what they are able to do. The course gives doctoral students the opportunity to understand the root causes of inequalities in the city schools as shown by the following quote from the syllabus: "As one delves deeply into the issues, one may begin to realize that our urban schools are a reflection of our deeply inequitable society." The course also helps them to consider the strengths that urban youths bring to learning as well as realize the rich resources that the city has to offer for science teaching and learning.

This course explicitly addresses the idea of how "Science literacy for all" can be achieved. Focusing on the possibilities and affordances in the city schools is one way of bridging the gap between the "haves" and "have not"; between the "rich suburban schools" and "poor urban schools." Without a careful look at the inequity that exists among the schools it would be impossible to achieve the egalitarian ideal of science literacy for all. The program at City Ville therefore focuses on improving urban science education as critical to achieving this goal.

Another required Science Education course is entitled "Curriculum and Pedagogy in Science Education." This course provides some historical perspectives on science curriculum and pedagogy. It also explores some key ideas in learning and teaching that have had a profound influence on the development of science curriculum, including conceptual change, situated learning, and social constructivism. The course also considers several current science curriculum efforts to systematically evaluate curriculum projects and the role of science curriculum in the current climate of educational reform. This course explicitly addresses the reform documents and it implicitly addresses the issues of "Science for all" in terms of multiculturalism and gender in teaching science. The following quote from the syllabus clearly shows this:

> These themes include issues of multiculturalism and gender in the teaching of science, research on teaching, learning, and curriculum, subject-specific teaching, transfer, and professional development. Although these themes will not be addressed explicitly, they will be central to our class discussions and may serve as the focus for class papers.

The course syllabus is explicit in its aim to engage students in a discourse on the development of the science curriculum through readings such as: "*Creating usable innovations in systemic reform: Scaling up technology-embedded project-based science in urban schools*" by Blumenfeld, *et. al., "Research towards an expanded understanding of inquiry science beyond one idealized standard"* by Songer, et.al, and *"Tools for bridging the cultures of everyday and scientific thinking*" by Hawkins and Pea. The readings for this course emphasize issues such as inquiry, which is at the heart of the National Science Education Standards. Science for All Americans (Rutherford & Ahlgren, 1990), Benchmarks for Science Literacy (AAAS, 1996) and the National Science Education Standards (NRC, 1998) all emphasize what every student should know and be able to do in order to become scientifically literate and they also emphasize that understanding can only be achieved through doing science as opposed to rote memorization. By emphasizing inquiry, this course therefore addressed the reform goal of 'teaching science for understanding'.

The two courses described above are just two of many courses that science education students are required to take but they give us an idea of how the program at

City Ville is engaging its doctoral students in a discussion and discourse about the goals of the current reforms in Science Education. What makes these courses more appealing is the fact that they are not just focusing on teaching and learning of science in the traditional way, but they are taking a critical look at the complex education system and considering contextual factors that influence students' learning such as school funding, resource availability, teacher development, and the students' backgrounds and experiences. The science education curriculum is also being looked at with consideration to all these other issues. The program is bringing together the content of the reforms and the context within which education is happening as a way of ensuring achievement of the reform goals of 'teaching for understanding and achieving science literacy for all.

Addressing the Current Science Education Reforms: Analysis of Interview Data

The reforms are incorporated in the discourse of the courses and one specific course called "History of Science Education" exposes students to documents such as the National Science Education Standards and Project 2061 Benchmarks. The following quote from Professor Gordon clearly demonstrates this claim:

> The first course our students take is a history of science education where they are exposed to all these documents because they are part of the history. They study not only the content of those documents but how and why these documents came to be and how they form the debate within the field. (Interview, 9/21/2005)

The standards are looked at from a critical standpoint and policy. According to Professor Macarthur, the doctoral curriculum at City Ville has not been driven by the standards but that standards do get incorporated into the discourse of the courses. However, Professor Gordon mentioned that she has used the reform documents to help students understand what has happened in the field and not what the field must be. She also emphasized the fact that when she teaches she helps students argue both sides of the reforms that is the advantages and disadvantages of the way the reform documents are written. In the following quotation Professor Gordon shows how the reforms have been used in two specific courses:

> They also take a class in 'Equity issues in science education' and they use those documents as reference for looking at how the field has established policy around issues of equity and to see how the field has responded to the ways in which equity issues play out implicitly and explicitly. They are also required to take a class on 'Curriculum and pedagogy in science education' and they look at how different curricular and pedagogical issues both have informed the writing and implementation of these documents and subsequent policies that led to these documents. We use the documents as a way to position what has happened in the field but not to say this is what the field is and must be. When I teach I help students argue both sides. (Interview, 9/21/2005)

Here Professor Gordon shows that the focus on urban education and achieving science literacy for all take precedence I the way she addresses her courses. She uses the reform documents to help students to see how people have interpreted the policy and what other ways of interpreting the policy are.

Although the faculty members at City Ville agreed that they are addressing the reforms in their courses, this does not seem to be apparent to all the students. According to the doctoral candidates interviewed, some felt that only part of the reforms was addressed and that it was left to the students to make sense of the rest of the reforms. These students also noted that how the reforms were covered depended on the professor teaching the courses. At least two of the doctoral candidates were in agreement with the faculty that the first course they took on "History of Science Education" exposed them to the reform documents. The following quote from Amanda, a doctoral candidate, illustrates this point and the fact that, besides the one class mentioned above, there was not much talk about the standards:

> The first class I took at City Ville the standards were the required reading. The presentation was mainly pro-standards. I started my masters program in 1998 and I guess they were still new then. But was certainly presented as a model on which science teaching should be based. During the doctoral study there wasn't much discussion about the reforms. In my certification exams you have to quote the National standards. I think they need to see ways that standards can be incorporated into the classroom and they need to study the standards first to see what's in there.

Amanda felt that there is a need for the program to really look into the standards in terms of how they can be applied to the classroom. Since Angela took the "History of science course a long time ago, it looks like this has changed because June a doctoral candidate was in agreement with the faculty that they explore the reforms in more depth in the doctoral courses. She however still highlighted the fact that the discussion about reforms depended on who was teaching the courses:

> We talked about project 2061 and we have talked about science education reform efforts, I would say that its very uneven what gets discussed in different classes, I think its more at the whim of the professors, and maybe there is a larger scale model in which the professors sit down and discuss that we should discuss the reform efforts here and this initiative there. With the National Standards we have done a unit in Evolution focused on the standards in Evolution or do a unit on redox reactions then you focus on the standards but as an overall coverage I don't know that we have done that and I don't know how practical it is to look at the different standards in all the different sciences. But I am aware of them and realized that I should be looking towards them as a guide when I am designing lessons. (Interview, 7/28/2005)

Pamela, the third doctoral candidate had conflicting views to these other two. She felt that she was not well informed about the reforms and she mentioned the fact that there seemed to be an implicit requirement to know the standards even if they were not discussed that much in class:

> I learned about standards a little bit more through teaching than through being a student. I did not find it easy to explore them. If I had a class that talked about it I would have been more informed about it. Project 2061, the only time I heard about that was when I took History of science education. People talk about that in passing but I have never had an entire course or somebody sit down with me and

> explain to me what those things are. It's something you are expected to know what it is but nobody teaches it to you so you are expected to learn it on your own or you learn about it by talking to other people. (Interview, 9/12/2005)

The doctoral candidates show conflicting ideas about the incorporation of the reforms in their coursework. They all agree that the reforms were covered to some extent in class, but they differ in their satisfaction with understanding what the reforms entail. One explanation for this discrepancy could be due to the fact that different professors dealt with the issues differently. Some professors may have directly addressed the reforms and took a closer look at examples like the ones mentioned by June and yet others could have just mentioned them in passing. The differences between the doctoral candidates' expectations are interesting to note. Whereas Amanda seemed comfortable with knowing that the standards are there and that she is expected to use them when designing lessons. Pamela felt that since they were expected to use the standards, she expected them to be taught to directly.

Similarly, the recent graduates also had conflicting views about how the reforms were addressed in their courses. Only one of the three recent graduates, Michael vividly remembered taking the mandatory course that addressed the reforms and the nature of the coursework as shown in the quotation below:

> Yes they were part of a mandatory course. It was one of the courses we had to take the very first semester when we got in. We had to read all these books and had to write papers on advantages or drawbacks they bring in science education. There were quite a few discussions during class time looking more like a debating with some people supporting the pro aspect and other people supporting the con aspect. In other courses we talked about the standards but we did not have to read the books. Most of the science education courses had something to do with the reforms. (Interview, 7/22/2005)

Michael is the only recent graduate who seemed to reflect the faculty's position about how the reforms are incorporated in the coursework. The other two graduates included in this study did not agree with this. Courtney for example did not seem to agree with Michael about the depth of coverage of the reforms and she had this to say about the reforms:

> I don't think there was discussion really. It was more sort of they are there and if part of the project you are doing is designing some curricula unit where you are talking about some issue then you better be prepared to relate to what the standards say about it and if its goanna be relevant for the schools. (Interview, 7/22/2005)

Her response shows that she engaged with the reforms only through working on projects. Again, these discrepancies may be partly due to the fact that some graduates who came earlier than Michael were not required to take the History of Science Education course. Courtney a 2004 graduate shows that she did not take this course, which may be why she does not share views with Michael. On the other hand, Michael graduated two years earlier than Courtney and one would expect that Courtney should have had experiences that are closer to what the faculty said.

From analysis of course materials, faculty views, doctoral candidates', and recent graduates' experiences, it is clear that the science education doctoral program at City Ville is incorporating the current science education reforms in the framework for their courses as well as addressing the goal of achieving science literacy for all. In this section I provided evidence to show how the doctoral program is addressing the current reforms. In the next section I am going to show the focus of doctoral students' mentoring.

Mentoring of Graduates Students Through Research and Teaching

The science education department at City Ville is comprised of five faculty members. All are involved in different areas of research. The type of experience and mentoring different doctoral students get depends on the faculty advisor and the type of research they are involved in. For example, one professor's research focuses on neuro-cognitive models of student learning; another professor focuses on Urban Science Education, feminist studies in science education, science in the community; yet another professor focuses on curriculum reform and two faculty members focus on teacher education. All the professors use qualitative research methods except for the professor working on neuro-cognitive models of student learning. The faculty members at City Ville mentor their doctoral students through working with them on research and teaching. Research assistantships are mostly grounded in a research grant that a professor has, so not every doctoral student gets a research assistantship. A smaller percentage of doctoral students get research assistantships since City Ville is a privately funded University, hence it does not receive state or federal funds to support students through assistantships.

Seven students teach in the teacher preparation program while 12 students have research assistantships and work primarily in the Urban Science Education Center, as well as on collaborative projects with the College of Science and the College of Engineering. A few students assist with science lab courses. Ten students who are studying to be urban science educators have fellowships in the Urban Science Education Center. All the assistantships and fellowships have a Science Education focus either on preparing doctoral candidates to do research in urban schools, to prepare teachers for urban schools, or to prepare them to become urban science teachers.

The mentoring level for doctoral students who teach varies from working closely with the faculty to being highly independent. However, one of the faculty members mentioned that the university requires that a mentor be assigned to a teaching assistant who observes them teach once or twice a semester and provide feedback. Students have formal research preparation through a required research practicum but there is no required teaching practicum.

Both Professor Gordon and Professor Macarthur have research grants that are currently supporting graduate research assistants. Professor Macarthur highlighted the formal mentoring that his research assistants receive in the following quotation:

> Right now we have a Spencer grant to bring together PhD students from science education together with technology education and cognitive sciences all in one interdisciplinary seminar to help them understand the multi-dimensional approach to research to bear on some issues of learning. Thinking how students come to develop some conceptualizations of experiences in science and technology and how we look at it from the different perspectives that involve cognitive and socio-cultural. There is a form of mentoring where we meet every week for at least one hour, that is the big group and individuals meet with their mentors on a regular basis. (Interview, 5/20/2005)

Professor Gordon also mentioned that her students are mentored formally through the Urban Science Center. She highlights the nature of the mentoring for her students:

> Another formal structure we have is the urban science education fellowship that I mentioned. This provides students with paid opportunity to conduct action research in schools under the guidance of faculty and it gives them a chance to be mentored into how do you work in collaborative relationships with schools so that that if they want to do something like that for the dissertation or when they move on to academic positions or a school based position they will have had that experience...... The urban science education center runs weekly seminars for the folks who are doing a cognate area in urban science education and in that weekly seminar readings are discussed and each week a different student is in the spotlight and is asked to present a question or dilemma related to the research or a piece of their data they want to talk about so it mentors students into being a part of a scholarly community. (Interview, 9/21/2005)

The above quotes show that both Professor Macarthur and Professor Gordon mentor their students to engage in collaborative research. In both cases the students have the opportunity to meet with other researchers and share ideas. In the case of Professor Gordon the meetings involve engaging in the discourse of science education and presentations. The students who are exposed to this type of mentoring acknowledged that they are being well-prepared for the job.

The formal mentoring all doctoral students receive is through taking a one credit graduate level course where graduate students are exposed to different faculty. Students also take a series of courses that deal with the nature and practice of science. A quotation from Professor Gordon below illustrates part of the formal mentoring process of doctoral students:

> For the formal mentoring we have actual program structures in place which include professional development seminars, a one credit class that meets every fall and every spring and students have to take at least 3 semesters of that and that covers lots of topics such as what are the different career options available to science education graduates, what are the current issues in science education etc? The professional development class they take for one credit is one way they are mentored. The cluster is small and it brings in a variety of faculty to speak and expose them to different faculty. (Interview, 9/21/2005)

Whereas some doctoral candidates and recent graduates are generally happy and satisfied with their mentoring experiences, others who have not had similar mentoring experiences as their colleagues in the Science Education Center or on the Spencer fellowship feel that they did not get as much mentoring as their colleagues. June a doctoral candidate who is happy with the mentoring from her advisor said this about her experience:

> I worked with Professor Gordon for a couple of two years through the group called urban science education and interactive technology and since then I have been doing research on my dissertation. I am very happy with Professor Gordon. I am always impressed by her diligence and her commitment to producing quality work. (Interview, 7/25/2005)

On the other hand, a recent graduate, Kathy did not feel that she received good mentoring and she did not feel well prepared when she started working. She felt that she did not get good advice on what she needed to do. She went through her program in two years, so she that felt she could have been advised to slow down and take more time to get mentoring and preparation for the job. Below is a quote that shows what Kathy felt about her mentoring:

> I did not have any formal mentoring when I was teaching. I had my advisor for my dissertation, technically he was my mentor but unfortunately we just talked about the content-- that was it. We did not discuss about my teaching. I think there should be more sort of group mentoring. Its nice also to talk to your peers and have informal discussions of issues in science education. I know Prof.... put up an informal discussion once a week. It became more scholarly and looking at current research, I really enjoyed that. You could even have online discussions for people who have family commitments etc. (Interview, 6/22/2005)

Kathy graduated from the program 5 years ago and she mentioned that things have changed since she graduated and that students were receiving more formal mentoring than they did in the past. Although the doctoral candidates are generally happy with the mentoring they are getting in research, some felt that they are not getting good mentoring in teaching because they either get to teach a required syllabus with not much feedback or they just use the knowledge from having taken the course earlier. There was a general feeling among recent graduates and doctoral candidates that teaching assistantships should be made compulsory so that everyone gets to learn to teach. Some recent graduates like Kathy found that it was hard to learn to teach on the job.

Roles Doctoral Candidates are Being Prepared for

According to faculty at City Ville, the doctoral students are prepared for university teaching, research and teaching in urban schools (See figure 4.1 below). Almost all the interviewees felt that they were well-prepared in the areas of teaching, teacher development, and understanding contextual factors influencing teaching and learning in schools.

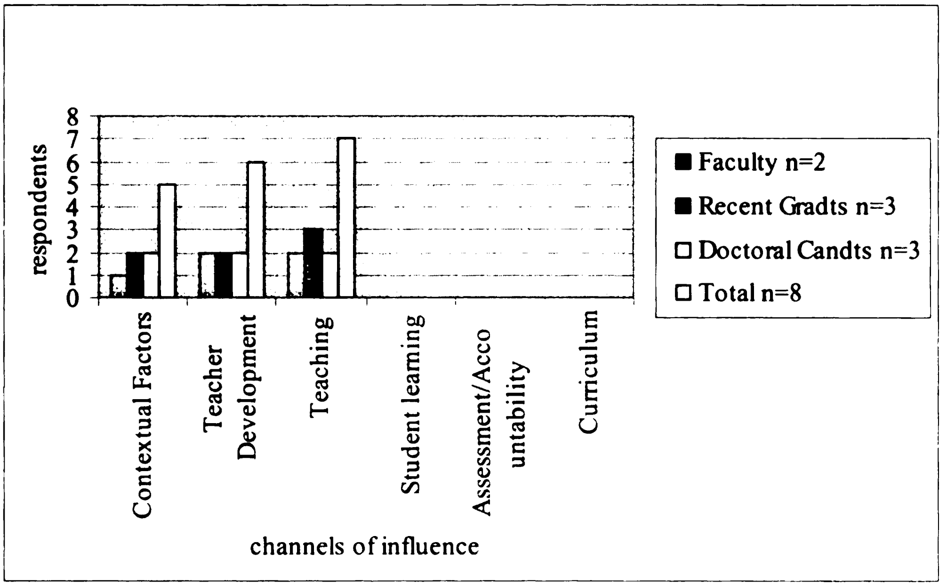

Figure 4.1: Roles doctorates are prepared for

Although the recent graduates and doctoral candidates were in agreement with their faculty that they were well prepared for future careers in teaching, teacher development and understanding contextual factors, non of them talked about how the program prepared them in areas of student learning, assessment and accountability and curriculum. Even faculty members did not mention how doctoral students were prepared in these areas.

There was a general feeling among some doctoral candidates and recent graduates that faculty were pushing them into academia whereas they were interested in doing other things. In the quotation below Pamela a doctoral candidate clearly articulated how she and her colleagues a were thinking of working outside of academe in sectors like non-Governmental organizations:

> I want to go and work for a non-profit organization. The push from my advisor and other professors is to go into academia. Eventually I want to work for a non-governmental organization, but I don't know when. I want to work for an organization that works with children or works with the public, like the Center for

> Science in the Public Interest. Something like that where you educate the public about what is happening and making them scientifically literate. Both PhD and Ed.D candidates are not interested in academia. (Interview, 9/12/2005)

This statement from the doctoral candidate shows a disconnection between the faculty intentions and efforts and doctoral students' aspirations and needs. It is however surprising why these doctoral candidates seem not to be interested to pursuing careers in academia. One hypothesis could be that maybe they feel overwhelmed by the problems they see in the urban schools as they work with teachers. Although I did not ask Pamela to elaborate on the reasons of this seeming apathy towards working in the academy among doctoral candidates, it is something worth following up in future studies.

Views and Perceptions about Challenges in Science Education

This next section answers my second research question: "What are the perceptions of science education faculty, recent graduates and doctoral candidates, about the challenges confronting K-12 science education and how are these challenges related to the way the programs are preparing the graduates? In this part of the study, my goal was to establish what faculty, doctoral candidates and recent graduates from the science education doctoral program at City Ville consider being the most important issues in the field of science education and how these issues relate to the current science education reforms. I asked the interviewees to tell me what they see as the most important issues that the science education community should focus on in terms of researching, funding, and as they prepare new leaders in the field. I asked an open-ended question asking about their views and follow up probing questions were used to get more information about the issues that the interviewees raised. I analyzed the responses to the above question using the framework for assessing the impact of National Standards on student learning (described in chapter 3). The framework identifies five channels through which reforms are enacted in the education system to influence student learning. These channels include contextual factors, teacher development, teaching practice, curriculum, and assessment and accountability. As part of my analysis, I paid particular attention to which factors the interviewees emphasized. I also looked for matches between what the science educators think are important issues in the field and what the National Research Council considers to be important issues that influence student learning (or channels of influence). After reporting on this analysis in the pages that follow, I then continue with a discussion of the findings, first looking at how faculty are interpreting the reforms and then comparing faculty concerns to those of recent graduates and doctoral candidates.

I categorized the interview responses using the five channels of influence from the National research Council namely: contextual factors, teacher learning, teaching, student learning, assessment and accountability and curriculum. Generally, the interviewees identified all the six channels of influence listed above to be important issues that the science education community should be focusing on, but some areas where emphasized more than others. The interviewees identified the areas of urban science education, student performance, teacher quality and what knowledge is worthwhile as the most important issues in the field.

The area that was emphasized by most interviewees was contextual factors. Figure 2, shows that six out of the nine respondents placed emphasis on factors that I categorized as *contextual factors* as the most important issues confronting the field of science education. The issues they mentioned include issues of inequity, social justice, school funding, high staff turnover and low teacher salaries. This was double the number of respondents who placed emphasis on each of the other five factors, namely: teacher development, teaching, students learning, curriculum, and assessment and accountability as significant issues in the field of science education. Another issue that respondents from all the three groups emphasized was *student learning* (Figure 4.2). At least one faculty member, one doctoral candidate and one recent graduate identified student learning as an issue that deserves attention.

Although faculty and recent graduates emphasized *teacher development* as an issue that required attention, recent graduates did not talk much about this issue. The remaining three issues namely: *teaching practice, curriculum, and assessment and accountability* were emphasized by doctoral candidates and recent graduates and not so much by faculty. Therefore the two faculty members only emphasized the contextual factors, teacher development and student learning (Figure 4.2).

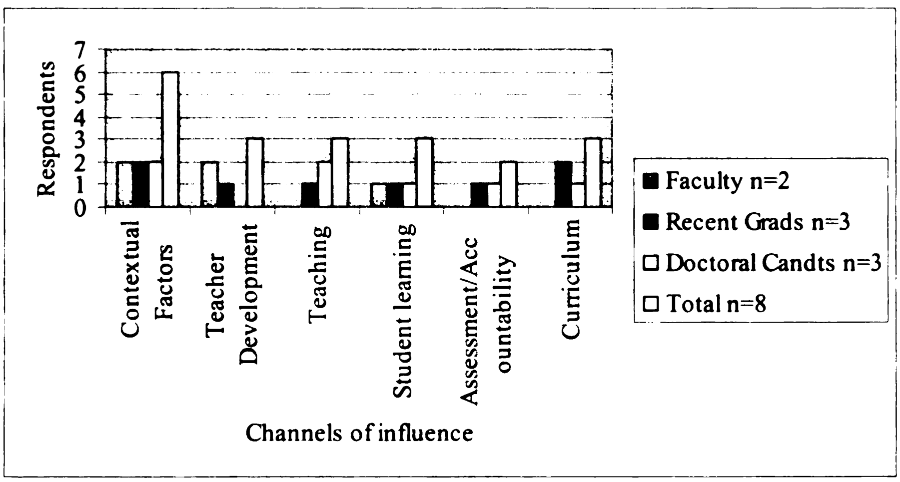

Figure 4.2: Views about the most important issues in science education at City Ville

Contextual factors

Issues that I categorized as contextual factors included talk about urban science education; specifically issues of inequity, social justice, teacher salaries, lack of resources and the quality of education urban students get compared to their peers in suburban schools. The quotations below show some examples of what the faculty, recent graduates and doctoral candidates see as contextual issues that influence student learning in science education: Both Science Education faculty members from City Ville considered contextual factors to be issues that require the attention of science educators. Professor Gordon for example, views issues of equity and social justice as major challenges confronting the Science Education community. She thinks these issues should be confronted in order to close the achievement gap that exists between the rich suburban schools and poor urban schools as shown in the following quote from the interview with her:

> As a field we have to confront issues of equity, in terms of looking at the achievement gap, looking at differential access to resources that is how well equipped the school is to teach science both materially and in terms of quality of teachers. (Interview, 9/21/2005)

Professor Gordon is highlighting a problem of science teaching in urban schools that has existed for a long time. There has been a ripple effect where lack of resources leads to shortage of qualified science teachers in urban schools because good science teachers choose to go and teach in schools that are well equipped. Specifically, Professor Gordon attributed the problem of science teacher shortage to two major factors namely, inadequate resources in the schools and lack of preparedness by the teachers to teach in urban schools which results in burnout. This is highlighted in the quotation below from an interview with her:

> .....in urban centers, the teacher turn over and teacher burn out rate is high and the number of teachers teaching science in urban centers in high poverty areas especially certified teachers is below 50%. I think the reason why teachers leave urban schools is because they don't have the knowledge base and skills they need to be effective in these settings so they burn out. I think there are other complicated reasons like salaries are lower and the schools themselves are under-resourced so it is difficult to do things they want to do. (Interview, 9/21/2005)

Because most teachers were not prepared to teach in urban schools, they do not understand urban youth and they find the job overwhelming and eventually leave for better schools. Professor Gordon sees the need for the science education community to focus on preparing teachers for the job of teaching in urban schools. According to Professor Gordon, understanding urban youth and what science means to them as well as knowledge of how to use available resources in the city to teach science are two key assets that are required for a science teacher to be successful in teaching science in urban schools.

One recent graduate Amanda agreed with Professor Gordon and she attributed the shortage of qualified science teachers to salaries that are uncompetitive compared to teacher qualifications. According to Amanda, science teachers are highly qualified in sciences and they could get better pay in other jobs. The fact that science is a skilled subject means that science teachers deserve professional salaries for them to stay on the job. Amanda highlighted the issue of teacher low pay and how this is exacerbating the problem of science teachers in urban schools in the quotation below:

> One of the reasons is, these teachers are paid on the same scale as all content teachers but I think those days are over. Realistically, its basic market economics, you cannot expect these teachers to give up more paying jobs in industry and other fields to become teachers, secondly its because teaching science is a very skilled thing to be able to teach science effectively, so you are asking teachers to have two highly professional skills, one is how to teach the content successfully and one is to have the content knowledge which is in and itself difficult. (Interview, 7/28/2005)

Amanda's point about teacher pay shows how difficult it is to attract scientists to science teaching as well as attracting good science students to education. Although this does not directly explain why teachers who do not have professional science qualifications leave their jobs in urban schools, it shows that shortage of qualified science teachers has led to science being taught by teachers who did not specialize in science.

Pamela a doctoral candidate from City Ville also shared similar concerns about the problems of science teaching in urban schools. Specifically she talked about how socio-economic status and lack of resources play a major role in influencing accessibility to quality science education in urban schools as shown in the following quotation from an interview with her:

> Depending on socio-economic status the kind of education you get is different from the kind of education rich students get. From my experience teaching, I run a couple of after school programs in high poverty schools where 90% of the children are living in poverty. There are three science teachers who quit in the middle of the year, they didn't have a lab, they didn't have any equipment, all the three science teachers were doing different things in their science classrooms, and it was a big mess. I also did a lot of research in the city schools, which are wealthy and mostly white, and it was very different although they are all public schools. (Interview, 9/12/2005)

Again this reinforces the existence of inequity in schools. Although efforts are being made by some educators to address the issues of equity and social justice, this interviewee sees these issues as challenges that are going to be there for the next 10 years or more. Below Michael, a recent graduate from City Ville express similar sentiments:

> I don't think there is going to be a change, within a decade or two we won't be in a position to tell people that the affirmative issues have been addressed. I think we will still be striving to achieve science literacy for all. The people in research right now dealing with these issues are not making that much progress as it was supposed to be. There aren't many that are working on this. Mostly people are focusing on the problem, they are not offering ways of overcoming the problem, so what people need now are ways of overcoming this problem and being able to

> offer science literacy for all. I think it's going to take so much time. (Interview, 7/22/2005)

The faculty, doctoral candidates and recent graduates from City Ville view these issues of inequity, teacher shortage and lack of resources as the most important issues that need to be addressed in order to achieve the science education reform goal of "science literacy for all". The views shown above confirm the doctoral program's commitment to urban science education. According to these views, it is clear that without social justice in the school system urban youth will continue to face the challenges highlighted above. Professor Gordon and the doctoral students are taking a critical look at the education system in their quest to achieve science literacy for all. In this case, "all" in "science literacy for all' is interpreted to mean all students including those in urban schools. They see issues of inequality in science learning among schools as the biggest hurdle to achieving science literacy for all. Social justice is therefore seen as a pre-requisite to achieving the national goal of "science literacy for all".

Student Learning

The issues I classified as student learning included talk about what it means to be a scientifically literate person, the role of media in urban science education, science not being taught in a way that is relevant to the lives of students, US students' performance on international tests and effectiveness of elementary science education. Professor Gordon for example, expressed her concern that the science education community does not seem to have a definition for what it means to be scientifically literate and what that means for what should be happening in the schools. For Professor Gordon, a scientifically literate person is one who is able to use the science knowledge they learn in school. She is concerned about what science means for urban youth and how it can be made relevant to their lives. The work that Professor Gordon is doing in the Urban Science Education Center focuses on helping teachers understand who the urban youth are, what science means to them and how science can be made relevant to them so that they can use it in their lives:

> We take a social justice approach to our work, which means we have an insider's perspective on what kids and teachers bring to the classroom. We work really hard to understand and build upon the forms of knowledge that teachers and kids bring to the classroom and we also work really hard to help the teachers and kids to use the science that they are teaching and learning in the classroom to take action in their lives and their community. With the work that we are doing around building stronger community connections within the curriculum, that could be something as simple as refining the lesson so that kids can bring in their perspectives but it can be something more complicated where the kids design a panel of community experts to come and talk about an issue that they are exploring. We are working on a curriculum that actually teaches urban ecology, we are looking at what happens to food we buy from the grocery stores, so that's the content. We are using a variety of curricula resources that the City Board of Education has adopted for the middle schools in the city. The idea of community connections is really broad and I think it embraces this idea of social justice and by getting at that community connections research that our teachers and fellows are working on they are also asking the question what do teachers need to know in order to do this. (Interview, 9/21/2005)

Professor Gordon is making science meaningful to urban youth by establishing better linkages between what goes on in the schools and what goes on in the home and the community and what goes on in places where informal science learning occurs. She is also focusing on curricular justice by looking at science curriculum from the perspective of what knowledge students and teachers bring to the classroom. This way science becomes more relevant to the students' lives. By so doing the students can identify with science and they can find science to be a meaningful. So Professor Gordon sees both social justice and curricular justice as prerequisite to achieving science literacy for all.

Kathy, a recent graduate from City Ville shared similar concerns with Professor Gordon about the relevance of science being taught in schools. She strongly felt that the science being taught in schools is not being made relevant to students' lives. She feels that people experience science in their daily lives and yet these experiences are not connected to science teaching in the schools. Her ideas were shaped by her dissertation research that focused on informal science as shown in the quotation below:

> My research has been on informal science, museums and television; the Internet now is very powerful. When I say TV I don't just mean science documentaries, I mean the X-files, CSI, ER, News, CNN, cartoons, and children's programs. I am really looking at Citizen Science – stuff we learn in science that impacts human life. I looked at mediated science but as a researcher and a scholar in a big city these are issues that I think may become more important. (Interview, 6/22/2005)

Kathy feels that science education should be related to the way people lead their lives. She thinks that the way we do research and think about it should be in relation to the way the communities lead their lives rather than trying to create these artificial constructs. Kathy strongly feels that external factors such as the media play a more critical role in science education and hence there is need to understand how what we learn in science impacts the individual's life especially in the city. Kathy is taking a critical look at how science can become more accessible to all students and how students can identify themselves with science.

On the other hand, Professor Macarthur expressed his concerns about student learning from a different angle. His is concerned about the lack of rigor in K-12 science education. Among other things, he decried the quality of science education that all American students are getting in K-12 education. Professor Macarthur talked at length about how lack of rigor in science education has created an achievement gap that is evident on international standardized tests. He highlights his point:

> One major concern in the field is the International science education gap - from the TIMSS studies and the National Education Association studies on student performance in the last 10 years have strong political and professional

> implications.- The ranking of US students' performance vis-a vis the other developed countries. I think this is a very critical issue that needs much more intensive analysis. (Interview, 5/20/2005)

Professor Macarthur also attributed the problems of poor scores to the science education community's lack of a deeper understanding of individual differences that come into play in science learning. He sees the need for more in-depth research into the area of diversity among learners. Diversity in this case refers to individual genetic differences and capacities in science learning among different individuals especially as they mature. He feels that there is need to understand the intersection between individual capacities as people mature and their cultural experiences and how this influences science learning. The quotation below shows Professor Macarthur's explicit clarification of his view about the importance of a cognitive approach to achieving science literacy for all students:

> I have a feeling that the productive research and insights you gain from this epistemological and psychological approach will soon come to a limit unless we get at what I would call the genetic neuro-cognitive basis of learning and by genetic I mean something broader than Piaget's developmental genetic epistemology. I don't think we fully appreciate what we mean when we talk about diversity, how people differ in terms of their capacities to deal with the processing of some of the information we want people to learn in science based on their genetic capabilities. I am talking about human individual differences, so people vary in their capacities. We don't take that into consideration. We think every person is keen about science and that every person is naturally a scientist. That may be true but as people mature I think we need to know how their hereditary propensity and competencies and potential interact with their cultural experiences to determine how they really learn. Science is a more demanding and we are scientists because we do well in the field but not everyone maturing is going to have the same propensities and competencies. We better know about that as scientists and how best to reach people. This would help address the issue of science for all. (Interview, 5/22/2005)

Professor Macarthur views a deeper understanding of the issues of diversity in science learners to be the key to figuring out how different people learn and help them develop their potential. So for Professor Macarthur science for all means teaching science for diversity among learners, and he sees the need to look closely at how to reach out to students who may not be as good at learning science as the average student.

It is clear that the two professors at City Ville are defining diversity among learners differently and they are finding different means to achieving the goal of science literacy for all. Whereas Professor Gordon looks at diversity in terms of advantaged and disadvantaged populations in society, Professor Macarthur talks of diversity in terms of differences among individual learners. Both meanings of diversity are important to consider when thinking about achieving science literacy for all, but for Professor Gordon it is hard to imagine how one can separate the impact of poverty from individual learner capability in poor urban schools. In this case, individual differences among "all" students, can be studied after achieving equitable distribution of resources among all schools.

In agreement with Professor Macarthur's concern about science teaching, June a doctoral candidate also echoed similar concerns about lack of rigor in K-12 science learning and poor student performance on international tests, especially as the students grow older:

> Rigor in American students learning,... students are not being competitive. I think a lot of reports in the last several years..., the TMSS report..., I particularly focus on physics education, so the American institute of physics, the NCTM all those suggested that American students compete, at younger ages they are competitive with students around the world but as they get older their competitive ability decreases. And then for the more anecdotal view I teach in inner city and have a sense of the amount of science kids know and more visibly the amount of math they can do coming into high school. We should certainly note that at the level I learned math in high school was much lower and this does not really prepare them for pursuing degrees in the sciences that involves math. To some degree they go for biology and the physical sciences. Those students in school who are interested in engineering in college haven't had the ability to stay competitive in their coursework. (Interview, 5/20/2005)

This lack of rigor is even more prominent in the urban schools where the graduates are not prepared for careers in engineering or other careers that require math or physics. Although June makes reference to general performance in the sciences, she also makes specific reference to the amount of science and math students in the inner city gets and how this limits their opportunities. June's concerns are similar to those of Professor Gordon whose focus is on the relevance of science taught to urban youth.

Michael talked about student performance. Even though Michael acknowledges the low levels of student performance in international tests, he also sees these tests as playing a significant role in helping people to know which countries are doing better on the tests and how these can lead to studies to see how the successful countries are teaching their students. Michael shares his feelings about the importance of studies that give a global perspective on student performance:

> The effort to understand student science understanding in international research studies such as TIMSS and PISA in order to get a global perspective in an attempt to use these results to inform the local school system. So you can see countries doing well in science and checking out afterwards why they are successful in science literacy so you go to study educational systems and you bring information to your local school system. These are what I saw as the two big issues. (Interview, 7/22/2005)

This lack of competitiveness by US students on an international scale is attributed to the limited amount of math and science subjects that prepare students for such careers as technology. This situation is worse in poor urban schools that do not offer science courses like physics. June also shows the impact of the lack of preparedness of students to compete in the global economy:

> I think that particularly the students for example in public schools have limited access to pursue careers in technology, in computer science, in engineering. It's just not part of the curriculum at all in most schools. Many schools in this city don't even offer physics at all. They take Regency Biology as a requirement for

> high school. I think in a world where there a lot of good jobs in engineering and computer science, innovation and technology, I think that overall American students become consumers of that so they purchase it but they lack the skills to ever develop it. Graduate programs in physics are almost entirely foreign students who go back to their countries because they get jobs in their home countries that are comparable in quality of lifestyle that they provide and for most people if they can be close to family and friends they are likely to do that. (Interview, 7/22/2005)

Again June attributes the lack of preparedness among students to limited access to science, specifically physics by students. Mostly this is due to shortage of teachers who are competent in that area. This again brings out the problem of teacher shortage in urban schools, which Professor Gordon also highlighted.

Teacher Development

Issues I categorized as teacher development included talk about the need to define a knowledge base for teaching, understanding the nature of science, and the need to improve science knowledge among teachers. Both faculty members at City Ville and only one recent graduate emphasized teacher development as an issue that science educators need to address (see figure 4.2). Professor Gordon strongly felt that in order to improve science teaching in the schools, the science education community should be clear on what the knowledge base for teaching should be, as shown in the following quote from an interview with her: "*There is need to* define *what teachers need to know and be able to do to teach science in a way we as a field define it*".

Professor Macarthur shared similar concerns with respect to preparing teachers to teach elementary science as shown in the following quote: "*We recognize the importance of early education in other fields but especially in science we haven't clearly investigated hard enough.*" Science teaching in elementary schools has always posed a challenge to the field mainly due to teachers who lack an understanding of the science content. More so now with the No Child Left Behind, science is being pushed to the margins since it is not the focus of testing. Kathy, a recent graduate also shared similar sentiments to Professor Macarthur with respect to the level of science knowledge among science teachers:

> The decreasing level of appropriate scientific knowledge among our teachers – As I teach teachers, more and more of them have minimal science backgrounds among elementary teachers. Most of them take a few ed courses then they go and teach. Unfortunately most of these people have prevented science experiences in their own education and how much can you do in one science methods course. This is my personal frustration, there is not so much you can do to change a whole mind set in one semester. How do we make teaching more accessible to people with stronger backgrounds in science. (Interview, 6/22/2005)

The frustration shown by the professors and one recent graduate show that achieving the goal of scientific literacy for all may just be a "pie in the sky" if the teachers are not well prepared for their job. Since teachers are the ones who have to make the goal real, they need to know what to do and be able to do their job.

Professor Macarthur also emphasized the need for the science education community to have an understanding of what we mean by the nature of science and how that needs to be clearly communicated in order for the science education community to be able to be successful at achieving the goal of producing scientifically literate citizens. Professor Macarthur illustrates this point:

> Understanding the Nature of science – If we are to teach people to be literate in science we have to be deliberate about what we are going to do and we have to understand what is the nature of what we are trying to communicate. In the broader sense the epistemology, philosophy and nature of science is an important issue. Although we have not reached much consensus we have only a few people like Norman Lederman and a few other people working in these areas. I think we clearly need to know what we mean by the nature of science for us to have any effect. (Interview, 5/20/2005)

The two professors brought up an issue that all science educators may agree with. The fact that there is no clear definition of what teachers need to know and able to do is a challenge to the field of science education. Different scholars emphasize different aspects of what teachers should know and able to do. A similar thing happens with the nature of science. Since there is no one definition, it is open to different interpretations by different people. In a way these professors see this as a drawback to achieving the national goal of achieving science literacy for all. If science educators are doing things differently, then they are likely to ignore some aspects that are seen by others as important.

Teaching Practice

The issues I categorized as teaching practice included talk about supporting urban science teaching, reforming teaching to reflect more constructivist approaches, helping teachers align their teaching to the standards and higher education's failure to teach all students. One professor, one recent graduate, two doctoral candidates from City Ville emphasized the need to support teaching practice as an issue that the science education community should focus on (see figure 4.2). June a doctoral candidate mentioned the fact that supporting teachers in urban schools both with curriculum and content could significantly help address the problem of lack of rigor in schools. She sees the need to come up with more rigorous curriculum that involves higher order thinking and teaching through inquiry as a way for students to develop a deeper understanding of science concepts.

> In terms of addressing those issues, the options are really vast, like everything ranging from supporting elementary science and mathematics teachers much more thoroughly in the areas of science and math to doing things at curriculum level that are basic skills focused but also require higher order thinking, require inquiry based approaches so students are synthesizing the content with the skills they are learning. (Interview, 7/25/2005)

Considering the fact that the science curriculum materials that have long been used in the schools have been found not to meet the requirements of teaching for understanding (Kesidou & Roseman, 2002), it is imperative that science educators find ways to make available high quality materials that support teachers to practice inquiry and that teachers use them effectively in order to achieve the goal of science literacy for all.

Amanda a recent graduate also emphasized the challenge of preparing teachers to adopt a constructivist view of teaching science, which in most cases is different from the way they learned in school. In the following quote, Amanda articulates the reasons why adoption of reform based teaching remains a challenge:

> There has been a whole lot published on constructivism and conceptual change in terms of the way science should be taught to students. There is a big movement to get away from lecture in the classroom, which is how many of the American students were taught when they were in high school. Many of the teachers were taught that way in high school. So we are trying to move away from that and take a more constructivist approach where the students are more actively engaged in learning in the classroom. (Interview, 7/28/2005)

As discussed earlier, most teachers have rarely seen teaching that is based on the constructivist or conceptual change theories, namely inquiry in practice. From my experience teaching pre-service teachers I have realized that they find the idea of teaching through inquiry to be very attractive and something that every teacher should do. But they have many questions concerning how this can be done in real life because their cooperating teachers are not teaching this way.

Professor Macarthur showed concern about lack of effective science instruction in the schools, especially in lower elementary. He pointed to the fact that there has been a wealth of research on constructivist theories of learning, but this has not been translated into practices that improve scientific literacy among learners. He pointed to the fact that the challenge facing the field of science education today is how to make inquiry an effective learning tool:

> The major issues that emerge are how to make inquiry really effective from some theoretical base. Constructivism has helped to formulate a theory of guided inquiry learning other than making it more an issue of philosophy and policy. (Interview, 5/20/2005)

Teaching science through inquiry is a challenge for most teachers and this is a challenge that the interviewees think will remain for some years to come. The reason why teachers are finding it difficult to teach through inquiry is because they are being asked to teach science in ways that are different from how they have always taught science. Most teachers have never seen anyone practicing inquiry which makes it harder for them. Since inquiry is at the heart of the National Science Education Standards, many see it as the best method to teach science in order to achieve science literacy for all. If the science education community does not come up with ways to make this an effective learning tool for science, then it may be difficult to achieve science literacy for all. Again here we see that Professor Macarthur's concern about inquiry science teaching refers to science teaching in general and does not specifically address science teaching pertaining in urban disadvantaged schools. This seems to be different than what Professor Gordon considers to be critical issues in urban science education.

Courtney shared her experience of helping teachers align the content to the standards and helping them teach for understanding and not for coverage as shown in the quotation below:

> But in the classes that I have been researching, that's definitely where I have been making sure that the content we were covering was aligned to the standards and that teachers could see those connections and also could see how they could

> approach the standards in creative ways and deeply get to the content rather than just a checklist. (Interview, 7/17/2005)

Courtney also highlighted the challenge caused by the disconnection between the teaching that is advocated for in K-12 education and college teaching. She showed her concern for college professors who think college science is only meant for a small percentage of the student population; hence they use introductory classes as a weeding mechanism. This is totally opposite to the reforms in K-12 education that is advocating for every student to learn science and be scientifically literate. In the following quote she shows her concern for the need to have collaboration between scientists and science educators as a way of achieving science literacy for all:

> There is still a fairly big information difference and also a difference between science faculty and science educators. A lot of the science faculty I talked to definitely have these ideas that if they have a 600 person classroom for introductory chemistry that they should design that class for the 6 people who are going to become chemistry majors, what about the rest of the class. Introductory science courses are gate keeping courses that keep people from seeing the relevance of science in their lives. I think it's a really big issue to try to have science faculty to recognize the contribution of the science education faculty. We really have to be equitable in higher education. Higher education needs to realize that people have needs in these classes and that people have different preparations than the traditional college prep. Its stuff that K-12 has been trying to accommodate for a long time and higher education has to start to look into that. (Interview, 7/17/2005)

Courtney shows the definite frustration shared by most educators who see college teaching undoing the hard work that K-12 education worked so hard to achieve. There is a growing need for college science professors to work closely with their education colleagues in order for the goal of science literacy for all to become a reality.

Curriculum

The issues I classified as curriculum included talk about aligning the science curriculum to the standards and to Science for All Americans and Project 2061

Benchmarks. Environmental awareness was also mentioned as an issue by one doctoral candidate who sees this as becoming more important and hence she felt that environmental education will in turn become more important in schools over the next 10 years. Two recent graduates and one doctoral candidate from City Ville (see figure 4.2) considered issues of aligning the curriculum to the standards to be issues that are posing a challenge to the field of science education and hence require attention. They all agreed that the standards documents were credible since they were written by educators and teachers but that implementing student-centered and inquiry-based learning was a challenge. Below is the example of a quote from an interview with Courtney, one of the recent graduates who shared her views about the challenges faced by teachers as they try to align their teaching to the state standards:

> The standards have been a big issue of pushing student-centered learning. Generally with the National Standards I think they are pretty positive because for the most part they do go into depth versus breath. Some of the state standards start to become more prescriptive and teachers find it hard to figure out which standards they should adhere to, which standards should take more precedence. The National Science Education Standards do come from a perspective of the education literature so in general the National Standards have been a good thing. (Interview, 7/17/2005)

Courtney raised an issue that educators are struggling with. Even though the reform documents specify what students need to know and be able to do, this does not automatically transform into practice. Looking to the future, some interviewees think that issues of curriculum will remain a challenge to the field, especially with topics like evolution where there is controversy on whether it should be in the school curriculum or not. Pamela a doctoral candidate shows how interference by the government is likely to influence what gets taught in science:

> Other issues in science education, the issue about curriculum and what to teach might become an issue, e.g. teaching evolution versus intelligent design. There is such a big debate which for me it's not even a debate. I think that the more government has a say in what gets taught, I think that must be an issue like what should be the content of science education, what should go in the curriculum, what we should teach the kids. Maybe when the administration changes it will not be the issue. (Interview, 9/12/2005)

This quote from Pamela is an added challenge to the ones that the field has been struggling to address. In addition to aligning teaching to the national and state standards, educators are battling in courts to keep evolution in the school curriculum. Being such an important subject that is at the heart of life sciences, removing evolution from the school curriculum would create a void that would make it difficult to fully achieve scientific literacy for all. For example how do you explain patterns in nature without touching on evolution?

Assessment and Accountability

Issues that I categorized as assessment and accountability include talk about the No Child Left Behind policies and the move towards accountability. Two recent graduates and one doctoral candidate voiced their concerns about the impact of the No Child Left Behind policies on the schools (see figure 4.2). The interviewees felt that the move towards accountability is not doing any good to urban schools where students already do not have access to quality science education. Standardized tests are being used to compare schools regardless of other contextual factors mentioned earlier. The quotation below from Courtney a recent graduate illustrates this point:

> The move towards greater accountability in science....the No Child Left Behind.... along with accountability goes the fact that many students don't have access to quality science education, so its difficult to hold the students accountable when they might not have been taught what they were supposed to have been taught. So, many students suffer, they have no access. So I think accountability is a big issue in science education as well.The poor urban schools

> are being punished for failing students and many of them are losing students who are moving to better schools in wealthier areas. The poor schools that need to be rescued in order to achieve scientific literacy for all are becoming a target and are punished for lack of student achievement. (Interview, 7/17/2005)

The No Child Left Behind policies also advocate for hiring of highly qualified teachers which the interviewees find to be problematic. Highly qualified people in the sciences for example chemistry would rather go to work in a lab that pays more money and offers less frustration such as that engendered by reluctant and under-prepared students, or unsupportive administrators in schools. Policies that are not easy to implement in reality are seen as challenges that will remain in the field for some time. Courtney also feels that the move towards greater accountability is forcing schools to focus on getting high scores at the expense of student learning and professional development:

> In terms of K-12 there seems to be growing tension between what the science education communities think should be good ways to go about changing schools. The way that accountability is coming to the fore, like in NY there is a shortage of highly qualified physics and chemistry teachers. The way the state wanted to fix this was, we will make it so harder to become a chemistry or physics teacher. So now anyone who is to become a chemistry teacher has a strong chemistry background but these are people who cannot even get into the certification program. To get around issues of accountability, schools are asking low achieving students not to come to school the days the tests are written. They are more focusing on how do I get these numbers up instead of how do I get professional development in my school. We have to find a way to find a middle point. I don' think the science education community wants to address these issues but its something we need to do. (Interview, 7/17/2005)

Issues of policies and the No Child Left Behind that were highlighted by doctoral candidates and recent graduates reflect a general frustration among science educators in the field. These interviewees did not talk about their own experiences with assessments in their own practice or any other forms of assessment other than NCLB driven assessments and the accountability that is attached to it.

Addressing Issues in Science Education

When asked how the issues in science education can be addressed, the faculty, graduate students and recent graduates all agreed that there is needed for combined effort between politicians, science educators and teachers. However, the interviewees felt that the politicians and business people need to play a greater role working with science educators and teachers to address these issues. The majority of interviewees identified that solutions lie in the context of the educational setting (see Figure 4.3 below). The context of educational settings in this case includes school funding, resource availability, poor teacher salaries, and teacher quality. They felt that these issues need to be addressed first in order for other factors to improve. However, none of the interviewees mentioned assessment and accountability as an area that needed attention from the leaders in the field.

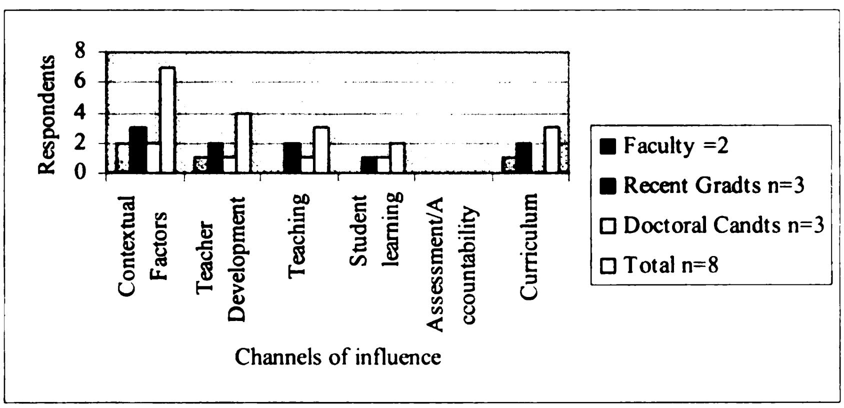

Figure 4.3 Solutions to addressing issues in Science Education

Although the contextual issues do not directly impact student learning, they impact the teacher's job, hence influencing student learning. There was also a general feeling among interviewees that the government should be involved in addressing these issues as well as issues of policies that are counter-productive to effective teaching and students' learning. June a doctoral candidate captures these sentiments:

> The political will is not there to do it. I guess you need more people in power that know more science, that will be more helpful, and have worked in a scientific field and have a sense of developments. A lot of people in policy do not understand that. Certainly the Bush administration, their questions about the type of science inquiries and how science is used to pursue political agendas. It doesn't particularly strike me that the Bush administration is particularly well vested in any kind of science and I think that very much affects their policy initiatives. (Interview, 7/25/2005)

The above quotation highlights the general frustration among science educators that, instead of bringing solutions, the current administration seems to be creating challenges for the science education community. It would therefore be difficult for any group to lead in addressing the challenges if the federal government is not involved in the process.

Mobilizing people from different professions is seen by Professor Macarthur as the best way to come up with a curriculum that addresses issues of diversity among students. He thinks that the way science educators are currently writing curriculum does not address the needs of learners who have different learning abilities. Professor Macarthur highlights the shortfalls of the current curriculum efforts, which he sees as peace meal projects:

> It's going to take a lot of prominent action. Mobilizing a broader base – business and politicians, industrialists and university people as well as resources to address these issues. It would be naïve for us to say that university people and science educators can make this happen. I think this obviously is going to take a lot more political action. For example the 1960s where the curriculum projects were started by scientists alone, they designed what they thought was a good curriculum from a scientific perspective and then brought in science educators and other people. I think that top-down approach isn't going to work in the future. There is need for large scale, integrated, task oriented, research objective curriculum projects where we look at the relationship between curriculum and learning. I think we are wasting money in this piecemeal approach we have been taking over the years of putting together a curriculum without understanding how the dynamics play out. (Interview, 5/20/2005)

Professor Macarthur feels that for the science education community to fully address the challenge of scientific literacy among all students there is need for a "Manhattan Project". He therefore thinks of reform in science education as a mammoth task that the whole nation should be concerned about. He used the phrase Manhattan Project as a metaphor to emphasize the magnitude of such a project. From the views of the interviewees at City Ville, leadership in addressing the current challenges in the field cannot be undertaken by an individual or by one organization, but it should be collaboration between educators from different fields, scientists, science educators, the community and the government.

Aspects of doctoral programs that need to change

The interviewees felt that there is need for the doctoral program at City Ville to improve in the areas of teacher development and curriculum. The interviewees unanimously agreed that doctoral students should be involved more in the process of learning to teach through teaching assistantships. From student mentoring it was clearly shown that the doctoral candidates at City Ville do not receive formal mentoring in teaching and one recent graduate testified that she had to learn to teach on the job. Although the assumption is that most education graduates have been teachers, the doctoral candidates felt that college teaching is new and there is need for mentoring in this area.

The recent graduates and faculty also agreed that the doctoral curriculum needs to address the current reforms more explicitly, especially with respect to aligning curriculum to the reforms. Although a number of doctoral courses analyzed in this study do explicitly address the reforms, what students get from their courses is greatly influenced by the professor who teaches the course. Professors' areas of interest and their areas of specialization influence what they value, as worth knowing and emphasizing in a doctoral course. One recent graduate felt that she could have benefited more if there was better collaboration among the courses. However, interviews with the recent graduates showed that there seems to be better coordination of the coursework and research. It seems that the coordination of the doctoral coursework seems to have changed since the former candidate graduated. One important observation related to faculty at City Ville is that Professor MacArthur will be retiring soon. This may be significant in that new faculty entering may bring different perspectives also and the nature of courses may change, or provide yet another way of how to prepare doctoral students.

Discussion

In this section I am going to compare the views of faculty, doctoral students and recent graduates. Data analysis showed that contextual issues such as equity and social justice and teacher preparation are the two issues that were commonly viewed by the faculty members, their recent graduates, and their doctoral candidates as being important challenges confronting the field. Whereas faculty members placed more emphasis on contextual issues, teacher development and student learning as issues that need to be addressed in the field, doctoral candidates and recent graduates emphasized all areas including three other areas that were not emphasized by faculty, namely: teaching, assessment, and accountability, and curriculum as issues that science education. There could be several reasons why faculty did not highlight the other three issues as challenges in the field, one of which could be that these issues are not directly related to their job or to their research interests.

All interviewees viewed the issues of equity and social justice as critical most likely because of the program focus on urban science education and the emphasis placed on equity and social justice research and outreach programs in the Urban Science Education Center. Professor Gordon works with urban schools and finds that inequity issues are real, hence the realization that 'science literacy for all should be viewed as a social justice issue. Issues of social justice are embedded in the social fabric and addressing them would require multiple partners such as politicians, businesses and the general public. In spite of these challenges, faculty members at City Ville view it as part of their community service to address the issues of urban science education from a social justice perspective Professor Gordon.

Schools are normally seen as places of learning, not places where people think much about who is getting what kind of knowledge and teaching science for social justice is a new discourse in the field. Science knowledge has always been considered to be neutral and value free and science educators have not thought much about the subjective nature of scientific knowledge and how it is socially constructed. Professor Gordon and her colleagues at City Ville are concerned about the lack of preparation of teacher educators with an understanding of what social justice means in science education.

Contrary to what faculty members emphasized as important issues in the field of science education, recent graduates, and doctoral candidates emphasized some issues that faculty did not emphasize. These issues include teaching, curriculum, and assessment and accountability. The faculty members seemed to focus more on issues that are directly related to their job of preparing teacher educators and doing research in their areas of interest. Doctoral candidates and recent graduates on the other hand seemed to focus more on all issues that influence student learning. This can partly be explained by the fact that doctoral candidates and recent graduates have just been exposed to all these issues in their courses and they view them as equally important and they may not have strongly aligned with any one issue in particular. Another reason why doctoral candidates and recent graduates tend to agree on all the issues that influence students learning is because of the emphasis that their doctoral program places on issues of equity and social justice. All the issues that influence student learning are major issues in urban schools because of lack of funding and lack of resources: hence they all need to be addressed.

From interviews with the faculty members at City Ville, it became clear that science educators are taking great strides to work towards achieving 'science literacy for all students' in urban schools. However, policies seem to be working against these efforts. It is interesting though that only the doctoral candidates and recent graduates highlighted policy issues such as the No Child Left Behind as a challenge to the field. Is this because faculty members do not see these policies as a challenge? It may be that faculty members are trying to ignore these challenges that are beyond their control and instead focusing on what they can address. From informal discussions with colleagues in the field, it seems there is a general feeling that these policies are a short-lived phase that will come to pass.

Although there is evidence that the faculty members at City Ville are concerned about achieving science literacy for all, the two faculty members seem to have different interpretations of what is needed to achieve the national goal. Whereas Professor Gordon sees the need to address issues of equity, and social justice as a way of achieving science literacy for all, Professor Macarthur sees the need to focus on addressing student learning needs. Professor Gordon seems to believe the problems of teacher burn out and high staff turnover in urban schools is due to inadequate preparation of science teachers to teach urban youth. She also sees this as being directly related to the fact that poor urban schools lack the resources that enables teachers to teach in the way that the science reforms advocates for.

Professor Gordon therefore believes that in order for urban students to have scientific literacy that is comparable to their suburban counterparts, there is need for doctoral preparation to prepare future science educators with a deeper understanding of urban issues and how to address them. ." Professor Gordon's work in the Urban Science Center focuses on helping teachers understand the urban youth in terms of what science means to them and designing curriculum that is relevant to the students' lives. One example of units they came up with was built around the "food from the grocery store". Professor Gordon articulated this in the interview: "But the part that we know we can work best on is preparing teachers to work best within the urban schools and understanding better who urban youth are and relate to them how to connect the science curriculum to them".

On the other hand, Professor Macarthur sees the need to prepare doctoral students with a deeper understanding of the challenges related to student learning and student performance, such as cognitive differences among learners, understanding the nature of science, effective science instruction and translating constructivist theories into practice. Professor Macarthur sees a direct relationship between the low performance of American students and lack of effective science instruction in the schools. He believes that implementation of constructivist theories into practice in the form of guided inquiry especially in lower elementary is one way student learning can be improved. Professor Macarthur's views about the challenges facing science education that he mentioned in the interview can be directly linked to his scholarly and research interests in neuro-cognitive models for student learning. According to him, the problem of student learning will remain a challenge in the next decade "unless we get to understand at what he calls the genetic neuro-cognitive basis of learning". By neuro-cognitive base, he was referring to differences among individuals in terms of learning and intellectual development. He emphasized the need to understand human individual differences and he showed his belief that people vary in their mental capacities. In this regard Professor Macarthur feels that it is wrong to assume that every student is keen to learn science.

It is clear that Professor Macarthur thinks research is science education should focus on studying the relationship between individual attributes and science learning, something that is silent in the national reform documents such as the National Science Education Standards (1996) and the Benchmarks for Scientific Literacy (AAAS, 1993). These reform documents outline what every student should know and be able to do at every grade level, what teachers should know in order to be able to do their job and how teacher education programs should prepare teachers for their job. The issue of student learning and cognitive development is normally a field that is studied by educational psychologists or cognitive scientists. The standards and benchmarks are generic in terms of learners' cognitive differences, which Professor Macarthur finds to be problematic. The National Science Education Standards and the Benchmarks do not give any indication of how teachers can accommodate learners with different learning abilities or the fact that some students may be functioning below grade level. The goal of the current reforms in science education is "to achieve scientific literacy for all" regardless of the differences among learners.

Professor Macarthur specifically attributed the problem of student performance to the current K-12 science standards and benchmarks that he feels were not informed by an understanding of how children learn. His concern is therefore to prepare doctoral graduates with a strong understanding of cognitive differences among learners and understanding how to address these issues. He thinks this is an important aspect of curriculum development and he feels that lack of this knowledge in the field has negatively influenced the quality of the latest science curriculum. This is shown in the following quotation from an interview with him:

> We have had sporadic attempts at curriculum development even Project 2061, I don't think we have given a lot of thought to understanding the longitudinal development of curriculum. We develop the curriculums top down based on philosophies and theories and designs, but I am worried about that because I don't think we know well enough the longitudinal issue of how children learn and develop and to use this to guide us in curriculum development. Project 2061 created the strand maps informed by research, but we just don't know how children at different age levels interact with those conceptual ideas. In terms of their learning and individual differences do we really understand that its appropriate and how best to reach them. That in the next 10 years will be a very important thing that we should be concerned about. (Interview, 5/20/2005)

In general, findings show that faculty and students share similar concerns about issues that are emphasized in the program but students seem to pay attention to more issues than faculty. Faculty members' research and scholarly interests define what they value most and what they consider to be important issues in the field. Doctoral students and recent graduates do not seem to have affiliated themselves with any one area but see all the factors influencing student learning as important. This raises concerns for breath versus depth in doctoral studies. The general trend shows that faculty is more concerned about depth in their particular area of specialization whereas students are concerned about breath of coverage of all areas. This raises the question of whether faculty expect doctoral students to get all of it and piecemeal their learning into a coherent whole.

Conclusion

The science education doctoral program at City Ville University has an urban science education focus. The program addresses the reforms through courses such as the "History of Science Education" which directly addresses the standards. The urban science education center strives to achieve the goal of "science literacy for all" by focusing on teaching science for social justice. This is done through helping teachers and teacher educators understand who the urban youth are, making science relevant to urban youth, and providing resources for science teaching in urban schools. Although some doctoral candidates and recent graduates agree with the faculty that the program is addressing the current reforms, two of them did not agree and felt that the reforms have not been fully addressed. This difference in opinion is mainly due to the different emphasis that the professors place on reforms in the courses.

In response to the question that asked what they see as the most important issues in science education, all interviewees agreed that issues of equity and social justice are challenges that confront the field of science education. Issues such as poor funding, high staff turnover, and lack of resources were identified as influencing the quality of science that urban youth receive. While faculty only identified three issues, namely contextual factors, teacher education and teaching as most important, doctoral candidates and recent graduates thought that that issues related to curriculum, student learning, assessment and accountability were equally important.

Both formal and informal mentoring exists for doctoral students at City Ville, but it's not uniform for all students. Students who work on research projects in the urban science education center were more satisfied by the mentoring they got compared to other students who did not work in the center. Students who worked in the center had more regular meetings with faculty, presented their research findings at conferences and had the opportunity of working with teachers in the schools. Although most doctoral candidates and recent graduate feel well prepared for the job, one student felt that she had to learn on the job because she did not feel she was well prepared for the job. There was a general feeling among doctoral students that there is need to improve the provision of teaching and research assistantships as a way of preparing doctoral students for future jobs as science educators.

CHAPTER 5

THE STORY OF MIDWESTERN SCIENCE EDUCATION DOCTORAL PROGRAM

Introduction

> We teach them how to read and write, how to vote and hold a job, but more than that is required. We must teach them not only to think, but to criticize, to conspire-if need –be against stupidity and arrogance, and against the non democratic, inhuman ways our society sometimes governs.
>
> *Ayers and Ford (1996)*

In the previous chapter I described the science education doctoral program at City Ville University. I showed how this program is addressing the current reforms through coursework and research. I also showed how the doctoral candidates are being mentored through working with faculty on research and professional development initiatives with teachers. In the case of City Ville, doctoral graduates are prepared to have a deeper understanding of urban science education and they get to work with teachers in urban schools, supporting them in their teaching, helping them understand urban youth and what science means to them and helping them to use resources at their disposal for teaching science. The City Ville doctoral program has an urban science education focus, and they are approaching science teaching from the social justice perspective.

In this chapter, I specifically focus on describing the science education doctoral program at Midwestern, analyzing their courses and views from faculty, recent graduates and doctoral candidates. I described the course of study, the mentoring doctoral students receive, views about the most important issues in science education and how these views influence the program structure. The findings discussed in this chapter will answer the question, ""How are science education doctoral programs interpreting the current reforms and how are they enacting them in preparing future leaders in the field?"

In this chapter I describe and analyze findings from the study of Midwestern science education doctoral program. I interviewed two faculty members, three recent graduates and three doctoral candidates. I also analyzed program documents such as syllabi and course descriptions as well as program descriptions in order to get a better understanding of the program structure and how doctoral graduates are being prepared. In my analysis I look for evidence of how the coursework and other experiences as well as faculty dispositions are focusing on the reform goal of achieving "Science literacy for all" as they prepare future leaders in the field. I used an interpretive approach that enabled me to assign meaning both to written and verbal text.

In keeping with the design of the study findings, in this chapter I will present the case of Midwestern University. I will follow the same format of the City Ville case by presenting the course requirements, doctoral mentoring and the views of faculty, recent graduates, and doctoral candidates. For analyzing data on views of faculty, recent graduates and doctoral candidates I used the National Research Council's Framework for assessing the influence of standards in Mathematics, Science, and Technology Education that I described in chapter 3. This chapter is made up of 4 sections that include analysis of coursework, mentoring of doctoral students, views of faculty, recent graduates and doctoral candidates, and a discussion that compares the views of the participants.

Geographic Location

Midwestern University is a large research intensive university located in a small city in the Midwestern part of the United States. The city population is about 50,000. The population is not very diverse both ethnically and socio-economically and mostly comprises of white middle class families. However, there is an urban area adjacent to the city where Midwestern is located. The urban population is very diverse both racially and socio-culturally. The College of Education at Midwestern was established in 1952 with the mission of preparing professional educators and leaders in the field of education. Midwestern is a State funded Land Grant University. The doctoral program at Midwestern serves students from diverse backgrounds both from in state, out of state and international. Doctoral funding for most of Midwestern students is through research and teaching assistantships. The majority of science education doctoral students at Midwestern engage in full time studies.

Program Description

The science education doctoral program at Midwestern is a specialist area of study under the Curriculum, Teaching and Educational Policy program. Generally students in this PhD program are required to be competent in both quantitative and qualitative research methodology and to be knowledgeable about teacher education. The science education doctoral program at Midwestern produced about 22 doctoral graduates in the last ten years. The department has 8 faculty members, and half of them hold joint appointments with the Division of Mathematics and Science Education in the College of Natural Sciences. The science education doctoral program at Midwestern has a current enrollment of about 15 full time students. About two thirds of the students are white

Caucasian American citizens and approximately one third are international, mainly from Africa and Asia. Minority racial groups such as African Americans, Asian Americans, Hispanics and Native Americans are poorly represented in the Midwestern science education doctoral program.

Participant Profiles

Faculty

The two professors interviewed for this study have different years of experience as science educators. Professor Atkinson has been at Midwestern University for almost 30 years and Professor Perry has only been there for three years. The two professors have different research agendas but they both work with the Science Education Center.

Professor John Atkinson

Professor John Atkinson has been a professor of science education at Midwestern University for about 30 years. He holds the position of Professor of Science Education. Professor Atkinson's scholarly interests are in the areas of science teaching and learning in the classroom. He studies how students' prior knowledge, language, and social relationships affect their engagement in science learning and the development of scientific literacy. He has expertise in the areas of science literacy, environmental literacy, secondary science education, and science assessment. He has held leadership positions in several national organizations and he has been a consultant to numerous science and education organizations and projects.

Professor Meredith Perry

Professor Meredith Perry has been assistant professor of science education at Midwestern University for three years. She has a joint appointment in the College of Education and in the College of Natural Sciences. Her research interest is in the area of teaching and learning of science, focusing on inquiry-oriented and model-centered constructivist learning environments. Her current research involves developing students' and teachers' understanding of the Nature of Science through scientific modeling. She has expertise in the areas of scientific literacy, elementary science teaching. Dr. Perry has been a reviewer for six different education journals, and she has taught several courses including; elementary science methods, science for elementary schools, online masters' course on inquiry and the nature of science, and PhD science education courses focusing on contemporary issues in science education, and teaching and learning science with technology.

Recent Graduates

Three recent graduates from Midwestern who were interviewed for this study graduated at least a year ago. One of the recent graduates, Joseph was an international student, and the other two, Joshua and James are American citizens. All the recent graduates were full time students during the tenure of their studies and their studies were paid for through working as research and teaching assistants in the department of Teacher Education.

Joseph

Joseph is an international graduate of 2004. He has since gone back to his home country where he is an Assistant Professor of Science Education. Upon graduation from Midwestern, Joseph got a job as a post-doctoral fellow at Midwestern and worked for 4 months before going back to his home country. During his tenure as doctoral student, Joseph worked as a research assistant on several research projects and also taught science methods courses for elementary teachers in the department of Teacher Education. Joseph has a bachelor's degree in science education and a teaching qualification. He taught elementary school for two years before starting the PhD program. His dissertation investigated Teachers' scientific knowledge, teaching practice, and students' learning activities.

James

James is an American citizen who graduated from Midwestern in 2003. He is currently an Assistant Professor of science education at a university in the east coast. During his tenure as doctoral student, James worked as a research assistant on several research projects and also taught secondary science methods courses. James has a bachelor's degree in science education and a teaching qualification. He taught secondary school for three years before starting the PhD program. His dissertation investigated Interns' narrative and paradigmatic ways of knowing science.

Joshua

Joshua is an American citizen who graduated from Midwestern in 2002. He is currently an Assistant Professor of science education at a university in the Midwest. After completing his studies he took up a position as assistant professor of science education at a university in the Midwest and worked for two years before joining his current university. During his tenure as doctoral studies, Joshua worked as a research assistant on several research projects and also taught secondary science methods courses. He won a teaching award. Joshua has a bachelor's degree in science education and he taught secondary school science for five years before starting the PhD program. His dissertation investigated teachers learning from mentoring experience.

Doctoral Candidates

The three doctoral candidates interviewed in this study are either in their fourth or fifth year. Two of the doctoral candidates are international students and one is an American citizen. They all have completed their coursework and at the time of the interview they had completed their doctoral candidacy examinations. Only one of the doctoral candidates was at the dissertation writing stage at the time of the interview.

Jennifer

Jennifer is a fifth year doctoral candidate and she is at the dissertation research stage. She is an international student who also got her masters degree from Midwestern University. During her doctoral studies she taught a diversity course for elementary and secondary pre-service teachers. She worked on several projects as a research assistant. At the time of the interview she had not yet started working on her dissertation. Jennifer taught secondary science for two years before she started her doctoral studies. She has since gone back to her country where she is doing her dissertation research.

William

William is a fifth year doctoral candidate and he is writing his dissertation. He is an international student. During his doctoral studies he taught science methods courses for elementary pre-service teachers. He has worked on several research projects as a research assistant. He his dissertation research focused on Agency in science.

Diane

Diane is a fourth year doctoral candidate and she is at the dissertation proposal writing stage. She is American citizen. During her doctoral studies she taught elementary science education methods courses to pre-service teachers. Diane is a doctoral fellow in the Center for Learning and teaching. She taught science for five years before she started her doctoral studies. She plans to conduct her research in the Western part of the country.

Science Center

The Center for Learning and Teaching

At least four of the science education faculty members at Midwestern run the Center for Learning and Teaching at Midwestern. The center focuses on critical research and development issues related to improving curriculum materials for K-12 science. The center's aim is to foster a new generation of leadership with specific expertise in the analysis of curriculum materials and in their development, evaluation, and implementation. Midwestern is one of 3 institutions that are part of the center that is coordinated by the American Association for the Advancement of Science (AAAS). Through this initiative, Midwestern and the other university partners have used this opportunity to expand their graduate programs in science education by recruiting doctoral and postdoctoral fellows who are funded by the center.

The center works closely with local school districts to inform the work of the center and to share the knowledge that is gained with K-12 educators. The center focuses on three main goals which are: (1) to develop the national leadership infrastructure at the doctoral and postdoctoral level, (2) to provide relevant inservice and/or preservice training to teachers and other professionals, and (3) to conduct research at the highest level on questions of national importance relating to the center's mission. The center has also impact on preservice teacher education students through the modification of science methods courses. It also offers professional development to teachers and administrators as well as to a select group of teacher leaders. The focus of all these activities will be the design, analysis, and implementation of innovative curriculum materials.

Findings

This section answers the following research questions: "How are science education doctoral programs responding to current reforms in science education in their coursework and other mentoring experiences offered to doctoral students?"

Courses Offered

The science education PhD program at Midwestern is an area of specialization under the Curriculum, Teaching and Educational Policy Program. All doctoral students have to fulfill the course requirements for the PhD in Curriculum, Teaching and Educational Policy shown in Table 5.1 below. However, the program is flexible and enables students to tailor their program of study according to their interest. In addition to the required courses, students with a science education focus can take science education courses that are offered every other spring as part of their selective courses. Science education students also attend a science education seminar every fall.

Table 5.1 Curriculum, Teaching and Educational Policy courses required at Midwestern

Course	Credit hours
2 Pro-seminar courses	6 credits
4 Educational inquiry and research courses	12 credits
3 selective courses	9 credits
6 electives	18 credits
Dissertation	24 credits
Total Credits	69 credits

Doctoral students are required to take a total of 15 courses, and each individual student's committee determines the specific number of credits they take depending on the interests of the student. Six of the required courses include two pro-seminar and four educational inquiry and research courses. The pro-seminar courses are offered during the first two semesters of the doctoral program. Beginning students take the pro-seminar courses together as a cohort. This is meant to build a professional learning community among the doctoral students. Three other required courses are selective, and these provide doctoral students with a general background in the major areas represented in the department, namely teacher learning, policy and the education context. The remaining six courses are elective courses, which define a student's area of concentration.

In addition to the required PhD courses, science education doctoral students attend a science seminar every fall where they meet with faculty to discuss contemporary issues in science education (Table 5.2). They also have the opportunity of taking electives on special topics in science education that are offered every other spring (Table 5.2).

Table 5.2 Science education focus courses offered at Midweatern

Science Education Electives	Credits
Contemporary issues in science, Curriculum and Teaching	1-6 credits Every Fall
Special topic in science Education	3 credits Offered every other year

Table 5.3 shows the special topics that were offered to science education doctoral students in the past 5 years. It is important to note that these courses are electives and are not required; therefore not all science education students took these courses when they were offered.

Table 5. 3: Special Science Education courses offered during the past 5 years at Midwestern

Special Topics in Science Education	**Credits**
Teaching Science for Understanding	3 credits
Exploring scientific literacy	3 credits
Curriculum materials in science	3 credits
Technology in Science Education	3 credits

The science education doctoral program at Midwestern has a teacher education focus. According to Professor Atkinson, the science education doctoral program at Midwestern has a degree of flexibility which enables students to shape their own program of study depending on their interests, with the guidance of their advisor and guidance committee. Professor Atkinson also highlighted the flexible nature of the content in the science education courses offered at Midwestern:

> In terms of the science education part of the programs, we have such a flexible program that I think it can go in whatever kind of direction we want it to, both 955 and 991A are two main courses and each time we teach them we teach them a little differently. (Interview, 5/20/2005)

Therefore 955 and 991A are the only two courses that are totally devoted to science education in the Curriculum, Teaching and Educational Policy program at Midwestern. Since the main focus of the doctoral program is teacher education, doctoral students are required take two pro-seminar courses at the beginning of their program. The first pro-seminar course draws on literature about teaching and learning in elementary and secondary schools and the connection between classrooms and the larger social context of the US education system, its structure, and how it has changed over time. The course also takes a closer look at the complexity of the education system and why reforms have failed to change it. The following quotation from the syllabus highlights the structure of the pro-seminar course:

> In this course, we will explore the educational enterprise and alternative ways of describing, analyzing, and interpreting the K-12 system. It will first explore the history of changes in educational thought and practice that shaped the drive to provide mass public schooling, and the consequent struggles faced in educating a diverse population: the purposes of education and the consequent manifestations or internal effects of competing purposes on knowledge, learning, teaching, and structure. It will then turn more directly to the recent era of reform and analysis, and will focus largely on shifts in the theoretical and interpretive perspectives that scholars have used in explaining the relationship between schooling and larger social and economic developments

The pro-seminar course provides doctoral students with an understanding of the complex nature of the education system and its socio-political context. Although the pro-seminar course does not directly address issues related to the current science education reforms, it addresses reforms in general and it provides science education doctoral candidates with lenses that they later use to analyze and understand current reforms in science education.

The second pro-seminar course explores issues related to teaching as a profession and the teachers' work. The following quotation from the second pro-seminar syllabus clearly describes what this course is about:

> The course will introduce some major frameworks that have been used to guide research, policy recommendations, and the work of teaching. Throughout the term we will consider the question of what it means to think about teaching as a practice from a variety of perspectives, drawing on a range of concepts and theoretical frames, in order to examine teacher learning and teachers' work as situated and embedded in multiple contexts.

Just like the first pro-seminar, the second pro-seminar course does not specifically address the current reforms in science, but it provides science education doctoral candidates with a more sophisticated and critical lens to think about science education reforms in terms of the job of teachers, and teacher preparation, the challenges facing the teachers, and why the job of teaching has resisted change over time.

In addition to the two required pro-seminar courses, students are required to take three selective courses. One of the selective courses entitled "Learning to teach," focuses on the intellectual, practical, and moral dimensions of teaching and learning to teach. It also focuses on the impact of formal and informal influences on teacher's knowledge, skills, and attitudes. In this course, doctoral students take a critical look at the debates in teacher education research using different lenses as shown in the following quotation from one of the syllabus:

> The themes explore many of the predicates that constitute various meanings of learning to teach. The readings are designed to provide 1) an overview of current debates in teacher education research about learning to teach, and 2) an array of lenses through which to read the research critically.

This course focuses on different traditions of preparing teachers and different views on teacher education using readings from critical theorists; for example *Popkewitz,* " How the alchemy makes inquiry, evidence, and exclusion"; *Dembo,* "Learning to teach is not enough—future teachers also need to learn how to learn."; *Garmon*, "Changing Preservice Teachers' Attitudes/Beliefs About Diversity: What Are the Critical Factors?"; Billings, "Fighting for our lives: Preparing teachers to teach African American students."; *Britzman,* "What will have been said about gayness in teacher education."; *Biesta,* Instruction or pedagogy: The need for a transformative conception of education; and *Foucault,* "The ethics of the concern for self as a practice of freedom"

This list of readings gives an idea of the critical nature of the doctoral preparation at Midwestern. Again, like the pro-seminar courses, these readings do not address issues related to the science education reforms directly, but they focus on questioning present practices in teacher education and the quality of teacher education programs. Issues of preparing teachers to teach diverse learners are also explored. These are issues that are at the heart of the current science education reforms whose goals are to achieve 'science literacy for all students'. *Garmon and Ladson-Billings* for example, write on issues of diversity and how to prepare teachers to teach children who are different from the teacher. These readings provide science education doctoral students with frameworks or lenses for thinking about the science education current reform goals of improving science teaching and learning which is pre-requisite to achieving the goal of science literacy for all.'

According to the faculty members at Midwestern, the science education doctoral courses incorporate the reforms in several ways. I chose to analyze two science education courses that were offered during the last three years to show how they addressed some of the issues that are pertinent to the current science education reform efforts. One of the courses: "Exploring scientific literacy," was offered in summer of 2003. This course was specifically targeted at exploring issues and challenges that are related to achieving the national reform goals of science literacy for all. The course highlighted the problems and challenges of achieving science literacy for all students. It engages students in discussions around literature that looks at the lack of clarity in what literacy means, how it can be achieved and why it is difficult to achieve it. The syllabus clearly captures the course objectives:

> The consensus about the desirability of scientific literacy as an outcome of schooling conceals a diversity of ideas about what scientific literacy is, how it can be described, and how it can be achieved...Researchers agree that our current teaching practices in school science help only a small minority of students achieve scientific literacy, and that our society is poorer as a result. In this course we will investigate the explanations for the current state and the visions for improving

> science education, including the following issues: Defining scientific literacy; the nature of science; the nature of science learners; current practices in science teaching; visions of alternative practices.....

This course engaged students in discussions of scholarship in the areas of identity, diversity, language and race, nature of science and current practices of science teaching through readings such as: "*Same School, Separate Worlds: A Socio-cultural Study of Identity, Resistance, and Negotiation in a Rural, Lower Track Science Classroom*" by Gilbert, & Yerrick; "*Understanding Cultural Diversity and Learning*" by Ogbu; "Writing *Science: Literacy and Discursive Power*" by Halladay & Martin; "*The construction of scientific facts" by* Latour & Woolgar; "*Science for all Americans*" by American Association for the Advancement of Science Project 2061; "*What is Literacy*" by Gee; and "*Talking Science: Language, Learning and Value" by* Lemke and several others.

These readings and the course description show that this course had the intent of engaging students to think critically about the way science knowledge is created, by whom and for whom? Students are also engaged in critical thinking about the implications of current teaching practices and how they relate to diverse science learners, who does the current practice benefit and who is left out? The course raises questions such as what should change in science teaching in order to achieve science literacy for all. Other questions raised in this course include "who is represented in science and who is left out? How does science teaching cater for those who have been left out? And how can we teach science in a way that brings in the outsider? One doctoral student, Jennifer who attended this course, found it to be relevant and practical. She described how popular the course was among the doctoral students:

> When I took the literacy course, to me that was a perfect class because it melded interests that I had, you know it really dealt with what does that mean for all students and we read some literature around that. I think that should be an indicator to faculty in this department that that kind of class, that kind of melding of issues of diversity and issues of teaching science, that kind of thing needs to be offered to grad students. There were a lot of students in that class. (Interview, 5/17/2005)

This shows that doctoral students at Midwestern have generally developed a critical thinking perspective and in the above quotation Jennifer speaks for her colleagues. Her sentiments show how the nature of this and other courses at Midwestern shapes and supports the way science education doctoral students and recent graduates think about issues in the field of science education. Joseph a recent graduate who also took the 'Exploring Scientific Literacy' course shared similar sentiments with Jennifer. He felt that he now understands socio-cultural issues from taking this class and from other experiences:

> These issues are mostly socio-cultural. When I teach these issues in my university in the future wherever I go, I feel confident, confident about this issue because I think I have learnt a lot about these issues from many faculty.

The science literacy course helped doctoral students to understand the two research traditions in the area of science literacy, namely: the *science education tradition* and the *socio-cultural tradition.* According to the course syllabus, both traditions share an understanding that science is much more than a body of knowledge or a set of methods for developing new knowledge. The two traditions differ, however, in the kinds of actions and meanings that they emphasize. On the one hand, the science education tradition emphasizes the language of science as giving understanding and power with respect to the material world, focusing on how the language of science mediates our relationship with the material world. On the other hand the socio-cultural tradition focuses more on how the language of science mediates relationships among people. Thus scholars in a socio-cultural tradition are interested in how scientific communities have developed their current prestige and power, how they include or exclude people, and how learners understand their relationships with the dominant discourse of science.

The critical approach taken in this course, just like the ones previously described, provides a context and lens through which science education doctoral students analyze and understand the current reform goal of science literacy for all - how it can be achieved and the impediments to achieving it. In this case, doctoral students were able to understand that science literacy for all does not just mean teaching content science to all students. The complex nature of the education system and its socio-cultural context need to be taken into consideration when thinking about addressing the goal of science literacy for all. This course therefore directly addresses the current reform goal of 'science literacy for all.'

Another science education doctoral course that has been offered to doctoral students at Midwestern in the last three years is entitled "Curriculum Materials in Science: Students, Teachers and Policy." This course provided students with historical perspectives on efforts that have been taken to reform science curriculum materials by the National Science Foundation and Project 2061. The course also considered several current science curriculum reforms and efforts to systematically evaluate curriculum materials by the Center for Curriculum Material and AAAS, and the role of science curriculum in the current climate of educational reform. Implicit in the discourse of this course are issues of the current reforms, especially the efforts being made by the National Science Foundation and AAAS to reform curriculum materials as a way of supporting reforms in teaching. These issues are clearly highlighted in the following quotation on the course syllabus:

> Science curriculum materials (textbooks, teacher's guides, software, online resources, etc.) are big! They play a big role in schools and classrooms. They are a big focus of efforts of the National Science Foundation to "reform" science teaching and learning, and they are big business. As the course title implies, we will examine curriculum materials from the perspectives of the student and student learning, the teacher, and the broader context of standards, accountability and textbook publishing, marketing and adoption. We will examine core and exemplary readings for each of these components of the course.

This course engaged students in discussions of scholarship in the areas of history of science education, curriculum materials, professional knowledge for teaching, curriculum materials and students, and teacher interpretation and use of curriculum materials through readings such as: "*"The Reforms of the Fifties and Sixties: A Historical Look at the Near Past" by* McClure*; " Curriculum Reform" by* DeBoer; *"Research on the Goals for the Science Curriculum," by* Bybee, and DeBoer; "*Those who understand: Knowledge growth in teaching*" by Shulman, *"150 different ways" of knowing: Representations of knowledge in teaching" by* Wilson, Shulman, and Richert; *"Nature, sources*, and *Developments of pedagogical content knowledge for science teaching" by* Magnusson, Krajcik, Borko, Gess-Newsome; " *Examining Pedagogical Content Knowledge: The construct and its implications for science education" by* Lederman; *"Reform by the Book: What Is--Or Might Be--the Role of Curriculum Materials in Teacher Learning and Instructional Reform by* Ball and Cohen.

According to the syllabus; "this course enabled students to take a critical look at the curriculum materials in use in schools that are predominately developed and marketed by commercial publishers." Students were expected to think about these questions: "How do materials come to be adopted? What roles do standards and accountability systems play? "Why don't better materials get developed and adopted?" This course directly addressed the current reforms in science education. By focusing on the role of standards in curriculum development, doctoral students got to think about the science content reform efforts and how curriculum materials need to address these. The course looked at the reforms from a positive perspective and how the curriculum materials should be used in a way that supports the reform goal of achieving "science literacy for all'.

Addressing the Current Science Education Reforms

Analysis of views from faculty and recent graduates and doctoral candidates show that the science education doctoral program at Midwestern is incorporating the current science education reforms in the framework for their coursework. As has been highlighted earlier, and as we shall see later in the chapter, the Curriculum, Teaching and Educational Policy doctoral program coursework at Midwestern in general takes a critical look at "teacher education", namely teacher preparation; the "context of schooling"; the education system; teaching diverse learners and resource for teaching. This critical approach directly influences the way doctoral students and recent graduates think about issues related to science education reforms and what the field should be focusing on in order to achieve the national goal of science literacy for all.

From the interviews, it was clear that not many courses address the reforms directly. This is mainly due to the fact that the science education courses are not required; therefore not all science education students take them when they are offered. Several doctoral candidates, recent graduates and faculty mentioned that the science education seminar offered every fall specifically incorporated current issues related to the science education reforms. Professor Perry agreed that 955 addressed the reforms and showed that there were plans to directly incorporate reforms in the science education courses:

> [The course] 955 the year before last was focused on the standards ......one professor had mentioned incorporating standards as part of that three-sequence course. We also talked about incorporating some historical viewpoints in the courses.

Professor Perry showed that the faculty at Midwestern discusses what should be in the content of the 955 and 991A courses. The reforms are more explicitly incorporated in the 991A science courses described earlier, in the "Exploring Science Literacy" and the "Curriculum Materials" course. One other 991A courses entitled "Teaching Science for Understanding" that was offered 5 years ago also explicitly explored the reform documents such as the National Science Education Standards and Project 2061 Benchmarks. Two recent graduates interviewed in this study had taken this course where they explored the reform documents. The other students had the opportunity of attending the science literacy course and the curriculum materials course described earlier. Some students felt that these courses prepared them to teach and they also used the standards as teaching assistants:

Joshua, a recent graduate who took the 991A 'Teaching Science for Understanding' course said that the reform documents were explicitly explored in this course. For example Joshua commented about how the reforms were addressed in the science seminar and how he incorporated them in his teaching:

> There was one course in particular that was based on the science education reforms. ...... and it was one of those special courses 991A. That was my first year at Midwestern, and we were 6 in the class and the special topic that this course was centered around was reform documents. So we looked at the National Standards, and the Benchmarks, and Science for all Americans and so on. So we had discussions about the impact of standards and about the documents themselves, how they were created, and some historical context. So that course

> was probably the most related to the standards, of any course that I took. Every once in a while when we had 955 class, we were talking about standards as well. So those would probably be the 2 instances, other than when we were teaching classes and teaching the teacher candidates about the standards. (Interview, 3/14/2005)

Joseph a doctoral candidate who also took this course reported that the course discussions were pro-standards and benchmarks. The following quotation from an interview with him supports this claim: "I learned about national documents only pro, not con. Other conversations focused on negative effects." Specifically he highlighted the fact that there was a tension among science educators:

> I know that there are also in the US, very serious tensions, conflict between the ideas around the nature of curriculum materials and national standards. For example people believe that national standards don't matter, or some people believe that national standards are very important. (Interview, 3/11/2005)

Although Joseph did not seem to align himself with any one of these views about the reforms, interviews with faculty and some doctoral students at Midwestern showed different views about the current reforms, specifically the National Science Education Standards and Project 2061 reforms. Whereas some professors are in support of the standards and take a positive spin whenever they incorporate them in their courses, Professor Atkinson reported that he addresses standards in multiple ways depending on the level of students. At the doctoral level he takes a more critical stance on the standards as a way of helping to rewrite the standards, but at the undergraduate level he focuses on helping teachers understand the standards and use them. Professor Atkinson leans more towards revising the standards than adapting them:

> I think that the way we use standards in the undergraduate courses is different than in the graduate courses. In the doctoral courses we are preparing people to question the standards and to revise the standards, probably to rewrite the standards. So I think it's important in the doctoral courses to help students to take a stance towards the standards… The larger portion of doctoral study is to

introduce people top scholarship, in science education the national standards are an important aspect of the scholarship and to some extent drives the scholarship, but they shouldn't drive the scholarship too much. It's important for people to know what limitations of the standards are, what should we be doing regardless of what the standards say, and how can standards move us towards what we should be doing and probably revise the standards so that they better support what we should be doing. (Interview, 5/20/2005)

On the other hand Professor Perry highlighted her commitment to the standards and using inquiry in science teaching. However, she feels that this is different from the focus of her research group in the Center for Learning and Teaching:

> So what happens is that in my research group for the Center we are doing a lot of work around Project 2061 criteria, and we talk a lot about that especially because it may not work well with the inquiry standards. Project 2061 does not talk about inquiry so it's not clear whether they oppose it or not. But there is need for them to buy into the idea that the other standards are worth talking about. (Interview, 4/11/2005)

Similarly, Diane, a doctoral candidate who also works on the Center for Curriculum Materials project, shared similar concerns about the tensions that exist in the acknowledgement of different reform documents by different faculty. Diane feels that although she realizes the existence of the tensions brought about by only emphasizing one reform document in the research project, she does not align herself with any one of the reforms:

> ...... some people like Project 2061 and others are a bit more critical – I am not in any one camp.- The Center does not emphasize some things, e.g. inquiry, diverse learners, etc. (Interview, 3/8/2005)

As mentioned previously by Professor Atkinson, the doctoral program at Midwestern addresses the reforms differently in the undergraduate courses and in the doctoral courses. Both Professor Atkinson and Professor Perry indicated that they refer to the standards in undergraduate courses, and the emphasis in these courses is on using standards as a tool to guide teaching.

Most of the interviewed participants mentioned that they mostly incorporate the reforms and discuss more about the reforms either in teaching assistantships or on research projects. For example James a recent graduate from Midwestern did not take any science education courses that addressed the reforms directly but he used the reforms as an important part of the framework for his teaching as a graduate teaching assistant. He taught secondary science methods courses for 8 semesters. He notes how he got to understand the standards from using them in his teaching:

> Most predominantly we used the standards extensively when I taught 401, 402, 802 and 804. So I did that cycle two times for a total of 8 semesters where I was trying to understand how these were benchmarks as well as (mumble)...so I don't think I have formal research although I would consider this quite extensive informal or practical experiences thinking about that research and stuff. (Interview, 3/10/2005)

Similarly, William a doctoral candidate said that he did not encounter a course where the reforms were addressed, but he learned about the reforms through discussions as well as through his research assistantships. William also showed that the critical and political nature of discussions in the courses was the typical nature of science education at Midwestern:

> Not so much about science education reforms because you don't have many apart from being in and one summer course that I did with some of the students, which was open. We don't have much focused on science education reforms but talking of reforms in other places, so I don't remember many discussions focused on political issues in my courses, but yes in research and my assistantship there are have been focused work. That's a natural platform for science education. (Interview, 5/13/2005)

From the faculty and student views, one can conclude that the science education doctoral program at Midwestern does not only incorporate the reforms in the framework of their courses, but also in the framework of their teacher education program, research assistantships and in casual discussions. It is important to note that the way the current reforms are incorporated in the courses is mostly in relation to teacher learning and teacher knowledge. Professor Atkinson, Professor Perry and James for example showed how they address the National Standards in their teacher preparation courses. Specifically the pre-service teachers learn how to use reform documents to identify the teaching and learning goals and to know what content they should be teaching at different grade levels. The rest of the interviewees showed how the reforms were part of the framework for their courses, the science education seminar, and research assistantships.

Mentoring of Graduate Students through Research and Teaching

The science education department at Midwestern is comprised of eight faculty members who are all involved in different types of research. The type of experiences and mentoring that doctoral students get depends on their faculty advisors' mentoring and the type of research and teaching experiences they get throughout their doctoral studies. One other professor works with professional development schools and yet another professor does research on curriculum reform focusing on environmental literacy, four professors conduct research on science curriculum materials, and two faculty members' research work focuses on teacher education. All the science education professors at Midwestern use qualitative research methods in their research work. The faculty members mentor their doctoral students through working with them on research and teaching. Research assistantships are mostly grounded in a research grants that individual professors have obtained or in the Center activities. Apparently, every doctoral student has either a research and/or teaching assistantship. Since Midwestern is a large research-intensive state funded university, most faculty members have research grants that support doctoral students by paying tuition, conference attendance and living allowances. Funds for teaching assistantships are provided by the university.

The four science education Professors who are involved with research work in the Center for Learning and Teaching conduct research on development and use of curriculum materials. Doctoral students who are mentored by these professors in the Center for Learning and Teaching are carrying out research that is preparing them to become leaders in research on curriculum materials development. From an informal interview with a faculty member who is co-PI on the project, he stated:

> The other thing the center is doing is preparing doctoral students and post-doctoral students to work on these issues through their own research and curriculum development as they leave and go out in the field, and a key part of the center's mission is preparing researchers to carry out these kinds of work. (Interview, 9/28/2005)

This professor also felt confident that the doctoral and post-doctoral fellows working in the Center for Learning and Teaching will possess unique abilities to work on research in curriculum development and that they will be more sensitive to the role of curriculum materials in teaching. Funding for the Center for Learning and Teaching helped to recruit people who will become specialists in research on curriculum materials:

> The doctoral students who are fellows in the Center will be at least more sensitive to the role of curriculum materials in improving science teaching. I think that more of them will be more likely to be involved in curriculum development or research in the context of curriculum development than would have been the case without the Center. So I think that bringing people into that area of work, just by itself would be different. As teacher educators, I think they will pay more attention to the role of curriculum materials for the teachers they are preparing than they would have done had they not had the experience of working in the Center. I think they will have specific tools and knowledge to use. I think they will be more principled in their approach to curriculum development and be more likely to contribute to the knowledge base than to just crank out curriculum materials. Interview, 9/28/2005)

Although doctoral students who are being mentored through conducting research on curriculum materials development are going to have unique qualifications in this area, there is evidence that they are also getting multiple perspectives in terms of interpretation and enactment of the reform. The professors who work with doctoral fellows interpret and enact the reforms differently in their research projects as shown by their areas of emphasis. This difference is mainly due to the challenges posed by having different reform documents that have the same goal of achieving science literacy for all, and there are no directions on how these documents can be used together. Whereas the National Science Education Standards place emphasis on inquiry, the Benchmarks for Science Literacy do not mention inquiry. As mentioned earlier, the lack of agreement on how science literacy for all can be achieved gives science educators the flexibility to interpret and enact the reforms the best way they can. I will give examples of how two professors think about the reforms and what they think need to be emphasized in order to achieve the reform goals.

Professor Perry feels that inquiry is critical to reform-based teaching and should be an essential part of research in curriculum materials. In her view, achieving science literacy involves approaches that should come from both reform documents. She highlighted how Project 2061 criteria that are used in curriculum analysis do not address issues such as inquiry that she feels are critical for reform-based teaching. Professor Perry shows her struggles with the two reforms and shows that she would like to see the Standards and Benchmarks used together. Diane, a doctoral research fellow with the Center for Curriculum Materials, share similar concerns with Professor Perry. Diane also prefers that the two reforms be merged because she wouldn't align herself with any one of them.

Both Professor Perry and Diane show their struggles to align with any one of the reform documents. On the other hand Professor Atkinson who also works with the curriculum materials projects specifically focuses his research work on environmental literacy. He is mentoring doctoral students who are working with him on this project to take a more critical look at environmental issues and think of ways to develop curriculum materials that reflect the current issues in this area. The quotation below shows the level at which Professor Atkinson thinks about environmental issues:

> The issue behind the environmental literacy project, the content of the curriculum is gradually going out of date, and in particular worldwide we want human populations to be better educated in environmental issues and the choices that we face because every country is going to be facing those issues. (Interview, 5/20/2005)

Doctoral students who are mentored by Professor Atkinson are focusing on how the National Science Education Standards or Benchmarks for Science Literacy can be re-written to reflect the impact of humans on the environment and how the systems are interconnected. Compared to the other two interviewees, Professor Atkinson does not show struggling with how to use the two reforms but his struggle is with changing the reforms in the two documents that he thinks are outdated in some aspects. The following quotation from an interview with him shows how he is thinking about environmental literacy and the standards:

> The environmental literacy project I think we are trying to hold two kinds of conversations, one is at the national level, a conversation about standards. Currently we are focusing on standards and assessment. We are interested in the National Science Education Standards or Benchmarks or Atlas of Scientific Literacy. Those National standards need to reflect recent research both in science and in education. The research in science has to do with the development of understanding coupled human and natural systems, that is to say if you look at any country today, the US, Zimbabwe or wherever, the vast majority of that

> country has been greatly altered by humans, there are very few natural ecosystems left, and we need to understand how those altered human ecosystems work and how they can be managed, that is farms, factories and cities so the world can continue to support the population. (Interview, 5/20/2005)

Professor Atkinson is taking a critical look at the reforms in terms of how they are dealing with interconnections between humans and the natural systems. In his view science literacy means being able to see the whole picture, that is having a holistic understanding of systems and how they are connected.

Two other professors in science education are working on professional development projects in the schools. Not much detail will be provided about their projects because they were not interviewed for this study. The doctoral students they are working with on these projects are being mentored to work with teachers and are gaining a better understanding of the professional development models that are used in these projects. In general, most doctoral students get to work with several faculty members on different projects. The focus of the doctoral program on teacher education means that there are more opportunities for most doctoral students to work with teachers. Although the doctoral fellows in the Center for Curriculum Materials in Science continue to work in the Center throughout their doctoral studies, they also work on other research projects as well as teach science methods classes.

In this section we saw that the research work of faculty at Midwestern is influenced and shaped by the way they interpret and enact the reforms. On the one hand there is a struggle to come up with ways to bring the different reforms together in research on curriculum materials, and on the other hand there is a critical look at the standards and working at revising the reforms. The professors are definitely involved in critically thinking about the reforms in terms of how they can be used and how they can be changed. This is reflected in the research they do as well as in the doctoral coursework. Professor Atkinson for example taught the 'Exploring Literacy' course that focused on critically analyzing what science literacy for all means and what are the obstacles to achieving it. Professor Perry on the other hand emphasizes inquiry and reform-based teaching in the science methods courses. Doctoral students therefore gain multiple perspectives from working with professors on the different research projects and taking the different courses. Most of the courses expose and challenge students to think critically about teacher education, teaching and the education context.

Roles Doctoral Candidates are being prepared for

The interviewees from Midwestern generally agreed that their program prepared its graduates for research and teaching (Figure 5.1). The recent graduates and doctoral candidates were satisfied with their preparation, which they feel gave them a broad base in the areas of teacher preparation and research.

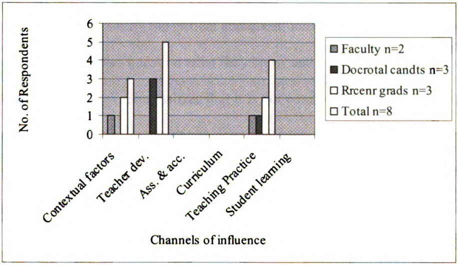

Figure 5. 1: Roles doctoral candidates are being prepared for

According to Professor Perry the program at Midwestern is doing a good job of preparing people for teaching. She contrasted this to other programs that are preparing doctorates to teach at other universities, thus making a distinction between the critical approach that the program at Midwestern is taking and the traditional methods courses that are taught in other programs. The doctoral students and recent graduates also felt that the program prepared them to have a critical understanding of issues in science education as shown by Jennifer:

> I think that's a hard question to answer because if I'm not prepared, I might not know I'm not prepared. Like if there's stuff out there that I don't know about, but I don't know about it, then I won't know I don't know about it. At least I'm in a place where I feel like I have a lot to learn. I think that's a good thing. At least I'm aware there are lots of things I don't know. I think the program in general does a pretty good job of trying to give you a broad base. You don't have to get too super specific and a little bit of freedom which I think is a good thing. I think it would be good if there were a few more things to learn, well I don't know. (Interview, 4/11/2005)

Jennifer pointed out that there is a bit of freedom which also defines the nature of the doctoral program at Midwestern. Although Jennifer did not sound sure about her preparation, she shows the critical and questioning nature of the program which makes doctoral candidates question what they know and what they do not know and what is important to know. She realizes that it is not possible to learn everything and that there may be information out there she does not know. This is a great way of learning to teach and becoming a life-long learner. In other words the program is developing life-long learners.

Another doctoral candidate, William, is happy about his preparation for a teaching career and the opportunities to do research in the field with teachers:

> I think we were being prepared for a resource in a teaching career. I am pleased to see that the professors at Midwestern are working actively in schools. So, like

> many of the professors here, [they] have programs going on in school districts and schools. So, [they] are leaders in a sense, learning how to do research, learning how to teach, and you learn how to work in schools. Those are the main focuses on working with schools and teachers. (Interview, 5/13/2005)

Similarly, James showed his appreciation for the broad nature of classes at Midwestern that prepared him for teaching and provided him with a strong research foundation:

> Broad nature of classes, teaching, and teacher education has a strong foundation. I think Midwestern does an excellent job of preparing us for research. I think especially from the broad nature of the program, the courses and that seminar and range of classes that I have that focus on careful thinking about teaching are very solid foundations. (Interview, 3/10/2005)

The ideas shared by Professor Perry, doctoral candidates, and recent graduates confirm the claim made earlier in that the program at Midwestern has a teacher education focus; hence it provides science educators with a strong foundation in teaching. The program also provides doctoral students a strong practical research foundation through working on research in the schools as well as working on projects such as the curriculum development projects run by the Center for Learning and Teaching. Although faculty, doctoral candidates and recent graduates interviewed in this study did not mention that the program prepares graduates to become leaders on curriculum materials, an interview with the PI for the Center for Learning and Teaching showed that the Center doctoral fellows are being prepared to become leaders in research on curriculum materials.

The professors at Midwestern and their doctoral students agree that the doctoral students are being prepared for roles in teaching and research. The doctoral candidates showed that they are ready to take up jobs in the academy, which is different from the way the doctoral students from City Ville who preferred to work in non-profit organizations. Generally the faculty's interests and goals align with the students, and there seem to be no tensions between academic careers and something else, unlike the City Ville students.

Views and Perceptions about Challenges Confronting Science Education

This section answers the second research question; "What are the perceptions of science education faculty, recent graduates and doctoral candidates about the challenges confronting K-12 science education and how are these challenges related to the way the programs are preparing their graduates?" In this part of the study, my goal was to establish what science education faculty, doctoral candidates and recent graduates from the science education doctoral program at Midwestern consider being the most important issues in the field. In keeping with the data analysis described in chapters 3 and 4, I analyzed the responses to the interviews using the framework for assessing the impact of National Standards on student learning (described in chapter 3).

I categorized the responses from the interviewees using the following five channels of influence that were identified by the National Research Council; contextual factors, teacher learning, teaching, student learning, assessment and accountability and curriculum (NRC 2002). According to the NRC, the contextual factors refer to external factors that influence student learning such as policy, governance, business and research groups. In my analysis, I also included issues of equity and research under contextual factors. Generally, the interviewees identified issues that can be categorized into all the six channels of influence listed above to be important issues that the science education community should be focusing on. In their responses, the interviewees put more emphasis on some factors than on others. Figure 5.2 below shows that all issues that influence students' learning directly and indirectly were considered to be important.

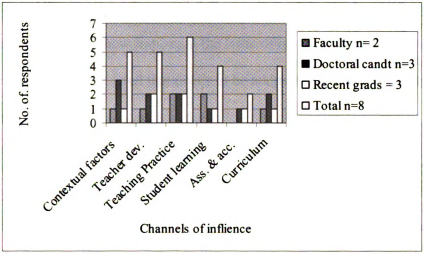

Figure 5.2: Views about the most important issues in Science Education at Midwestern

However issues related to assessment and curriculum did not receive as much attention in the interviews compared to issues such as contextual factors, teacher development, teaching practice and student learning (Figure 5.2). I analyzed issues that are related to each of the channels of influence and I provided some quotations to substantiate the claims I made about the interviewees views.

Contextual Factors

Although the program at Midwestern focuses more on teacher development and teaching, there is so much concern among stakeholders about the context within which the school system operates. The views I categorized as contextual factors in this chapter include talk about the challenges of achieving science for all and addressing issues of equity, paying attention to socio-cultural issues and poverty. There is evidence from interviews with faculty, doctoral candidates, and recent graduates that they consider issues of inequity in science education to be hindrances to addressing the goal of science literacy for all. Professors Atkinson and Perry, all three doctoral candidates, and one recent graduate showed how important the issue of inequity in science education is, and they see this as an urgent need that needs to be addressed in order to achieve science literacy for all.

Failure by the education system to achieve science literacy for all was sited by Professor Atkinson as the most important issue in the field of science education. Specifically, Professor Atkinson talked about lack of understanding of science among students as well as the achievement gap that exists between the richer students and poorer students:

> Certainly the most important issue is the abundant evidence that our science education system is not being very effective. That takes two forms, a) general evidence that even the most successful students are retaining their misconceptions not learning important science and b) the achievement gap between richer students and poor students, and we haven't done much to improve neither of those. (Interview, 5/20/2005)

Interviews with Professor Perry and the recent graduates at Midwestern showed that they attribute the ineffectiveness of schools and the achievement gap to issues of inequity, poverty and socio-economic issues. Professor Perry elaborates on the collective views of the science education community at Midwestern about how the issues of poverty and inequity in science education are critical to achieving the goal of science literacy for all:

> Another huge issue is' science for all'. I remember talking to other folk about 3 years ago thinking about what were the most pressing problems. I went to a talk at AERA about the role of poverty in education and how poverty was at the root of lots and lots of fundamental foundational problems that we deal with in schools and in education in general and science for all. So we are dealing with a lot of hard issues that are not de-contextualized from the life of adults and children in society. Equity is a huge issue and hugely problematic. I think one of the reasons we talked about it three years ago is because someone from the UK had asked what the biggest issues in science education in the US are and poverty is one issue

that kept coming up. (Interview, 4/11/2005)

In agreement with Professor Perry, the three doctoral candidates interviewed in this study also highlighted the importance of closing the achievement gap as a challenge confronting the science education community. Jennifer expressed the issues surrounding science for all in a more global context. She views science literacy for all as an important issue that is at the heart of the National Science Education Standards and that professional associations such as NARST have been paying close attention to the issues of race and class. She also showed how these issues are prominent in the literature.

> Looking at sessions at NARST, it seems to me that there's been this growth in the last couple years around issues of equity, particularly around race and class. There's been maybe a falling back of the interest in gender. It used to be the big thing was a woman in science and I think that is not as big as it once was. It's still there but I think there's been a bigger emphasis on race and class based on the kind of sessions and topics and titles happening at NARST. I think that's reflective in ed. literature and ed. This is an issue that is in some ways perennial in the United States because of history and context. We have groups of people, who have been at a great disadvantage in many different ways, and you rely on the school system to be one way in which to level the playing field then I think there is going to be a tension for that. I think that it is growing in science and I think that it has been there a long time in other places, more prominently and I think it's growing in science. That is certainly a huge one, and they do. The standards, they talk about this idea of literacy and what that means, science literacy and that it is for everyone, and that the point is for everyone. It is supposed to be for all kids, there's this kind of built in. That's my critique of the course. There's not enough explicit attention paid to that I don't think it's fair. (Interview, 5/17/2005)

Jennifer attributed the perennial nature of the problems of equity to the fact that some groups of people have been disadvantaged and that the challenge now facing the science education community is to achieve equity in the quality of science being taught in all schools. She sees post-modern ideas that highlight the fact that knowledge is socially constructed as one way that can help science educators to be more critical and to teach science that is relevant to all students.

> The content is not cultural right? I think even with kind of postmodern ideology being out there that everything is cultural and everything is interpreted that has created an avenue for looking at science in a little different ways than it has in the past. (Interview, 5/17/2005)

Diane agreed with Jennifer; people who think about diversity bring a critical stance. Both professors and doctoral candidates agree on the challenges posed by issues of equity and socio-cultural issues to the science education community and the need to address these issues in order to achieve the national goal of science literacy for all. However, the doctoral candidates think that the science education program at Midwestern is not doing enough to address these issues. Jennifer thinks that this is mainly due to the fact that the professors do not know how to address these issues:

> I guess that's a question about our professors about education in general a bit in the ivory tower. They really prepare teachers for environments they're not familiar with themselves, and don't know what to do themselves. We have to practice what we claim. There is need for diversity among faculty. This is my critique, that's my main critique of the college. I know that it's being addressed, they are really trying to figure out how to infuse things everywhere and it's supposed to be infused everywhere. I think the big problem is that the method classes are taught by graduate students largely and the professors can say my baby, my passion is whatever, if I don't have room, if I don't have time or the mental space and energy to try to figure out what I'm going to talk about, kids who are different from you and how to get this kind of stuff across to them. I think there's a real effort. (Interview, 5/17/2005)

Jennifer shows real concerns for the failure by her program to address issues that the whole science education community agrees are critical to achievement of science literacy for all. She realizes that the professors are trying to address these issues but there is no action. She points to the fact that empty claims are made with little action taken. James agreed with Jennifer about the lack of action on the part of the science education doctoral program at Midwestern to address equity issues:

> I don't think many people know how to address issues of equity. I think this is

> one of the areas that I recognized now as really as a social justice issue. I think there are a number of things that limited actions, predominantly that people who become science educators are often middle class white. So there are few under-represented groups in science education so I think those issues have left traditional science educators out of science. I think there are a lot of other things behind that. I think with better understanding there could be a lot more progress and a lot more opportunities for people to participate. (Interview, 3/10/2005)

Professor Perry confirmed these sentiments about why the science education doctoral program at Midwestern is failing to address the issues of equity in their science education doctoral program:

> It's so overwhelming for me but I don't even know how to work from it. There keeps being research over and over again showing there isn't science for all, so how that's not being done but there is very little work that shows how it can be done. So I find this overwhelming and I don't have great insights for it...I wonder what we can do in schools when they are learning science and I wonder how much we can do given the underlying inequalities with respect to lots of things, such as poverty. (Interview, 4/11/2005)

These views show that the faculty and doctoral candidates at Midwestern are critically looking at and questioning their practice in terms of what they are failing to do to address equity issues. These critical reflections and questioning their own practice resulted in their acknowledgement that they lack the expertise to address the issues of equity in science education. Professor Atkinson expressed hope of the potential by the science education doctoral program at Midwestern to address the issues of equity in the future because the program hired a professor who has expertise in the issues of equity and social justice. He expresses that the new faculty who has been hired has brought hope for addressing issues of equity and closing the achievement gap:

> I don't think we have very good ideas about what to do about that. I am certainly looking forward to having the new professor join our faculty because I think she has been very thoughtful about the issues of the achievement gap, that it's very deeply rooted in the way we fund schools and in both mainstream white culture and minority culture. There are some things we can do that can fairly reduce the size of the achievement gap but we are far, far away from making that work.

(Interview, 5/20/2005)

Both professors and doctoral candidates at Midwestern clearly articulated the causes of inequity in science education and they showed concern for addressing the issue and were frustrated with the fact that they do not have the expertise to address these issues. Their concern and frustration led to action mainly because they view the issues of equity as something that will be a challenge for some time to come. In the quotation below, Professor Atkinson explains the complex nature of inequity in schools that is not just limited to material resources but to human and social resources as well:

> Certainly this is a difficult issue to address because the underlying problem is that schools lack the resources, materials, human and social recourses to sustain effective programs. In science education you have to work on all those, the material resources are things like the curriculum materials and the human resources are science teachers and the way they are educated. The social resources are building communities of practice. (Interview, 5/20/2005)

The faculty members and students at Midwestern have shown a complex understanding of issues of inequity and questioning their practice has led to hiring a new faculty member who will lead and provide expertise in addressing these issues.

Teaching practice

The issues I categorized as teaching practice included talk about working with teachers in the schools to help them improve scientific literacy for all students. Five out of the eight interviewees talked about challenges related to introducing inquiry as a teaching method in the schools and teaching science for understanding. Professors Atkinson, two doctoral candidates, and one recent graduate identified improving teachers' practices in order to achieve the goal of science literacy for all as a challenge confronting the science education community. Professor Atkinson talked about the challenges related to bringing reforms in the science curriculum and teaching. He specifically highlighted his concern about the need for students to become more environmentally literate and the need for teachers to be knowledgeable about teaching issues related to this. Professor Atkinson showed concern for the need to work with teachers to improve literacy among students. His conversation about science literacy is at two levels, the first is at national level and this is related to the need for environmental literacy and this is how he framed the second conversation:

> The second conversation is the local conversation, working with local teachers on developing ways of helping students become more environmentally literate in their classrooms. (Interview, 5/20/2005)

Professor Atkinson, who is working on developing curriculum materials that focus on making environmental literacy an integral part of the science curriculum, sees his role as an advocate for helping teachers to achieve the goal of helping students to become environmentally literate. The environment is part of our daily lives, and it is becoming more important as issues such as global warming, pollution, and the overuse of natural resources such as oil become concerns.

Similarly, William, a doctoral candidate, highlighted a specific challenge related to acceptance of and use of inquiry in science teaching by teachers. In the quotation below, William attributed the lack of use of inquiry in schools to lack of role models that can show teachers how to do inquiry. He shows the challenge faced by teacher educators who are promoting inquiry but are failing to model it in a way that helps teachers understand it:

> Introducing inquiry as a teaching method is still having a hard time- it is not in line with the grammar of schooling, it is not being modeled properly for teachers to follow. It's not something that shouldn't be done, but I think over the last ten years it has been a part of educators to somehow convince teachers to adopt inquiry as a dominant teaching factor. My opinion is that they are still having a hard time doing it. This is like all reforms; if you look at it with science education

> standards they are all about inquiry. Frankly, my impression is that it is not being modeled properly for teachers to follow. People are making the input and in trying to do so sometimes you end up with a caricature of inquiry. (Interview, 5/13/2005)

From William's point of view, one gets the sense that there is no agreed upon definition of inquiry and teaching through inquiry and as a result the results are not very satisfactory.

In relation to the idea of helping students become more knowledgeable about reform-based teaching, Jennifer, a recent graduate, talked about the challenge of teaching science for understanding. Her concerns are similar to William's concern about the challenge of changing the teachers' practices from just focusing on covering the syllabus but to focusing on how they should learn science in order to develop deeper understanding.

> There is this kind of perennial problem of what's been called teaching for understanding or that sort of thing, where kids are really learning something as opposed to something else. I think that goes along with a lot of in depth look at what is worth knowing and what kids need to know about. There's that part of the standards. The other thing I think the standards tries to do is integrate you know its not just content standards about what kids should be learning but find a way to approach those things that will help them understand what's going on as opposed to just giving back something. How do we achieve that? In order to achieve that, we need to integrate other programs like professional development. (Interview, 5/17/2005)

Professor Atkinson, William, and Jennifer, all see the need for working with teachers and helping them to reform their teaching practice as important issues that the science education community should be focusing on. Implicit in their concern is the fact that science educators are the custodians of change; hence these issues should be the focus for research and outreach. Still on the issue of working with teachers to bring about reform, Professor Perry and Joshua attributed the lack of reform adoption by teachers to the complex nature of schools. Professor Perry talked about the difficulty of bringing about reforms in a complex education system:

> Trying to have reform happen in a very complex system that does not want to change in many ways. The schools, the public, the government, the issues of poverty and environment-- that is hard to change. (Interview, 4/11/2005)

In this case Professor Perry is not thinking of just helping teachers to change their practice but she is also thinking about how this can be done in a complex education system. She defined the complexity of the education system as being comprised of both the administration and other issues such as poverty.

Similarly, Joshua talked about the challenges brought about by the conservative nature of schools. However, he thinks that reform is slowly changing in some schools due to pressure from the state tests, standards and parental pressure:

> The conservative nature of schools – this is changing, different strategies are being tried. I think that in the last 10 years, there have been more schools that have been willing to try something different than what there were in the past. I think they have probably changed because of some of the pressures that schools are feeling from state tests or the standards movement or from parent groups, or employers or whatever. But that conservative nature of schools, I think its still there definitely, but I think that maybe there has been some chipping away at the edges of it. (Interview, 3/14/2005)

Implicit in both Professor Perry and Joshua's statements are the issues directly and indirectly related to the teacher's practice. The complexities of schools go beyond what teachers can do to control their practice. "The conservative nature of schools" as it was referred to by Joshua can be seen at different levels, ranging from a) the teachers' own resistance to change their practice because they are comfortable with the way they have always done things; b) resource availability in the schools which may limit the things science teachers can do in their classrooms; and c) lack of support from administration and parents for teachers who are willing to try and change their practice.

The concerns shown by professors and students at Midwestern reflect the nature of their doctoral program, which has a teacher education focus. Doctoral students have the opportunity to work on research projects related to teaching practice, where their concern about issues related to reform-based teaching are enhanced.

Teacher Development

The issues I categorized as teacher development included talk about the challenges of proving the relevance of teacher education through authentic research and the challenge of preparing elementary teachers to teach science. For example, Professor Perry talked about her concern with the pressure from government for scientifically based research and the need to prove that teacher education is important. She also talked about the challenge faced by science educators in the schools where science content is valued more than the way it is taught. She thinks there is need to counter this way of thinking through research:

> Well, so I think one big issue related to our government is whether we can be able to prove that as science educators we have a purpose and whether we can prove our purpose and role for improving education and for helping to educate preparing teachers. Basically that our presence is useful and that what we are seeking is important, like the standards. I guess there is a sector of the population that just doesn't think that anything other than learning terminology in science is important, including some of the teachers. There is a small sector of the population, scientists and science educators, who are trying to think about that. (Interview, 4/11/2005)

Professor Perry also showed her determination to work towards proving the importance of teacher education through research to demonstrate effective practices. She also talked about how her desire to research in this area attracted her to this institution where people cared about similar research in teacher education. Joseph shared similar concerns with Professor Perry about the need to prove the importance of teacher education. He considers teachers to be very important. They play a critical role in students' learning; hence he sees the need to focus on teacher education research.

> I think my view is that the teachers actually ------take the central role to facilitate student learning. So actually, we need to prepare good quality teachers for the future so that they can actually nurture some good classroom environment and to teach students for science understanding. We need to prepare good teachers, so we need to develop some good ------- and good practice for doing that, important part of education. (Interview, 4/11/2005)

Both Joseph and Professor Perry show their conviction about the importance of teacher education and the need to continue working on preparing teachers to teach for understanding.

> For past several decades I think that in science education, the students were the central focus. I think teachers were considered to play a secondary role compared to students' role. But now we think that in the past 10 years I think, teachers need to take more important role to facilitate good students' learning. I think that's a very important debate now. Some institutions believe that the teacher has really minor impact on student learning. Some people believe that, but in other institutions including ours, we believe that teachers are the most important people, they influence students' learning or whatever. I think the struggles that we have had, we as researcher, we as teachers, are one of the important issues in teacher education. So we know that we are actually struggling, we are working hard to resolve that kind of complaint, problem, tension or something, but those are I think the most important things we need to actually keep working on. There are several issues to actually cause those kinds of problems in teacher education, some problems and questions we need to handle. (Interview, 4/11/2005)

Joseph pointed to the fact that earlier research had focused on conceptual change and student learning and the teacher's role was not seen to be as significant in students' learning. This point could explain the struggle faced by science educators to prove that teacher learning and teaching methods influence students' learning.

On a different note, Joshua talked about the challenges of preparing elementary teachers to teach science. He showed his concern for the lack of an in-depth understanding of content knowledge, the lack of motivation to teach science, and the school system's lack of support for teaching science. Joshua has concerns about effectively preparing elementary teachers for science teaching:

> I think one of the issues is definitely elementary science. I teach elementary science methods, and I am very concerned about the subject matter knowledge of elementary teacher candidates. They don't have a very firm grasp of even very elementary science concepts. They are willing to try, but a lot of them will say well, I had bad experiences myself when I was in elementary and middle school of science. So I was turned off to science. I only took the minimal amount in high school. And now I am going to be an elementary school teacher, so I didn't have to take more than 2 or 3 science classes in college. I don't really like science; I'm not interested in science. And now they are going to be expected to teach science.... they're fine with spending half a day teaching kids how to read. And having science take a back seat to reading and mathematics, and so that is going to be an issue, I think its an issue right now, but its going to become an even larger issue in the next 10 years. (Interview, 3/14/2005)

Similarly Joseph talked about the general lack of understanding of the nature of science among science teachers as a challenge that is confronting the science education community. He highlighted the need to prepare teachers to have an understanding of how science ideas are developed and the need to emphasize those views of science in teacher preparation:

> And the second thing is actually teachers' views of science and nature of science. You know that in order to help teachers better or science understanding we need to help them have good views of science, if they have some incorrect or inaccurate ideas of how science has been developed, if they don't understand Thomas Kuhn's ideas of normal science, scientific or some other, you know scientific ideas, then they would have difficulty actually of shaping some good scientific science classroom practice or ------ (not clear) understanding--- (unclear) so I think the best way if we can push them to-- for us to emphasize teachers' good views of science. So our teachers actually understanding of science... (Interview, 3/11/2005)

Both Joseph and Joshua show their concern for improvement in science teacher preparation in order to have teachers who have a good understanding of science both at the elementary and secondary school levels. In order for the goal of science literacy for all to be achieved, teachers themselves should have a good understanding of the content.

Again the views shared by the interviewees about teacher development in this section reflect the nature of their program that focuses on teacher education. This issue influences the kind of research that doctoral students and faculty decide to engage in and the focus of the courses.

Curriculum

The issues identified as curriculum included talk about the role of standards in the curriculum, curriculum development, and environmental literacy curriculum. Generally the faculty, recent graduates, and doctoral candidates from Midwestern see a close connection between the national standards, Project 2061 Benchmarks, and the science curriculum. The general feeling is that the standards and benchmarks are good enough and they have informed the curriculum, but several interviewees at Midwestern see the need to move beyond the current standards and benchmarks and to improve curriculum materials. According to one doctoral candidate interviewed, doctoral candidates and post-doctoral students at Midwestern are looking more at what is missing in the current standards:

> Project 2061 Benchmarks and criteria for curriculum analysis were the starting points and were very important in conceptualizing the center's mission. But I think as we proceed we are sort of seeing a need for [or] going beyond that in various ways. The standards need to be interpreted and clarified and perhaps reconceived in some way, and I think our different projects within the Center are coming at that at different levels. Most of the projects elaborate on and interpret and bring additional things to bear on defining learning goals beyond what's just on the standards. Our science literacy project is doing a fundamental rethinking of what standards ought to be like and what they ought to include and so I think that's a longer-term look.

The Center for Learning and Teaching is developing graduates who are taking a critical look at the available curriculum materials as well as the available standards and finding ways to improve them. In a way the graduates from the Center for Learning and

Teaching are being prepared to become leaders in research and development of curriculum materials. According to a faculty member who is one of the principal investigators for the Center for Learning and Teaching, the graduates who are specializing in curriculum development will be more prepared to take a critical look at curriculum materials and their use as they prepare teachers. I asked the Center Co-PI how he thinks the doctoral students specializing in curriculum development will be different from the other doctoral graduates. As mentioned earlier, he was confident that these graduates will be more conscious about curriculum materials and will explicitly address them in their teaching. He went on to emphasize the preparedness of center fellows in the area of curriculum development:

> I think that more of them will do more work with curriculum and curriculum materials and I think they will do so with a particularly stronger background because theoretical background thinking about the research and not just the development of the materials. Midwestern has been heavily oriented towards teacher education and professional development and I think for our graduates, the ones that did substantial work in the center will be more sensitive to develop curriculum materials and will be more likely to incorporate that in their research and will be more likely to be involved in curriculum development efforts. (Interview, 9/28/2005)

Professor Atkinson was in agreement with Diane and the Co-PI for the Center with regards to the fact that they are taking a critical look at curriculum materials and thinking of how to move beyond the current standards and benchmarks at the same time. Professor Atkinson who is leading the science literacy group in the Center went on to talk about the need to improve environmental literacy worldwide. He shows the need for the national standards to reflect recent research both in science and in education.

Taking a more critical look at the work done in the Center for Learning and Teaching, Diane, a doctoral candidate, feels that: "the national standards helped educators think about what science should be about and what students should know." She also feels that "Project 2061 benchmarks are useful resources but they assume a narrow vision and they are content-driven." She went on to highlight that the Benchmarks are a critical aspect of the Center for Learning and Teaching. Professor Perry shared similar sentiments about the need to balance the National Science Education Standards and the Benchmarks in the work done by the Center. Lack of consensus on definition of reforms and how to achieve them brings about these challenges. The concerns raised by professors and doctoral students about how reforms should be used shows a difference in what different faculty and their students value in research, and this is also influenced by how they interpret the reforms.

Addressing Issues in Science Education

When asked how the issues in science education can be addressed, the interviewees all agreed that there is a need for combined effort between politicians, science educators, and teachers. However, the interviewees felt that the politicians and business people need to play a greater role working with science educators and teachers to address these issues. The majority of interviewees identified solutions to lie within the context of the education system and teacher development (Figure 5.3). In this case context refers to areas of school funding, provision of resources, and improving teacher salaries.

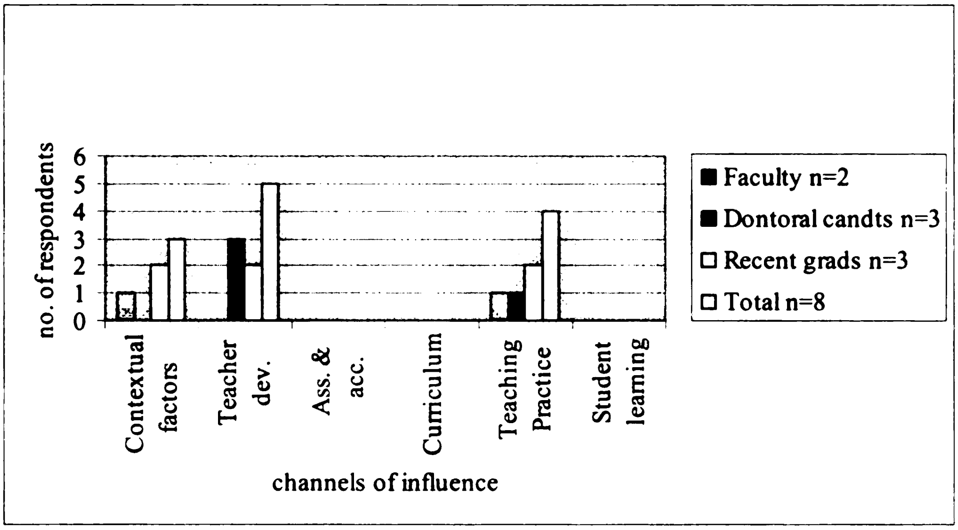

Figure 5. 3: Solutions to addressing issues in science education

Professor Perry feels that addressing issues related to the reforms needs leaders who can help bring about a consensus in terms of how the reforms should be addressed. In the quotation below she shows the complications that are brought about by differences in opinion among science educators:

> I think it would be nice if there was a leader who would set aside their agenda for the purpose of trying to get people together for a consensus. If that is true for this institution it would be interesting to see how true that is nationally. Although I think there is some generational flair to some extent. People of certain generations who were trained with the conceptual change model or the inquiry model, or socio-cultural model, whatever, sort of evolved at the time and then people here have the teacher education background. (Interview, 4/11/2005)

Several other interviewees also felt that there is need for some sort of leadership to address the challenges confronting the field of science education. For example Joseph felt that there is need for two different types of leadership.

> I think I can make actually two categories, which include: 1) people in one area will be like policy makers in science education. 2) The second part of the leaders is more like researchers and university faculty who are working in the university as researchers. What I mean by policy makers are those people who are involved in policy making and are involved in writing influential policy documents like

> curriculum materials, federal curriculum policy or whatever ideas to George Bush, for example the No Child Left Behind Policy. (Interview, 3/11/2005)

Joseph felt that although faculty are engaged in research that can help advance ideas and help address issues in the field, federal policies do have a strong impact on science education. Science education leaders at federal level can help make the research findings and faculty ideas happen. William also believes that there is need for leadership both at the university and federal levels, but he also thinks that several of the challenges could be addressed by having better teacher education programs:

> People like you, professors, those in the university, everybody, policy makers. And also making them competent because having better teacher education programs having a lifelong and those teaching in the profession and developing strong teaching community where it can be effective. I think they will find teachers, will begin to find solutions to these problems. (Interview, 5/13/2005)

Professor Atkinson also felt that the issues of equity and closing the achievement gap are complex and that there is need to make the required resources available as well as providing human resources through teacher education programs. He also talked about the need to make social resources available through building communities of practice. Generally the interviewees from Midwestern felt that there is need for leadership both at the university level and the federal level. This is mainly because they felt that the issues in science teaching could not be addressed if issues of equity are not addressed. The federal leadership is therefore needed to ensure provision of materials and resources that will make teaching successful.

Aspects of the Science Education Doctoral Program that Needs to Change at Midwestern

Although the doctoral candidates and recent graduates feel that their program gave then a strong foundation, they felt that a few things could change in order to make the experience complete. For example James a recent graduate felt that there was need for the program to provide students with writing for publishing experience:

> One thing I think that would be better is if I had more experience writing for publication so like I have I think a limited experience in writing for publications as opposed to writing for courses. I think as a faculty member you should have more opportunity for graduate students to work with faculty on writing. I think more training as well from a faculty viewpoint how do you see a faculty member working with a student, how do you write grants? I have not written grants. I think that would be something worthwhile ...(Interview, 3/10/2005)

Writing for publication is not a requirement at Midwestern. Although students get a good foundation of research experiences in different areas, they may graduate without having written for publication. James talked about how he is learning to write for publication on the job although he had the opportunity of working on several research projects as a doctoral student.

Some of the interviewees felt that the program at Midwestern needs to revamp its courses to include more specific science education courses. Since the program has a teacher education focus, only a few science education courses are offered and not all students get to take them because they are offered every other spring semester and by the time a science course is offered a student may be done with their coursework requirements. Below Jennifer thinks that the science education courses should not just focus on traditional methods and theories but that they should include issues of diversity:

> I was going to say maybe some more specific science ed. grad classes because there are not a lot and there's [course] 955 and that's it. I like 955 in that you can get a sense of what other people are doing. The reason I hesitate about saying there maybe should be more grad classes in science ed is that I think that it's fine to say as long as those course offerings are a spectrum. I think that it's also difficult to be giving numbers. What I mean by spectrum is that it isn't just focused on teaching for other standards for example or it isn't just focused on learning or theories of learning or something like that, but that there are these issues of diversity say for example. (Interview, 5/17/2005)

On the other hand William a doctoral candidate felt that the program needed to reduce the coursework required in the College of Education and maybe allow students to take courses from outside the College.

> I guess one that I would do different is there's too much coursework. There is too much coursework within the College of Education. If coursework could be used and somehow teachers could find inquiries to enroll in courses outside the College, these two things I guess. (Interview, 5/13/2005)

Discussion

Achieving science literacy for all is the goal of the doctoral program at Midwestern. The faculty and doctoral candidates showed a strong sense of concern for addressing issues related to low achievement in science and closing the achievement gap that exists among schools, and improving teachers' practice, and teacher development. There was a strong sense among faculty and doctoral students that the issues of equity, poverty, and socio-cultural issues need to be addressed in order to achieve the goal of science literacy for all. The interviewees openly questioned what their program was doing in terms of addressing the challenges and they acknowledged that they were not addressing issues of equity because they did not know how. The sense of frustration about the lack of information and knowledge about how to address these issues was shared both by faculty and doctoral candidates. Professor Atkinson mentioned the fact that the program had hired a specialist in issues of equity in science education, and there is a sense of anticipation among interviewees who are looking forward to working with the new faculty member to address the issues of inequity in science education.

The interviewees also generally agreed on what issues needed attention in science teaching and teacher development. The way faculty and doctoral students at Midwestern think about these issues can be attributed to the fact that their program has a teacher education focus and students are required to take courses in teacher education. The students showed a more sophisticated view of science education, which is informed by understanding the education system. From the analysis of courses such as 'Learning to teach' and the 'proseminar' courses that the students are equipped with a critical lens through which they view science education and the issues associated with achieving 'science literacy for all'. Both students and faculty were questioning what the program is doing about the issues that need to be addressed. James a recent graduate supports the claim I made about how the teacher education influences the way doctoral students think about issues in education:

> I think one of the things that has helped our abilities is to investigate those kinds of questions and to develop a more rigorous foundation in sociological thinking. What has helped us is using smaller case studies or smaller sample size level studies to understand what the challenges are in a different context. So I currently think that students can have a strong foundation in critical theory and other things to give them the tools to investigate these questions at a productive level. I think another thing graduate schools have to do is send out students to learn how to do studies that encompass that. (Interview, 3/11/2005)

There were also mixed feelings about the science education reforms among the faculty, doctoral candidates, and recent graduates at Midwestern. Overall, the program at Midwestern view the current science education reforms as an important step to ensuring that students get quality science education. The standards and benchmarks are used in the pre-service teacher education program, and most interviewees mentioned that they use either the standards or the benchmarks in their teaching, even though they may not have encountered them in their doctoral courses. Although they all use the standards in their teacher preparation courses, Professor Atkinson mentioned that at doctoral level he wants students to think more critically about the reforms and how to improve them. Professor Atkinson and two recent graduates felt that the standards were no longer useful and they need to be rewritten. For example, Professor Atkinson shows his acknowledgement of the usefulness of standards at the time that they were written and that there is need to re-look and revise them:

> I think they did a pretty good job of capturing the conventional wisdom of science educators in the 1990s and that wasn't terrible but it's not great either. The fact that there are standards is useful; we are better off having standards than not having standards. They certainly could be worse than they are. (Interview, 5/20/2005)

In agreement with Professor Atkinson, James also critiqued the reforms especially the Benchmarks for being too many. However he looks at the way differently than Professor Atkins, because he thinks it would be politically unwise to revise the reforms now when some people are still learning about them. James said:

> I think that they are probably productively wrong. Productively wrong, meaning it's not correct but it was worthwhile. It wasn't the right answer, but it was where you needed to go to make progress. By that I mean I think particularly the benchmarks you know there's no way any teacher is going to or a school system is going to be able to design teaching experiences that kids learn all of that; it's too much. So there were just too many, so from what we know about how long it takes to learn these things well, there's no way you can teach those things well. I think that has actually had a negative effect in that it undermines the credibility of things and to say here's what we should teach but it's impossible, but it's productive because it's farther along towards the direction we need to go than the year before. So from an evolutionary standpoint I see it as a necessary step and one that we can figure out how to use to move beyond and they're all critical issues to doing that. Well, it would be difficult to say we need to revisit the standards partly because when there are people still learning things about them you know I'd say it would be politically unwise. (Interview, 3/10/2005)

Similar sentiments were shared by Joshua a recent graduate who also thought that the reforms, especially the national standards, are asking teachers to do too much. He shared his feelings about the reforms:

> Now I will say this about "Science for all Americans". Um, in looking at that document, I don't know how many scientists there are or people who have devoted their career to science that would have a rounded understanding of all the topics that is in that book. In my opinion these standards documents are too

> ambitious. They just include too much. I mean the argument goes, that there is "Science for all Americans", here are things that somebody who graduates from high school in the US should understand about science. But I don't think it is being done. (Interview, 3/14/2005)

Professor Atkinson agreed with the political nature of reforms and he thought that changing them will need political willpower. However, he is optimistic that when the right time comes he will be able to contribute to the changes in reforms. He is specifically interested in making environmental literacy central to the science standards. He reveals his strategic plan of having documents ready that can be used to champion the new wave of reforms:

> The process that produced them [standards] was political then and will be even more political if they were revised, so whether it's possible to make a better document, I am not sure. I think if it was politically possible to make a better document intellectually that's what the environmental literacy project is all about, that is to say, if I have my own way the standards would be quite different both in content and in what they advocate in terms of pedagogy. I think we all have our voice in addition to everyone else having their voice, but it will be just one voice among many. I think that the Bush administration's stance on environmental issues is way out of line with even the Republicans. Even the Republican mainstream recognizes that the environment is more important. The next administration whether democrat or republican is going to be more focused on environmental kind of issues than the current administration. When it changes I think we are going to have some ideas in place that people will come looking for. Deciding you want to change something you need something written and that way it will be possible to change the standards. When the political willpower is there from other sources we will provide materials that will help people act on their will. (Interview, 5/20/2005)

Therefore, Professor Atkinson and the two recent graduates show that they do not support the reforms, and they think they are asking teachers to do too much. Professor Atkinson also thinks that the content standards need to be written around the theme of environmental literacy since this is becoming a major concern in the world today. These sentiments are reflected in the focus of doctoral course entitled 'Science Literacy

Exploration' that was taught by Professor Atkinson where he raised questions about what science literacy means.

Similarly, Professor Perry thinks the reforms are overwhelming and need to be revised. However, she also feels that the reforms bring some order to the field of science education:

> In general I think that the standards are for the better that with such hodge-podge of stuff before and at least now there is some sort of document about what science teaching should look like. I really care obviously about helping teachers and kids engage more in practices of science and habits of mind for all kids. Those are complicated things and I am not so sure whether the message is so complicated. I looked at the inquiry standards book people still don't know what it is and there are people who are still fighting against inquiry because either they think it doesn't represent scientific practices deep enough or they think it's too superficial. I support the vision and I wish people supported the vision in more concrete ways. To some extent there is validity in that the standards are a little behind times and there are always advances in talking a bout what we should be doing and talking about. To be constrained to just doing the standards would be very limiting if we are really trying to break out of the mold.

Although Professor Perry supported the standards, towards the end of this quotation she acknowledged that the standards are a little outdated and that there is need to keep thinking about how to improve. Similar views are reflected in the way Professor Perry thinks about how the standards are incorporated in research. This shows the different ways of thinking among faculty at Midwestern. Similarly, the students also share a critical approach to thinking about the reforms and other issues in science education.

Conclusion

The doctoral program at Midwestern has a teacher education focus. Analysis of course documents show that the courses equip doctoral students with a critical lens through which they view issues in science education. Science education courses such as 'Exploring scientific literacy' explicitly addresses the reforms from a critical viewpoint, questioning what scientific literacy means and how it can be addressed. The program also explicitly addresses the reforms through courses such as the 'Science Curriculum and Teaching' and 'Teaching for Understanding" which directly explore the reform documents. The Center for Teaching and Learning strives to achieve the goal of "science literacy for all" by focusing on critically analyzing and conducting research that aims at producing curriculum materials that support reform-based teaching. The Center also engages in outreach projects and helps teachers and teacher candidates to critically analyze available curriculum materials and modify them to suit their needs.

Although some doctoral candidates and recent graduates agree with the faculty that the program is addressing the current reforms, they all showed some reservations about the usefulness of the reforms and were more critical about them. Professor Atkinson and two recent graduates explicitly expressed their views that the reforms need to be revised. They however acknowledged the political nature of the reforms and that it is not easy to revise them. Nonetheless, Professor Atkinson is taking a strategic move at preparing materials to push forward for reform once the political climate is right.

All interviewees emphasized issues of equity and social justice as a challenge confronting the field of science education. Issues such as poverty, poor funding of urban schools, and lack of resources were identified as influencing the quality of science that students receive in urban schools. They expressed their concern that the reform goals of 'science literacy for all' will not be achieved unless issues of equity are addressed. Both faculty and their students agreed that addressing issues of equity was complex and they acknowledged that their program did not know how to address these issues. However, according to Professor Atkinson they hired a professor who has experience dealing with issues of equity and social justice. Consequently, there was hope among interviewees that in the future they will at least address some of the equity issues with support from the new faculty member.

Both formal and informal mentoring exists for doctoral students at Midwestern. The doctoral students get experiences working on different projects both in teacher education and in science education. The Center for Learning and Teaching provides funding for fellows who are being prepared to become leaders in research on curriculum materials and curriculum specialists. The fellows in the Center for Learning and Teaching also get to teach methods courses and work on other teacher education and science education projects. Almost all doctoral students get experience teaching science methods courses and the doctoral students and recent graduates feel that they get a strong preparation in both teaching and research. However, some recent graduates feel that there is need to prepare students to write for publication. In general all interviewees shared similar concerns and they all took a critical look at issues in the field of science education, in some instances questioning their own practices.

There seems to be a tension among what the doctoral program advocates and teacher preparation expectations. We have seen that the doctoral program takes a complex critical approach to preparing its doctoral students to think of science education from multiple perspectives (Kincheloe and Weil, 2004) and ask questions that enable them to come up with solutions to addressing the challenge of achieving 'science literacy for all' students. On the other hand, teacher preparation expectations are different. Although doctoral students report that they take a critical approach to preparing teacher candidates, Professor Atkinson showed that he approaches issues such as standards differently when teaching teacher candidates and when teaching doctoral students. When teaching doctoral students he takes a more critical approach, and he expects doctoral students to think more critically about the standards and how they can be changed. On the other hand, he expects teacher candidates to know the reforms and apply them in their teaching. It is clear that the focus of the doctoral program is to prepare leaders who have a complex critical approach to issues in the field and who will lead in bringing about change. At the same time there seems to be a tension between a complex critical approach in doctoral study and a simplistic critical approach in the teacher preparation program.

Science educators at Midwestern agreed that they do not know how to address issues of equity in science education. Addressing issues of equity requires a complex critical approach; similar to the one the professors at City Ville are engaged in. Because of their commitment to complex critical thinking, the science education doctoral program at Midwestern hired a professor who has experience in urban science education. This professor is going to focus on addressing issues of equity in preparing teachers. Hence both the doctoral program and teacher education programs at Midwestern are going to take a complex critical approach to science education.

CHAPTER 6

THE STORY OF SOUTHERN VALLEY SCIENCE EDUCATION DOCTORAL PROGRAM

Introduction

In chapters 4 and 5, I have presented two cases, two different doctoral programs, which emphasize different approaches to addressing reforms in science education for their students. In this chapter I will present the third case, the science education doctoral program at Southern Valley University, a large research intensive university located in the Southern part of the United States. This university is located in a larger town than Midwestern but smaller than City Ville. It is located in the warmer southern part of the United States—a climate that is close to my background of growing up in the warm Southern Hemisphere.

Again, I summarize the description and analysis of the course of study at Southern Valley, present faculty, doctoral candidates and recent graduates' views about the reforms and important issues in the field; and what mentoring and preparation is like as a doctoral student at Southern Valley. As a reminder, the central research question for this study is: "How are science education doctoral programs interpreting the current reforms and how are they enacting them in preparing future leaders in the field?"

I used the National Research Council's Framework for assessing the influence of standards in Mathematics, Science, and Technology Education that I described in chapter 3 as a framework for analyzing data from the cases. Key features of this framework include channels through which policies and reform impact student learning in K-12 education. This chapter is made up of 4 sections--the background information, a description and analysis of courses offered, faculty research and mentoring provided to doctoral students, and the views of faculty, doctoral candidates, and recent graduates. Finally, in the discussion I compared and contrasted the views of faculty, doctoral students and recent graduates. In the conclusion, I provided a summary of the patterns that exist.

Geographic location

Southern Valley is a large research-intensive university located in a medium sized city of about 120,000 people in the Southern part of the United States. The city has a diverse population with the largest minority group being Hispanic American. Southern Valley is a publicly funded university and most doctoral students are supported through research and teaching assistantships as well as fellowships. The Science Education doctoral program at Southern Valley is housed in the Department of Teaching, Learning and Culture and it is called Science Society and Technology Education. Faculty members from the Science, Society and Technology Education program are either co-PIs or actively participate in the Center for Learning and Teaching, which is funded by NSF. The Center is run collaboratively with the College of Natural Sciences.

Participants

Faculty

The two professors who were interviewed have been at Southern Valley for at least 15 years. They both have extensive public school teaching experience and they are both working in the Center for Learning and Teaching. Their scholarly interests are similar—classroom learning and teacher learning. They are both interested in use of technology in science education.

Professor Laura King

Professor Laura King is an Associate Professor in the Department of Teaching, Learning and Culture, specializing in Science Education and has been professor at Southern Valley for almost 15 years. She has 20 years of public school teaching experience. Her research and teaching interests are in the areas of classroom science learning, teacher education, field-based teacher learning, philosophy, & sociology of science education, information technology and promoting conceptual change in culturally diverse science classrooms. She has published book chapters and journal articles in science education journals in diverse areas, some of which are: philosophy of science education, multiculturalism in science education, teacher education and nature of science. She won the Montague (CTE) scholar award and served on numerous committees of professional organizations, such as the executive board of the National Association for Research in Science Teaching and the Technology Committee for the Association of Science Teacher Educators. She has been on several editorial boards including Science Education and Journal for Research in Science Teaching and also served as associate editor of American Education Research Journal.

Professor Sarah Evans

Professor Sarah Evans has been Associate Professor of Math and Science Education at Southern Valley for almost 20 years. Her research and teaching interests are in the areas of classroom observation, design study methodologies, science curriculum design, model-based science teaching and learning, teacher education and problem-based science learning. She has published articles in the International Journal of Science Reform and has some articles accepted for publication in the Journal of Research in

Science Teaching and the Journal of Science Teacher Education. She was President of the School Science and Mathematics Association and co-editor of the Contemporary Issues in Technology and Teacher Education Journal. For the past two years she has taught the following courses: Research Methods in the Learning Sciences, Trends in Curriculum and Instruction, and Advanced Elementary Science Methods.

Recent graduates

Only two recent graduates were interviewed for this study. They graduated from Southern Valley at least two years ago. These two recent graduates have taken up jobs working on projects at Southern Valley University. The third candidate could not be interviewed because she backed out of the study at the last minute, which explains why only two recent graduates were interviewed from Southern Valley.

Noel

Noel graduated from Southern Valley in 2003 with a PhD in Science Education. Upon graduation, Noel took a position as a Research Associate in the Center for Mathematics and Science Education at Southern Valley, and he also teaches physics. During his tenure as a doctoral student, Noel worked with the Center for Mathematics and Science Education on professional development projects with science and mathematics teachers. His job in this Center also involved developing products and internet resources for use in physics classrooms. Noel also worked as a physics lab instructor and was a teaching assistant for an elementary methods course. Noel is certified to teach secondary science. He taught physics and mathematics for fourteen years before he joined the PhD program. His dissertation investigated preservice teachers' learning to teach physics, and he won Dissertation of the Year Award.

Candice

Candice graduated from Southern Valley in 2004 with a PhD in Science Education. Upon graduation, Candice took a position as a Research Scientist and is currently interim director of a school improvement and research consortium at Southern Valley. She is teaching mathematics education courses. During her tenure as doctoral student Candice worked as a teaching assistant and taught mathematics and science methods courses. She also taught introductory college physics. Candice is a certified teacher and taught high school physics before she joined the PhD program. She also worked on several federally funded programs for high school science improvement and worked as a college adjunct faculty teaching physics. Her dissertation investigated Modeling and its Impact on Instruction. She also won a Dissertation of the Year Award.

Doctoral Candidates

The three doctoral candidates who were interviewed for this study are in their third, or fourth year of study. At the time of the interview, only one doctoral candidate was writing his dissertation. Two of the doctoral candidates had teaching experience when they came on the program. All three doctoral candidates have worked as research assistants in the Information Technology Center.

Carla

Carla is a 4^{th} year doctoral candidate who is currently at the dissertation writing stage. Her dissertation focuses on problem solving in Environmental Sciences. Currently Carla is working as a research associate at Southern Valley and plans to continue working there after graduation. She has worked as a research assistant for the Information Technology in Science summer workshops. Before coming to the PhD program, Carla taug

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taught middle and high school science for 36 years before joining the program. She won the State Teacher of the Year Award in 1989. She has presented several papers at conferences and professional development workshops. She is a member of several professional associations such as American Association for the Advancement of Science, American Educational Research Association, and was president of Kappa Delta Pi, Mu Chi Chapter.

Jim

Jim is currently a 4th year doctoral candidate and he is currently writing his dissertation. During the tenure of his doctoral studies, Jim worked with pre-service teachers as a field instructor in urban schools. He has also worked on professional development projects with middle school science teachers. He worked as a research assistant with the Information Technology in Science Center. Before coming to the doctoral program, Jim taught middle school science for 5 years. He has presented papers at several professional conferences.

Cindy

Cindy is a third year doctoral candidate. She has worked as a research assistant with the Information Technology in Science (ITS) Center during her doctoral program. She also worked as a part-time science and mathematics teacher employed by a Christian school in the area. She also worked as an instructor assistant in the chemistry department. Cindy did not have teaching experience. Before coming to the doctoral program, she worked as a quality assurance chemist for a pharmaceutical company and as a chemical technician for research and development for a private company. Cindy came to Southern Valley on a full scholarship offered through the Information

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Technology in Science Center and the National Science Foundation. She joined the ITS second cohort during the summer of 2003.

Center for Learning and Teaching

The Science Education doctoral program at Southern Valley as part of the College of Education and Human Development is an active participant in the Center for Learning and Teaching partnership with the College of Natural Sciences. This Center was established with funding from the National Science Foundation. The Center offers an interdisciplinary graduate program that seeks to replenish the nation's supply of science and mathematics education specialists through collaboration among scientists, mathematicians, education researchers and education practitioners. The Center for Learning and Teaching has the following goals that are posted on their website:

1. Production of education specialists through a program of study focused on the interaction between scientists and mathematicians, education researchers and education practitioners.
2. Creation of new knowledge through research on the impact of information technology on learning and teaching science and mathematics.
3. Development and dissemination of quality professional growth experiences structured around the impact of information technology on learning and teaching science and mathematics.

The mission of the Center is to change the culture and relationships among scientists, educational researchers, and teachers by engaging all in the use of information technology to learn about how science is done; how science is taught and learned; how science learning can be assessed; and how scholarly networks between scientists, edu

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educational researchers, teachers, and students can be developed. The Center is led by scientists and educators, and brings together researchers, educators, master teachers, and students from a variety of disciplines by collaborating on the use of information technology to transfer current research into the classroom.

Participants in the Teaching and Learning Center take coursework during two summers with a three-week intensive experience on the Southern Valley University campus as part of a scientific team. All courses are team-taught and include faculty specializing in science education, educational psychology and information technology, as well as various science disciplines. During the first academic year after the first summer, participants will be involved in instructional applications in their classrooms that are unique to their science team. Successful involvement in this professional development experience will qualify participants to complete coursework and science team experiences designated for the second summer, which is another three-week intensive experience. The ITS Center has developed a core of 12 credit hours worth of courses as described below:

Table 6.1: Information Technology in Science core courses

Course	Credits
Practical applications of Information Technology in Science Teaching and Learning	3
Theory of research	3
Problem based science applications	6
Total	*12*

Upon completion of these 12 credit hours, all candidates receive a Science Education Specialist Certificate. Those pursuing degrees may incorporate these 12 credit hours into a degree program with the approval of their degree committee. Since its inception 5 years ago, 70 students have been recruited into the PhD program through the Information Technology Education Specialist program. The majority of graduate students are enrolled in masters and Ph.D. programs in science education; but there are also some enrolled in various science departments such as geology, chemistry, wildlife and fisheries science, as well as a few in instructional technology through the Educational Psychology Department.

Findings

Courses Offered

The traditional science education doctoral students at Southern Valley are required to take 4 core courses, 5 research courses, 8 departmental and general electives, and 13 credit hours of dissertation research for a total of 64 credit hours (Tables 6.2 and 6.3). The four core courses include: curriculum theory, instructional theory, philosophy of education, instructional theory, philosophy of education, and history of education. These account for 12 credit hours. The research methods courses include ways of knowing and paradigms of research, quantitative research methods, qualitative research methods, advanced quantitative and qualitative research methods and research in area of emphasis and these account for 15 credit hours (Table 6.2).

Table 6. 2: Required core and research methods courses at Southern Valley

Core Courses	Credits	Research Courses	Credits
Curriculum theory	3	Ways of Knowing and Paradigms of Research	3
Instructional Theory	3	Experimental / Quantitative Research	3
Philosophy of Education	3	Naturalistic / Qualitative Research	3
History of education	3	Advanced Qualitative or Advanced Quantitative Research	3
		Research in Area of Emphasis	3
Total	12		15

Some of the departmental electives offered to doctoral students include: Trends in Curriculum, Research Methods in Learning Sciences, Research and Foundations in Science Education, Science Curriculum, Educator as Researcher, Knowing and Learning in Mathematics and Science, and Advanced Elementary Science Methods (Table 6.3). Please note that these are just some of the courses offered, hence there is no total number of credits indicated.

Table 6.3: Department elective courses offered at Southern Valley

Course	Credits
Trends in Curriculum and Instruction	3
Research Methods in the Learning Sciences	3
Research and Foundations in Science Education	3
Science Education	3
Educator As Researcher	3
Knowing and Learning in Mathematics and Science	3
Advanced Elementary Science Methods	3

Interviews with faculty and analysis of the course documents showed that the science education doctoral program at Southern Valley is working on improving science literacy among students by preparing their doctoral students to become leaders in research and teaching that focuses on doing authentic science and teaching science for in-depth understanding. The coursework emphasizes on using technology, doing authentic science, and understanding how people learn. Faculty and doctoral students interviewed for this study unanimously agreed that the program emphasizes these areas as well as model-based reasoning. In addition to teaching science education doctoral courses, both Professor Evans and Professor King are actively involved in research and teaching in the Center for Learning and Teaching where teachers are recruited to practice authentic science, to use technology, model-based reasoning and inquiry science teaching. Emphasis on technology is explicitly incorporated in most of the elective courses offered to doctoral students. Alongside the technology course, the elective courses also emphasize "How People Learn" using the work of John Brandsford (Bransford et. al, 2000)

I analyzed three course documents to show the program emphasis and how the science education doctoral program is interpreting and enacting the current science education reforms as they prepare future leaders in the field. One course where use of technology and model-based reasoning is explicitly addressed is entitled "Trends in curriculum and instruction". This course focuses on using computers to promote model-based reasoning, through emphasizing mental models and Understanding by Design (Wiggins & McTighe, 1998). One of the course goals below clearly shows what doctoral students are expected to know and be able to do in this course:

> The first goal of this class is for you to learn to work collaboratively to produce a complex project. The project will be related in some way to modeling of a scientific or mathematical concept.

The course engages doctoral students in modeling scientific concepts using technology. This provides them with tools for preparing teachers to use technology to enhance science understanding and improve scientific literacy among learners. This course also engages students in discussions around the discourse of authors like" Lehrer & Schauble "*Modeling in mathematics and science*", Gilbert & Boulter (eds.) "*Developing Models in Science Education*" and Jackson-Metcalf, *et. al.* "*Model-It: A design retrospective*". The course also emphasizes the importance of how technology can be a tool that helps teachers bring the work of scientists into the classroom with the goal of developing deeper and enduring understanding of science concepts. Since the main goal of the National Science Education Standards is to help students understand science through work that stimulates how scientists work, this course focuses on using technology to do authentic science.

The nature of this course implies that the professors for this course are thinking critically about how to improve understanding of science concepts as a way of achieving scientific literacy. In this case the assumption is that there is need to improve science instruction and learning in order to achieve science literacy for all. Technology is one of the innovations used to help make science concepts more meaningful to students through creation of models and doing authentic science.

The doctoral program also offers a course that explicitly addresses some of the current reform issues as a part of its framework. The course entitled "Science Curriculum" covers themes such as "Project 2061 analysis", "Concepts of curriculum and purpose of curriculum study" and "Curriculum evaluation" among many others. The course engages students in exploring the history of the science curriculum, its current status and the purposes of the current science education reforms as shown in the science curriculum. This is evident in the reading list that features authors like: DeBoer, "*A history of ideas in science education: Implications for practice*", Posner, "*Analyzing the curriculum*", Wiggins & McTighe, "*Understanding by design*" *and* the National Research Council "*National Science Education Standards.*"

This course prepares the doctoral students to have a holistic understanding of the current reforms. It shows the strong commitment that the faculty at Southern Valley has towards the National Standards. Professor King explained:

> We are believers in the reform movement, we are believers in the standards, we have been participants, and we realized that the big step in the implementation of specifics takes a lot of energy and creativity and talent but we are very much champions of the reform documents, we site them all the time in our research. (Interview, 7/1/2005)

This statement from Professor King is reflected in the nature of their program in terms of what they want doctoral students to know and be able to do in science. Teaching for understanding and inquiry-based teaching are the two major goals of the National Standards and we can see that the doctoral coursework at Southern Valley is tailored around these goals.

Another general elective course entitled "Educator as Researcher" specifically prepares graduate students to become mentors for teachers who join the Center for Learning and Teaching during the summer. Below are the course themes that incorporate the learning goals for the course:

1. Cognition (how people learn), inquiry, and information technology;
2. Team mentoring, distributed expertise, and learning trajectories;

3. New models of assessing student learning: the what, how and transfer of learning; and

4. Research designs suitable for teacher research.

The major textbook for this course is entitled "*How people learn: Brain, mind, experience, and school*" (Bransford, Brown and Coching, 2000). This book is used as a framework for the course design as shown in the following quotation from the syllabus:

> How People Learn (Bransford, Brown, & Cocking, 2000) was used to create the framework of overlapping learning goals for learners in the course as follows. Students in the course should review HPL, Chapter 6, pp. 131-154 for an overview of the HPL Framework.

Both faculty and students referred to the framework during the interviews as an important component of their coursework. They all agreed that in order for pedagogy to be effective, there is need for understanding the ideas contained in this work. The program therefore put emphasis on both pedagogy and cognition in their effort to achieve the reform goal. In an interview with Professor King, she showed how their program uses the HPL strategy to understand student learning in elementary school:

> The more we know about how people learn, (we use that phrase from John Bransford, we call it the HPL strategy to gauge student learning in elementary schools) the better we can become at our job. We provide conceptual experiences, incorporating technology. Normally, Innovation in science education often comes too late in K-12 education. If a child is not challenged at an earlier age, a good curriculum at a later grade may not do them much good since they have not been exposed to rational thinking and solving problems. (Interview, 7/1/2005)

What is important to realize about this course is that its goal is to prepare doctoral candidates to mentor science teachers in the Center for Learning and Teaching within programs conducted in the summer months. Its focus is on helping doctoral students understand How People Learn (HPL) and using scientific inquiry. Again this shows the doctoral program's commitment to teaching science for understanding and improving scientific literacy among learners. Understanding HPL was emphasized in Science for All

Americans (Rutherford & Ahlgren, 1990) and using scientific inquiry is at the heart of the National Science Education Standards (NRC, 1998). Again this course shows the program's commitment to the current science education reforms.

Addressing the Current Science Education Reforms

As shown in the analysis of courses previously, the science education professors at Southern Valley have incorporated the current reforms in the framework for their doctoral courses. According to the faculty members interviewed in this study, each of their courses has Benchmarks and the National Standards embedded either in the background or the planning or they are upfront in the course. Both Professor King and Professor Evans emphasized how much they believed in the reform movement and that they have been active participants in the reform process. Professor King mentioned that implementing the reforms needed energy, which is the reason why the reforms are embedded in their coursework.

What Professor King said is explicitly shown in the goals and course readings for their courses. She went on to talk about a course entitled "Science Curriculum" that deals with Benchmarks for Scientific Literacy: "The way that course has been put together deals specifically with benchmarks for scientific literacy and how one might judge, I use the wonderful curricula that came from MSU." True to Professor King's word, one of the goals of the science curriculum course reads, "Critical exploration of the needs and issues in school science programs, consideration of the foundations and strategies for the design, selection, and evaluation of science curriculum". Standards and Benchmarks are used explicitly as part of the reading materials for this course. When asked what her views were about the current reforms, Professor King was positive in how their state is using the standards, and she also felt that their doctoral students were familiar with the reform documents:

> I personally am very impressed... the science education community that I work with is in favor of the Standards and Project 2061. In our state, the teachers have to teach according to the state standards and the state standards are based on the national standards, so it's fairly prescriptive, not how you should teach but what you should teach at every grade level. Our doctoral students are quite familiar with the national science standards documents. (Interview, 7/1/2005)

A majority of the doctoral students and recent graduates agreed with Professor King that the current reforms in science education are incorporated in the framework for their courses. Noel, one of the recent graduates from Southern Valley, echoed exactly the same sentiments as Professor King:

> Results and recommendations from these reforms permeated almost all of our coursework. They directly led to discussion on equity and equality issues, inquiry based teaching methodologies, and the role of technology in teaching and learning. We were all constantly made aware of the recommendations from these reforms. I perceived mostly positive thoughts about each of them. (6/24/2005)

Whereas Noel seems to have developed positive thoughts about the reforms, another recent graduate, Candice, had a different view about how the reforms were incorporated in the framework of the courses. She pointed to the fact that the way reforms were addressed was not consistent and that it depended on the professors who were teaching the courses:

> Very spotty, some pay more attention than others. What has been incorporated is how students learn and scientific research. There is no mechanism to bring the reforms to campus – some professors see reforms as pre-college stuff that they don't want to deal with. (Interview, 6/22/2005)

This interesting contrast in views among doctoral candidates about how reforms are incorporated in the framework of the coursework can partly be explained by the way different professors structure their courses and what they emphasize. It is possible that these two recent graduates may have taken the courses from different professors. Although the curriculum course explicitly addresses the reforms, it is an elective course; therefore, some doctoral students may even choose not to take it depending on their program plan. This was true of one doctoral student Carla who missed out on the class that addressed the reforms because she had to take other electives.

> Within the program it depended on what courses you chose to take. I probably missed some of them because I was also taking some courses over in the geography department so I think I missed some that would have been more beneficial to me and were standards based, but still they have been there and discussed. I think we all agreed they were all very important. (Interview, 6/14/2005)

Carla confirms Professor King's claims that they think the standards are good and use them always. One of the doctoral students Jim also agreed with Carla and highlighted the fact that the standards were addressed in an elective course which science education doctoral students took by default. The required courses for their program are the general curriculum and instruction courses. However, it looks like all the students and recent graduates who took the curriculum course developed positive thoughts about the reforms compared to Candice who did not feel that the reforms were addressed consistently in her courses. When asked what her views were about the reforms she did not give a well articulated response other than to say: "Its difficult – no financial support, a lot of requirements". There was however a big difference between Candice's views of the reforms compared to Carla's views. Although Carla mentioned that she missed the course that addressed the reforms because she had to take courses in geography, her views about the reforms were positive and well articulated:

> Definitely my research deals with the standards…I think the standards are quite influential but the average teacher in the classroom probably is not concerned about them but is concerned about the state standards, that's the ones they are

> required to teach by and the test goes with these standards. The state standards are specific. I specifically like the freedom and the broadness of being able to choose. (Interview, 6/14/2005)

Carla seemed to have developed a more sophisticated understanding of the reforms from working on research that deals with the standards and not necessarily from coursework. On the other hand, another doctoral candidate Jim seems to have a preference of the Project 2061 Benchmarks over the National Science Education Standards.

> I think Science for all Americans is a wonderful document. I think its not being done and I think it's an empty model and not something that's happening. Project 2061 sets a really good framework for evaluation of curriculum. It gives 5 different components of a good curriculum. The NSES is fairly broad but I don't think that's necessarily a bad thing. (Interview, 6/14/2005)

Jim seems to be the only one who talked about the Benchmarks when everyone else talked about the National standards in the interviews.

On a different note, Noel a recent graduate who has positive views about the reforms thinks that the reform documents need to be revised since a lot of things have changed in the last 10 years. He stated: "I see nothing wrong with them, although they may be getting slightly outdated since the world and society have changed greatly in the last 10 years." Noel is the only one who seems to take a critical look at the national standards with an idea of changing them.

Mentoring of Graduate Students through Research and Teaching

There are 8 faculty members in the science education department at Southern Valley. Six of the faculty members are tenure track and two are non-tenure track faculty. The faculty members are engaged in different areas of research that include integrating technology in the classroom, impact of information technology on learning, web-based instructional materials, problem-based learning, model-based learning, and promoting conceptual change. The doctoral students at Southern Valley are mentored through working with professors on research projects. Some professors have individual research grants that support student assistantships and two professors in particular are part of a large NSF funded Center for Learning and Teaching that focuses on Information Technology in Science. This grant is providing financial support to the majority of doctoral students who are on the program. Since its inception, the grant has supported about 20 doctoral students. Professor King shows the important role played by the Center for Learning and Teaching in mentoring doctoral students:

> The Center for Learning and Teaching in the last couple of years has done a better job in setting students up in doing research for the PhD program. The Center has 12 credits taken during the summer. Information technology is embedded in these courses. (Interview, 7/1/2005)

The Center for Learning and Teaching provides structure for mentoring in research. In addition to mentoring in research the doctoral students who are funded by the Teaching and Learning Center are trained to become mentors for teachers who come to the program in the summers. The mentoring into leadership roles is embedded within one course described earlier.

There is also unique mentoring at Southern Valley where doctoral students in the College of Education have the opportunity to work closely with faculty in the natural sciences as lab instructors and science doctoral students get to work closely with education faculty in the Center for Learning and Teaching. This networking is an effort to promote authentic science teaching in the schools. Several doctoral students teach lab courses in the college of science. The Center for Learning and Teaching fellows have formal mentoring through conducting research for the center and their own dissertations as shown in the following information from the ITS website:

> The Center for Learning and Teaching is a multi-college department. The research doctoral students can be related to the Center but it depends with their departments. Some students are in the natural sciences department. Doctoral students are strongly recommended that their dissertations have to be related to information technology. They are all involved in different kinds of research projects and mentoring in the ITS is intensive.

Mentoring doctoral students is emphasized in the Center, but there is fear that soon this may come to an end when funding for the Center runs out. Funding for the Center is temporary and professor King fears that once the funding runs out that the program will be back to its traditional state where there was not much formal mentoring in research and leadership development. Professor King expresses her concern about the sustainability of the funding provided for mentoring of doctoral students:

> Almost all [doctoral students] are funded by the Center for Learning and Teaching – so the mentoring they get is because of the Center, but when funding runs out in two years we will be back to a more traditional approach. The professors oversee 64 participants who come into the program. The PhD students take an active role as leaders in the summer program, and they have gone through a course to prepare them for this. (Interview, 7/1/2005)

Jim agreed with Professor King that doctoral students get tremendous mentoring in research:

> There is tremendous mentoring in research. We are mentored pretty well because most of us have been teachers before so to go on and teach to undergraduates requires some tweaking but its not like we have never done it before. Research on the other hand is new to most of us when we first come into the program and it requires a lot of mentoring and slowly that mentoring drops off to where you are able to do most of it on your own with just some help from your advisor or other faculty. (Interview 6/13/2005)

Here Jim also shows that the doctoral students get good mentoring in research but teaching assistantships are limited. This is mainly because the School of Education at Southern Valley employs clinical faculty whose primary responsibility is to teach the methods classes. The doctoral students therefore do not get to teach many of the methods courses. According to Professor King, the doctoral students only manage to teach at least once a semester:

> I wish we could but as far as teaching assistantships are concerned, our department has clinical faculty members who are PhDs whose primary job is teaching, and they teach the methods courses in the elementary and middle school program sometimes. Doctoral students do not have an opportunity to teach a methods class because there aren't that many available. We have many more doctoral students. Although we don't require teaching assistantships, we certainly understand the value and we try to provide students with a semester or so of teaching in methods courses but we can't always succeed at that. (Interview, 7/1/2005)

There seems to be a general belief at Southern Valley that there is need to mentor doctoral students in teaching, but not as much as in research. Sentiments from doctoral students show that they believe that since they were teachers for some time their job is to prepare pre-service teachers to survive in the classroom. Jim, a doctoral candidate highlighted this in his interview. He felt that the most important thing in preparing teachers is to help them survive on the job; hence he sees it important to some extent to teach them the way he taught:

> There is no strict required type of mentoring for teaching that I know of, but most of the time mentoring will be informal. But I think part of teaching a methods course is teaching how to survive within the system as well, for instance if all you did in a methods course was just teach how to teach for understanding, are you really prepared to go into a school that is set up now, maybe you are doing more harm than good if you don't at least teach a little bit about the way that you taught and survived in the system. (Interview, 6/13/2005)

This quotation from Jim raises some interesting questions about whether his focus is on reform-based teaching or if he is just preparing teachers to survive through teaching the way he taught. Unfortunately the study did not go into investigating Jim's teaching. Further studies in this area could yield some useful information that connects doctoral preparation to practice.

Another doctoral candidate Carla agreed with Jim that there was really no need for mentoring in teaching. She actually thought she did not require any input from her professors in her teaching:

> I think requiring doctoral candidates to practice teaching at the University would be good for them, but I don't know about requiring it necessarily. Depending on what courses you take, there are definitely courses you learn more about how to teach. I did not get a whole lot of mentoring while I was teaching except when I went out and looked for help. I had a lot of experience in the classroom already so they might have assumed that I would know what I was talking about. I had taught for 30 years already. I don't think I needed input from my professors. When I needed help I asked someone who had taught the course already and asked especially when I taught a new course. (Interview, 6/14/2005)

These doctoral students certainly have a different view of mentoring and teaching; they are relying on their past experiences in teaching, the number of years they had taught, assuming they were successful, that mentoring new teachers is just about survival and that evidently teacher mentoring is easy; and no need to receive feedback from their professors on their teaching.

The doctoral program offers courses that specifically focus on teaching doctoral students how to teach methods courses. Below, Noel, a recent graduate from Southern Valley shows that there was a tradition where doctoral students are left to work on their own from his personal experience:

> Some teaching assistants are basically left to their own and only receive mentoring and/or guidance when they seek it out. This was my personal experience my first year as a teaching assistant. (Interview, 6/24/2005)

A closer look at the courses and interviews show that the faculty at Southern Valley are incorporating the reforms in the framework of their program for preparing future leaders in their doctoral program. Evidence from the course descriptions and interviews also show that the doctoral program at Southern Valley has positive views about the reforms, especially the National Standards and they seem to interpret the reform goals of 'science literacy for all' as a call for developing stronger cognitive and pedagogical tools that enhance students' understanding of science concepts. In this case using technology and model-based reasoning are the ways that the program is preparing doctoral students to address the challenges of improving students' learning capacity. Faculty members and students consider working closely with scientists, practicing authentic science, and using technology as powerful ways to improve the teaching and learning of science.

Roles Doctorates are Prepared for

Interview data showed that the Graduates from Southern Valley are prepared for specific roles in K-12 teaching and administration, teaching at University and research. There was evidence from the interviewees showing that a sizeable number of students go back to K-12 teaching and administration. According to Professor King, this is mainly due to the fact that the program does not require students to study full time, hence some of them stay in schools throughout their studies and go into K-12 administration after they graduate as shown below:

> Our doctoral program does not require people to come in full time, as long as they meet the residency requirement. A number of our doctoral candidates will stay in the classroom through much of the doctoral program and emerge working in the school district they were in or in a leadership position. Our history and focus is to produce science education faculty at the university level and in school districts. (Interview, 7/1/2005)

Professor King highlighted the traditional nature of their program by mentioning its history and focus, which is to produce faculty and K-12 teachers. Carla agreed with Professor King that the program prepares its graduates for teaching as shown below:

> I would say the two main ones are either to be a professor at a university or college or to teach in the classroom. The other emphasis is to be researchers in science education. Also to be leaders in professional development is another emphasis and outreach. (Interview, 6/14/2005)

Other graduate students feel that the program prepared them for research. Jim feels that the program adequately prepares them for research and grant writing. He emphasized the amount of research experience they get at Southern Valley:

> Since this is a research 1 institution, we are definitely pushed into research, doing research is one of the central focused that we do. Since research costs money, grant writing is also emphasized. Almost everyone is involved in research. (Interview, 6/13/2005)

However, Professor Evans pointed out that their doctorates are prepared for specific roles, which are mainly K-12 teaching and administration, and teaching at university level:

> We don't prepare them for everything – Most of our graduate students want to be either school leaders in science education or they want to be a professor somewhere. We occasionally have someone who wants to advance in the area of informal science education. It's pretty traditional and we take it case by case. (Interview, 9/7/2005)

It is clear from Professor Evans' views that faculty believe that their students are interested in K-12 teaching and administration or in becoming a college professor; hence they prepare them for those roles. Professor King also emphasized the traditional nature of their program and that they do not normally have students who go into different areas.

Views and perceptions about challenges in science education

In this part of the study, my goal was to establish what faculty, doctoral candidates, and recent graduates from the science education doctoral program at Southern Valley consider being the most important issues in the field and how these issues relate to the preparation of doctoral students. I asked the interviewees to tell me what they see as the most important issues that the science education community should focus on in terms of researching, funding, and as they prepare new leaders in the field. I analyzed the responses to the above question using the framework for assessing the impact of National Standards on student learning (described in chapter 3). I categorized the responses to the interviews using the five channels of influence identified in the National Research Council's framework for assessing the impact of National Standards namely: contextual factors, teacher learning, teaching, student learning, assessment and accountability and curriculum. Figure 6.1 shows that the interviewees identified all the channels of influence listed above, except curriculum as important issues that the science education community should be focusing on. However, some areas were emphasized more than others. The interviewees emphasized the areas of student learning, teacher development and teaching more than areas of assessment and contextual factors.

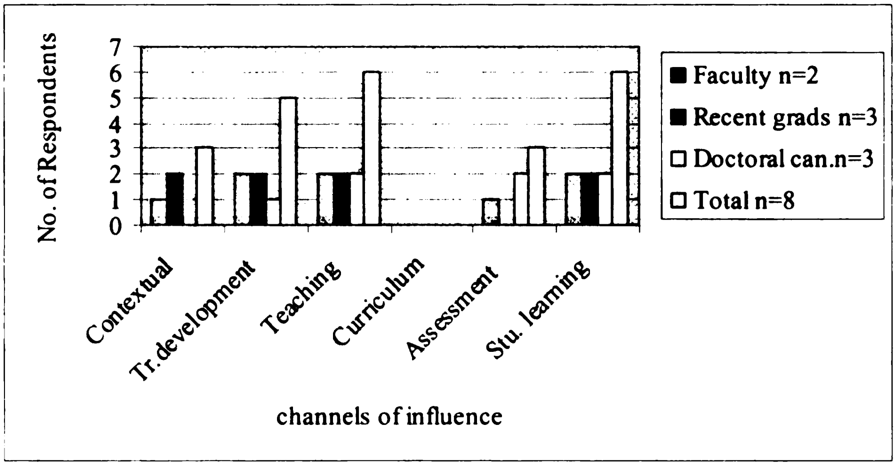


Figure 6.1: Views about the most important issues in Science Education at Southern Valley

The areas that were emphasized by most respondents were student learning and teaching, followed by teacher development. Six out of seven respondents identified student learning as an important issues in the field.

Contextual factors

The issues I identified as contextual factors include concern about policies and issues of equity. Professor King voiced her concern about how religious fundamentalists are influencing policies on what gets taught in schools. She specifically talked about how the teaching of evolution has become a big debate in some states.

> Another area in America which influences the teaching of science is the religious fundamentalist pressure on textual materials in the big states--Texas, California, Michigan—the kinds of materials that teachers end up having to work with and their devotion or lack of devotion to certain important topics like evolution. So when a new teacher comes in and given a curriculum or told what to teach, they may have little choice about the extent to which they can discuss topics they think are important. You are probably aware of the statistics in this country of people who are ignorant of what we know about the evolution of living things is astounding. It's a lot of poorly educated parents who are sending their children to school and if the teachers have too much pressure against what they are doing it is a huge issue. There is a threat to many fundamental religious beliefs by evolutionary theory. (Interview, 7/1/2005)

Professor King shows how parents can influence policies and how teachers can end up having little control over what they teach depending on the policies in the state.

Recent graduates and doctoral candidates shared their concerns about equity issues in science education. Noel talked about how lack of funding is leading to budget cuts and schools are forced to make cost-cutting decisions that influence student learning. Candice a doctoral candidate and Cindy a recent graduate talked about the lack of minority and women in science and the fact that the Hispanic population is not being served fairly in their state. Cindy explained that equity is difficult to achieve in Southern Valley because *"we are not reaching the Hispanic population, why not test people in their language."* Because of an increasing number of Hispanic immigrants, Cindy felt that learning would make better sense if students were tested in their own language. However, faculty did not highlight issues of equity in the interviews, and neither are these issues emphasized in the coursework.

Student Learning

The issues I identified as student learning included talk about lack of interest in science learning among young people, producing literate students, and improving student achievement. Student achievement according to the interviewees can be accomplished through understanding how people learn, using mental models in science learning, and knowing how to teach students with learning disabilities. Professor King clearly articulated the importance of understanding how people learn and student motivation as solutions to the challenge posed by the fact that science concepts are difficult to understand. Professor King replied:

> We must understand how people learn and what it takes to engage students meaningfully. Scientific knowledge is generated in complex ways; it is not intuitively obvious how to do that. When we see the sun rise in the east and sets in the west, the scientific explanation for that is not intuitively obvious; its hard to understand what is happening; it requires deep thinking and mathematical formulas. What it takes to engage students meaningfully and seeking problems to answers that are not easy, e.g. the Private Universe, these are bright people but when you ask them to explain scientific phenomena they can't remember, because its not common sense. You have to struggle to remember what's happening. (Interview, 7/1/2005)

Professor King emphasized the fact that science concepts can be too abstract for students to understand, and it takes a lot of effort to engage students in activities that help develop an in-depth understanding. Understanding how people learn is seen as one way that can help science educators come up with pedagogy that is complimentary to learning styles.

Doctoral candidates from Southern Valley who talked about the challenges of producing scientifically literate students echoed similar concerns. Jim talked about how student achievement can be improved by using mental models that make the student thinking visible:

> Modeling in science is extremely important definitely the difference between expert views and novice views are important, what an expert sees versus novices, how do they see and how do they think and how do they organize the information in their mental models. I think models are kind of huge broad things. I am talking more about a scientific model, what an expert scientist would use to study or look at a certain situation to learn more about something. Definitely scientific models, even mental models, what's going on inside the students' heads; that's what I mean by modeling. (Interview, 6/13/2005)

Jim emphasizes the difference in knowledge between an expert and a novice and the need to close the gap by using scientific and mental models. Both Professor King and Jim show concern about how the science education community should approach teaching of science, which is a difficult subject. Their ideas about how this can be addressed focuses on the learner and how educators should understand the learner's cognitive abilities and how these can be enhanced through modeling that visually show how students are thinking.

Professor King also voiced her concern about how the education system is failing to meet the needs of a competitive technological world and how this has led to the US workforce losing jobs to international competitors. In the following quotation Professor King showed the importance of technology and how the US is being out competed by other nations such as China and India:

> I just finished Tom Freidman's book "The world is flat" and that is a book that I think all science educators should read. It's about how internet technology has flattened the world so I can easily hire for the same price of a graduate student here in Southern Valley, I could just easily hire a PhD from Bangalore India who would analyze data for me while I am sleeping and when I arrive at my office it would be delivered via technology. There is going to be additional pressure on all of us in the US to do all the above things better so that we can compete in a global market. The average worker in the US earns $1500 or $2000 a month. The same skilled worker in China earns $150 and so if I own a company in the US I would do better by hiring a Chinese worker. That increases the pressure on education to deal with this somehow and make our students be better enough than the PhDs in India. (Interview, 7/1/2005)

This quotation justifies the emphasis that the program at Southern Valley places on use of technology in science education. There is a sense that use of technology has made communication possible in many ways, and the potential of using technology to enhance understanding of science concepts is viewed as critical in this case. In agreement with Professor King, Candice a recent graduate views how important technology is becoming and how useful it will be in the future:

> Technology is changing things a lot. We will be using technology more in the future. Education will change so radically but the field is not prepared for that. Money is not available to stay abreast increasing technology. (Interview, 6/22/2005)

These sentiments about technology are reflected in the way the Center for Learning and Teaching has technology as its focus. Technology is seen as an important component in improving 'science literacy' as well as preparing students to become successful in a competitive world market.

Teacher Development

The issues I identified as teacher development included talk about teacher knowledge and the need for better-qualified science teachers. Specifically, issues of professional development, lack of science knowledge among elementary teachers, lack of collaboration between science educators and scientists in preparing teachers, teacher resistance to learn new technologies, and learning to teach in inner city schools were issues raised by the interviewees. Generally the interviewees from Southern Valley considered teacher development to be a critical issue in science education. They all mentioned different concerns related to teacher learning. Professor Evans for example talked about the need to produce specialists in science education through professional development. She feels that there is a need for teachers to work closely with scientists to gain knowledge that they can transfer to their students. She explains how the Center for Learning and Teaching is helping teachers to bring authentic science in the classroom:

> Our Center for Learning and Teaching focuses on producing specialists in science education. This is professional development. We thought about how teachers could work with scientists, perfecting a model for teachers to transform what is in the lab to inquiry in the classroom. (Interview, 9/7/2005)

Here emphasis is placed on the collaboration between science educators and scientists in professional development efforts to help teachers teach authentic science.

Similar concerns were shared by Candice, who raised concerns about the lack of appreciation of the use of technology among some science teachers. She talked about her experience from working with teachers in the field and raised concerns about the fact that some teachers are resistant to learning new technologies: "In professional development projects with teachers, some are more receptive to technology than others." Both Professor Evans and Candice view a close working relationship between scientists and educators as important in bringing an understanding of technology and science content to the teachers.

Similarly Professor King shared concerns about elementary teachers' lack a good understanding of science or the high expectations placed on the elementary teacher or elementary science specialist to teach science when they are really not knowledgeable in science:

> Many elementary teachers are not well educated in science. We should have specialists in elementary science, the poor elementary teacher who is expected to be a specialist in everything is also expected to teach science, so they don't feel comfortable with it and so they either do it poorly or they do it at a minimum and that just feeds into the whole problem. (Interview, 7/1/2005)

Professor King shows the complexity of preparing elementary teachers to become specialists in science when they have to teach everything. Noel attributed the problem associated with preparing teachers for science teaching to lack of funding and the strong competition with reading, early childhood and multicultural education which are receiving more money and are currently given priority by the government. He said,

> We still face the challenge of getting all science teachers to be "highly qualified." I see science educators in Southern Valley continually working to address these issues, although it often comes down to funding decisions. It would seem we are in strong competition with reading, early childhood, and multicultural education for money to spend on reform and teacher training. (Interview, 6/24/2006)

On a different note, Jim, a doctoral candidate, raised the issue of teaching 'science for all' as a challenge for teachers who are learning to teach in inner city schools. He acknowledged the fact that how people learn is a good framework that focuses on good teaching strategies, but it does not focus on issues that are critical to urban science teaching, which requires culturally responsive teaching.

> There are two ways of looking at learning to teach in inner city schools. The one kind that is culturally responsive teaching and the other kind that is teaching as good teaching. How people learn focuses on good teaching strategies for effective instruction. It doesn't necessarily go into culturally responsive teaching. (Interview, 6/13/20005)

Other interviewees whose concerns were mostly focused on using technology and understanding how people learn did not share Jim's concerns about science teaching in urban schools. The course documents analyzed in this study and the interviewees emphasized the importance of improving teachers' content knowledge. The focuses on research and professional development targeted at producing highly qualified teachers with a deeper understanding of content knowledge. Professor Evans said that there is need for teachers to learn science content from scientists and transfer this knowledge to their students, and Dr. King feels that there is need to have specialists in elementary science in order to avoid having teachers who are generalists being expected to teach science well. Most recent graduates and doctoral candidates share similar concerns with their professors except for two doctoral candidates who feel that whereas the framework for their doctoral preparation focuses on good science teaching, it does not address issues of urban science teaching. One of the students specifically mentioned that the program is not reaching out to the Hispanic population.

Teaching

The issues I identified as teaching included concerns about teachers working closely with faculty, threat to nature of scientific knowledge by post-modernist views of science, teacher competence, use of technology, teaching for understanding, implementation of standards, and using inquiry in science teaching. Professor King shared her concern about how scientific knowledge was being eroded by different ideologies. She specifically referred to the need to preserve the western cannon of the nature of scientific knowledge, citing how postmodernist thinking has misinterpreted what it takes to generate good scientific knowledge:

> Over the last twenty years in science education there have been numerous threats to the western cannon (the established way of looking at the nature of scientific knowledge), that is, post-modernist views of science or relativist views, especially in the academy have allowed in some cases misunderstandings about what it takes to establish best knowledge in science- - the way it is portrayed and the way it is understood, its often taught in its final form and focused on Friday tests. Most scholars perceive science as white Anglo Saxon exclusive club and have misinterpreted what it takes to generate good scientific knowledge, the issue of evidence, reliability, etc. (Interview, 7/1/2007)

Implicit in Professor King's views is the idea that teachers should strive to teach science in a way that will help students to understand and think about science the way scientists do. These notions tie in with Professor Evans' views of the need to produce specialists in science education. Her idea of how teachers can become specialists is that they should work closely with scientists in their labs and transform what is in the lab to inquiry in the classroom, stating: *"There is need for teachers to work closely with scientists, perfecting a model for teachers to transform what is in the lab to inquiry in the classroom"*. Both Professor King and Professor Evans see challenges related to how teachers can focus on a deeper understanding of science concepts.

Jim, a doctoral candidate agreed with the professors about the importance of developing teachers who are specialists and who can use multiple representations in their teaching. In the following quotation he emphasizes the importance of understanding how people learn and how he uses the work of John Bransford in professional development:

> Multiple representations I think is very important, different ways of looking at the same phenomena from different views and respecting those views. We study a lot about John Bransford's How people learn, a book that looks at leaner-centeredness, and it looks at knowledge-centeredness, assessment centeredness, and all those fit within the community. This is one of the books we learn from and that's also the one that I use when I do professional development with middle school science teachers. It's a learning tool and it's also linked to other research that was used to create the book and it's a book we use in professional development seminars. At Southern Valley we use the book pretty extensively. (Interview, 6/13/2005)

Therefore, Jim clearly stated how the HPL framework of the coursework is influencing the work he does with teachers in schools.

Jim also views issues of conceptual change and teaching for understanding as important in the field of science education. He talked about teaching for understanding in a more holistic way and showed how it is multifaceted, involving what the student knows, how the teacher get to know what the students knows and how the teacher can facilitate conceptual change.

> Teaching for understanding is probably the most important issue right now because it incorporates a lot of the learning sciences in there. For instance presuppositions that students come in thinking or knowing, ways to assess that, the importance of knowing that, developing strategies to develop and work around that and that Incorporates formative assessment where you are constantly assessing students' mental models and then develop adapt instruction learning and teaching around that. (Interview, 6/13/2005)

Jim talked about the importance of assessing students' mental models, which is a reflection of the emphasis of modeling in the doctoral program at Southern Valley. However, Carla brought up different issues to those mentioned by the faculty and fellow students. She talked about the challenges of using standards in the classroom and training teachers to use standards.

> I think the movement towards standards, whether its state standards or National Standards, using them in the classroom and training teachers to use them is one thing. Melded in with that is using authentic science and inquiry in teaching science. (Interview, 6/14/2005)

The two professors and the doctoral student's concerns about improving the quality of science teachers is reflected in the research and outreach work done in the Center for Learning and Teaching where teachers are brought in to come and work side by side with faculty. Teachers are mentored to use technology to teach authentic science. Although the faculty at Southern Valley did not mention this as a challenge in science teaching, analysis of course documents and interviews with faculty show that they incorporate standards in the framework of their courses and they are very positive about the standards. However they do not mention the challenges faced by science teachers as they implement the standards in their classrooms.

Assessment

The issues I identified as assessment include talk about high stakes testing that is part of the No Child Left Behind reform and the impact it is having on science teaching. Professor King and two doctoral candidates shared similar concerns about how the focus on testing in math and reading has pushed science to the margins in the school curriculum. Professor King alluded to this:

> Another issue in the United States is because of standardized testing, reading and mathematics have taken the place of science in many elementary schools, lack of science teaching in elementary schools until a test comes along that requires you to teach it. For example, in Southern Valley a few years ago we had 5th grade science testing so suddenly teachers who weren't teaching science because they spent all their time with reading and mathematics began to teach some science. (Interview, 7/1/2005)

Professor King talked about the positive effects of standardized tests especially where science is also tested. Her views reflected the general sentiments among interviewees that standardized testing was helping to close the achievement gap However, by closing the achievement gap it was not clear whether incorporating a science test was considered to narrow the gap.

On a different note Carla viewed high stakes testing as having a negative impact on the way teachers teach because the tests do not support reform-based teaching. She talked about the need to develop tests that allow teachers to reform their teaching without fear of the test results:

> High stakes testing in all the fields including science is having a big effect on everybody, and I think one of my big problems with that are the lack of a test that will test in a way that teachers can actually use to teach and not be afraid of the test results. I think some test development needs to be done. (Interview, 6/14/2005)

There are definitely mixed feelings about high stakes testing among interviewees at Southern Valley, but the bottom line is that assessment is not reflected in the course documents as an area that gets attention in the doctoral program. The kind of testing that is seen as a challenge is federally mandated hence faculty may feel they do not have much control over it. However their views of standardized testing for science implies that it is a good thing if it causes teachers to teach science in schools.

Addressing Issues in Science Education

When asked how the issues in science education can be addressed, the faculty, doctoral candidates, and recent graduates at Southern Valley had different views ranging from preparing teachers to be leaders to educating administrators and business leaders about education issues. Figure 6.2 shows that all the three groups of respondents felt that solutions classified as contextual should be employed to address the challenges in the field. Contextual issues in this case included talk about the role of the administration at different levels and change in policies.

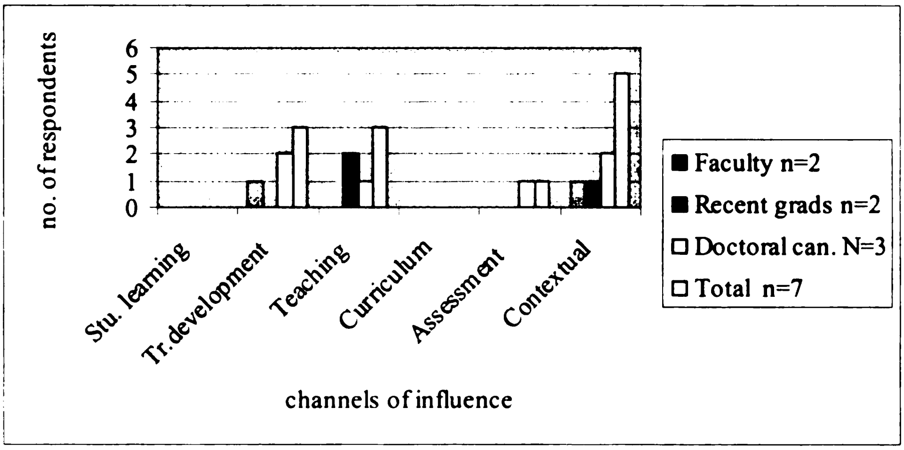


Figure 6.2 Solutions to address issues in Science Education

Professor King, for example, felt that there is need for administrators to value education and put more resources into education in order to ensure that the graduates remain competitive. She went on to show how lack of support in developing people with a deeper understanding of science has led to other countries becoming leaders in the field of science.

> I think we have to educate administrators and legislators, business leaders so that we are all on the same frequency about the need and value for better math and science education to stay globally viable. I do think the funding agencies like NSF can help with the cause, and I think they are moving in the right direction. In some ways the US is no longer a leader and China and India are leading in certain aspects. (Interview, 7/1/2005)

It was clear from the interview with Professor King that administration especially at federal level needs to put more money into supporting science research and initiatives.

Jim, a doctoral candidate shared similar views with Professor King that administrators need to play a major role in addressing the issues in science education. However, he emphasized the need for collaboration between administrators, policy makers, and science educators in the implementation of reforms in science education. In other words, all parties to have an equal voice:

> Collaboration between administrators, policy makers and science educators…if policymakers, educators and administrators do not have a stake or buy into it, then I don't think it is going to be really effective. All of those camps have to be present at the conversation in order for this reform to be effective. In order for it to work everyone has to have an equal voice. (Interview, 6/13/2005)

On the issue of producing science teachers with a deeper understanding of science, Professor King felt that there is need for more involvement and collaboration between scientists and science educators in order to improve the teaching of science. However, Carla had different ideas about how issues of recruiting good teachers and retention should be addressed. She talked about how alternative certification can help provide enough science teachers:

> I wish I knew some good answers for the equity issues and teacher retention and recruiting good science teachers. I think its going to be difficult. I know we have some programs in place with alternative certification of people with degrees, as long as we do some good training on pedagogy with those teachers that may work ok, but its being done, I think we have to continue that in order to get enough science teachers. (Interview, 6/24/2005)

Carla also sees teachers as playing a critical role in addressing issues in science education. In the following quote she shared similar ideas with Professor King that issues in science education can be addressed through teacher training and professional development:

> I think it has to start with training teachers in colleges and continuing with professional development for in-service teachers to know the things like what research shows about how people learn and one of the best ways of teaching and doing a better job overall with preparing teachers to do the things we are asking them to do, [and] training the elementary teachers in inquiry, etc. (Interview, 6/24/2005)

Still on the issue of preparing and recruiting teachers with a good understanding of science, Noel felt that that content specific educators need to lead reform in the different areas of science. He also felt that the content specialists should have classroom teaching experience.

> We need content specialists for each science discipline who understand the unique features of teaching and learning that content. We cannot expect someone who may be expert in teaching and learning physics to be able to lead in reform of biology teaching and learning. I also believe that classroom teaching experience is important. Too many university science education specialists/researchers have very little actual classroom teaching experience and they are not as effective in leading classroom teachers as those who have more experience. (Interview, 6/24/2005)

Cindy shared similar thoughts as Jim, that teachers are the answer to good science teaching. She talked about the fact that teachers need to take more leadership roles in science education and that administration at all levels should be made of former teachers. She said: "Teachers need to take more leadership. Admin determines [that] good teachers stay; bad teachers leave. "Admin should be made of former teachers."

Candice thought differently about what is needed to address effective science teaching. She states that science teachers need to have an understanding of technology: "Educators need to be comfortable with technology and be knowledgeable with using technology and provide materials of technology."

For assessment, Jim came up with ideas of how he felt that issues of teaching for understanding and assessment should be addressed. High stakes assessment should be more authentic so that it tests for deeper understanding of science concepts, rather than testing for factual recall. Jim explains that if high stakes testing is made more authentic, it could be beneficial to the students, teachers, researchers and educators.

What I would like to see is more authentic testing. I think high stakes testing is

> going to be here for a while, I think for the next 10 years so its there and I think a way to bring the two together is to make this test more authentic, testing for deeper understanding rather than just factual recall. A test could be something that actually benefits both, not only the teacher and student but also the researcher and the educator because its going to bring what the teachers are so concerned about which is this test that will bring it closer to our side. (Interview, 6/13/2005)

Cindy shared similar ideas about how researchers should use research to prove that authentic assessment is possible and that it works. She shows that researchers should play an important role in addressing the challenges posed by high stakes testing that is not authentic:

> Science education researchers should conduct scientifically based research that shows that assessments that look for deeper understanding is possible and that they are important, with a control group taking a standardized test versus a test that assesses deeper understanding. I think if we go into it without anything to back us up other than theory we could be in trouble. Having thought this for the first time I would say that there is a need for more research that we can go to the table showing that there is scientifically based research showing that it's possible and should be done. (Interview, 6/16/2006)

Here Cindy shows the struggles that science educators face when it comes to mandated policies like high stakes testing. She showed the need for proving that authentic assessment can be done.

Aspects of the Science Education Doctoral Program that Need to Change at Southern Valley

The interviewees from Southern Valley had different perspectives about what needs to change in order for the doctoral program to address the issues they highlighted earlier. Generally the interviewees highlighted a need for more emphasis on research and teaching courses, increasing the number of elementary specialists in the program, and more courses that focus on culturally responsive teaching. The two recent graduates, Jim and Candice, and one doctoral candidate, Carla, felt that more emphasis on research is needed. For example Carla thinks the program can intensify the research experiences for doctoral students:

> When I did my preliminary exams one of my professors' question was that exact question, how would I design a program for people coming in for a degree in science education. One of the things I really emphasize would be to start doing research courses and training at the very beginning and let that grow throughout instead of waiting until the second year. Start working on small projects and get training. Right now I am writing my chapters as stand alones ready for publishing. (Interview, 6/14/2005)

Although the Center for Learning and Teaching improved the research experiences for doctoral students, there is a general concern that once the money for the Center runs out, the earlier shortfalls in research experiences may resurface. Jim showed concern about the need for continuation of the Center for Learning and Teaching:

> Before the Center came in, I don't think that our program was as reliant on research as it is now, in other words, the focus on previous research, how to do research, how its specifically pertains to the learning sciences a lot of that was not there. Now that the Center for Learning and Teaching is there I would say that the doctoral program really is doing an excellent job of becoming research based focusing on research and the issues of teaching for understanding. The Center for Learning and Teaching served me well and it's something I would like to see continuing. (Interview, 6/13/2005)

The Center for Learning and Teaching is doing well in terms of providing research experience, but since it is a 5-term funded program, there is some nervousness about what will happen once the funds run out. Hence Carla feels that the doctoral program coursework should offer more research courses especially mixed methods.

Professor King has different ideas on what needs to improve in the doctoral program. The Center for Learning and Teaching did not support elementary teacher educator preparation:

> All the funding we have and all the doctoral students we have on our doctoral program will specialize in secondary or higher education because the Center for Learning and Teaching is a funded program for participants who teach grades 7

> through undergraduate so what we need are more elementary science education specialists, and we have very few funded students who come through, so we are not contributing that much right now. I can't say over the years but as long as I have been here which is 10-15 years, our science education program has been much more secondary. We have occasionally a student who would come through and specialize in elementary science education. I think there is a need. (Interview, 7/1/2005)

Prof King also felt that the program needs to offer more teaching assistantships to doctoral students:

> Another area I mentioned earlier is that its difficult to find enough teaching assistantships for our students because the undergraduate courses are taught by clinical faculty and that is a philosophical decision that is made by our department. There is a delicate balance there. We need more teaching assistantships for our graduate students who have teaching experience but they are few. We have a very large department. The TE program is housed in my department so there are many sections of math and science but the department head and faculty agreed that having graduate students come and go isn't as consistent as hiring a clinical member who will teach it for years. Tenure track faculty are pressured to seek external funding and to publish that the administration has relieved us of undergraduate teaching so that we can focus more on graduate teaching and working on projects, so we are not involved much at all in what is going on in the undergraduate programs. (Interview, 7/1/2005)

Professor King however sees the dilemma between having instructors who stay on and teach the course for a long time as opposed to graduate assistants who come and go. This gives the program a "transient" character. Whereas the idea of having course instructors is meant to free up time for professors to do research and publish, she feels that doctoral students also need to practice teaching. Related to professor King's concern about teaching assistantships is Noel's concern about having more courses focusing on classroom teaching and learning:

> I would like to see Southern Valley offer more courses in the doctoral program that specifically address issues directly related to classroom teaching and learning, rather than being a program stressing educational research. Many students like myself, were not pursuing the degree to become educational researchers, but to become better teachers and teacher trainers. (Interview, 6/24/2005)

Noel clearly shows that there is a need for more focus on preparing doctorates for careers in teaching through coursework. His concern for more courses on classroom teaching could be a result of the fact that the students are not involved in teaching experiences and they only get research experiences. Specifically Jim showed concern about learning to teach in urban schools; therefore, he felt that the program should offer courses that address issues of multiple perspectives and culturally responsive teaching:

> I supervise student teachers in inner city schools. I am a former inner city middle school science/math teacher so I have experience in these settings so I do a lot of mentoring and supervising student teachers. ...It all comes down to culturally responsive teaching, identifying and trying to meet the needs of every student, school should be community based. I believe multiple perspectives and epistemologies should be valued and respected, and I think there should be high expectations for everybody. (Interview, 6/13/2005)

Throughout the interview Jim showed that his interest is in working with urban teachers and here he shows that the program needs to prepare doctoral students to address these issues. The interview and the document analyses show that the doctoral program at Southern Valley emphasizes improving science pedagogy through engaging doctoral students in understanding how people learn and model-based reasoning. The program also emphasizes use of technology in science teaching and doctoral students have the opportunity to work with faculty from the Natural Sciences and Science Education to gain authentic science experiences.

Discussion

In this section I will compare the views of faculty, recent graduates and doctoral candidates. All interviewees at Southern valley agreed that using technology to teach authentic science and modeling are important tools for achieving 'scientific literacy for all students.' The issues highlighted by interviewees as important in science education reflect the 'How People Learn' framework that is used in their coursework. Southern Valley faculty and students' views show that they view a scientifically literate person as one who has a deep understanding of science concepts and understands science the way scientists do. This is shown in the way professors view development of specialist teachers as a challenge to the field. They see teachers working with scientists as essential for transferring scientific knowledge that is generated by scientists from the lab to the classroom.

Both professors at Southern Valley share similar concerns about teacher development and student learning that reflect their philosophies and scholarly interests as shown in the coursework and research done in the Center for Learning and Teaching. Although the doctoral students generally agreed with the professors about the importance of technology and understanding how people learn, at least two of them showed concern about the fact that issues of equity are not explicitly addressed in the coursework. These students viewed issues of equity as an important challenge in the field, given the growing Hispanic population in the state. One recent graduate also talked about a lack of equity in terms of limited access to physical science by girls and minorities. These are complex issues that present challenges to the field and yet they are not explicitly addressed in the program. Since Southern Valley is already tackling the complex issues of model-based reasoning and using technology to enhance understanding of science content, can we say it is hard to address more than one complex issue at a time? Analysis of the City Ville program showed that it is focusing on one complex issue of urban science education. From this evidence, we can conclude that these doctoral programs are addressing one complex issue in their coursework, which is specifically targeted at addressing equity in science learning. Model-based learning, using technology in science teaching and providing authentic science experiences to students ensures that 'all students,' not just the ones who are going to become scientists can have an understanding of science. Hence equity is achieved.

The complex issues addressed by the doctoral program at Southern Valley are related to the scholarly interests of the professors. For example, the focus on classroom-based practices, teacher development, student learning and teaching, are related to Professors King and Evans' scholarly and research interests. Professor King emphasized understanding how people learn as the framework for their coursework which reflects her views about science as a body of knowledge that "has been generated in complex ways" and that "it is not intuitively obvious how to do that." This is also reflected in the emphasis that the program places on theories of how people learn and model-based reasoning.

Professor Evans talked at length about the importance of deeper understanding of science concepts. Their interpretation of 'science literacy for all' has a focus on student learning of authentic science experiences the same way that scientists do, through use of technology and creating mental models that show their understanding. Looking at the science education elective courses that are offered at Southern Valley, only one science methods course includes an explicit emphasis on inquiry in science teaching and learning. Most of the courses focus on use of technology and modeling in science. However, the positive orientation on "How People Learn" provides a strong entrée into constructivist learning and pedagogy.

Whereas all doctoral candidates and the two recent graduates pointed out some contextual factors that are important in the field, the professors did not highlight contextual issues in their discussion. The contextual issues highlighted by students included limited emphasis on issues related to learning among minority-students.

Another interesting point worth noting is that, although the students and recent graduates reported that they are being prepared for research and teaching, their professors emphasized that they prepare their graduates for university and K-12 teaching and administration. The difference between what students believe they are being prepared for and faculty's intentions is interesting mainly because, the students do not get extensive practice teaching methods courses. This is because and they do not have teaching assistantships for their students. Since doctoral students get to do more research assistantships than teaching, this may lead them to believe that the program emphasizes research. Also since Southern Valley is a research 1 university, there is bound to be focus on research. The professors views show the need by doctoral students to understand and use research findings from their own and other people's investigations to improve their teaching, whereas, the students and recent graduates appear to believe that the emphasis in the program is to make them into researchers, as opposed to being both researchers and users of research.

It is also interesting to note that there is a belief among some students that the doctoral candidates are capable to teach teachers since most of them have been teaching for a long time; hence they did not think that mentoring in teaching is necessary, as highlighted by Carla. Jim also clearly articulated his belief about the need to teach preservice teachers to survive in the classroom. The program's focus on model-based reasoning, use of technology in teaching science, and understanding how people learn clearly shows that the intention is to strengthen doctoral students' pedagogical knowledge.

Conclusion

The science education doctoral program at Southern Valley focuses on teaching science for in-depth understanding through use of technology and model-based reasoning. Efforts are being made to prepare science teacher specialists and university science educators through working with scientists in order to bring authentic science teaching to the classroom. Analyses of course documents shows that the science education courses either implicitly or explicitly address the current reforms and 'science literacy for all' as the program goal. The faculty and graduate students have positive views of the National Standards, and according to Professor King they are supporters of the standards. The professors promote standards in the schools through working with teachers in the Center for Learning and Teaching and they always quote the standards in their work.

Generally the professors and their students agreed on the goals and focus of the program. Both the faculty and students emphasized the use of the 'How People Learn' (Bransford et. al., 2002) model in their courses and professional development work. The faculty and doctoral students at Southern Valley acknowledged the tremendous work done in the Center for Learning and Teaching in terms of providing research experiences, and they showed concern about what will happen after the funds for the Center run out.

It appears from the data obtained from the interviews and analysis of the program documents that Southern Valley is doing a credible job tackling a complex issues of improving science literacy by ensuring a deep understanding of science by all students, not just those who are going to be scientists, which highlights the way the program is interpreting the current reform goal of science literacy for all.

CHAPTER 7

SCIENCE LITERACY FOR ALL: VIEWS, PERSPECTIVES AND PHD PREPARATION

In this study I investigated how three science education doctoral programs; City Ville, Midwestern and Southern Valley are preparing their graduates for leadership in supporting teachers to achieve the national goal of science literacy for all. I focused on how science education faculty are incorporating the reforms in their courses, and how they are interpreting and enacting the reforms through coursework, research and outreach.

To summarize, in chapters 4, 5 and 6, I analyzed findings from each of the three science education doctoral programs as individual cases of doctoral programs. I described and analyzed: a) the nature of the coursework; b) how doctoral students are mentored through research and teaching experiences; and c) the views of faculty, recent graduates, and doctoral candidates about issues in the field of science education and how faculty views influence the nature of the doctoral programs.

In this chapter I will present a cross case analysis and discussion of data on the three universities. First I will discuss the similarities and differences across the programs, then I will discuss the unique features of that each program has, and finally I will present some of the crosscutting issues across the doctoral programs. Presenting the crosscutting issues is important because it will show that even though the three cases are unique this data can be generalized to a larger population and provide insight into the preparation of doctoral students for reforms in science education.

Similarities and Differences across the Programs

In Table 7.1, I show that the three doctoral programs have similarities in the ways: 1) the programs generally interpret the current reforms; 2) they all have a science center; 3) they require some similar courses; and 4) they all provide some assistantships for their doctoral students. I will discuss how these similarities reflect the way the doctoral programs are interpreting the science education reform goals of achieving science literacy for all.

Table 7.1: Similar features across the three doctoral programs

Features	City Ville	Midwestern	Southern Valley
Interpretation of reforms	-Achieving excellence in science teaching -Improving understanding of science concepts among learners	-Achieving excellence in science teaching -Improving understanding of science concepts among learners	-Achieving excellence in science teaching -Improving understanding of science concepts among learners
Science Centers	-Urban Science Education	- Science Learning and Teaching Center	- Science Learning and Teaching Center
Doctoral Program Requirements and Coursework	-Research Methodology: qualitative and quantitative	-Research Methodology: qualitative and quantitative	-Research Methodology qualitative and quantitative:
	- Science education seminar	- Science education seminar	- Science education seminar
	-Curriculum and Pedagogy	-Curriculum and instruction	-Curriculum theory
	-Qualifying examinations	-Comprehensive examinations	-Qualifying examinations
	-Dissertation and oral defense	-Dissertation and oral defense	-Dissertation and oral defense
Assistantships	-Research assistantships for fellows	-Research assistantships for fellows and other students	-Research assistantships for fellows and other students

Analysis of courses and research experience required of students show that the three doctoral programs are interpreting the current reforms at two different levels. At one level, all the programs show that they are interpreting the reform goals as a call to achieve excellence in science teaching and improving understanding of science among learners in accordance with the reforms goals (AAAS, 1993; NRC, 1996). By achieving excellence in science I am referring to improving science pedagogy in ways that support understanding of science concepts. Beyond this interpretation, each of the programs interprets the reforms somewhat differently.

At the first level of interpretation, there seems to be a general understanding among science educators at these three institutions that the current reforms are calling for innovations to improve science teaching and learning and to change from traditional pedagogy that emphasized rote memorization of facts to reform-based pedagogy that emphasizes teaching and learning for understanding (White & Gunstone, 1992; Wiggins & McTighe, 1998; Wiske, 1998). For instance, excellence in science teaching through use of inquiry (Haury, 2001; Llewellyn, 2002) and teaching science for understanding are addressed in the curriculum and pedagogy courses offered by the three doctoral programs. There are variations among the curriculum courses. Whereas Southern Valley requires students to take a curriculum theory course that combines the history and development of the science curriculum and development of pedagogical theories, the doctoral students at City Ville are required to take a curriculum and pedagogy course that focuses on issues related to the history and development of curriculum mostly from the 60s to the present. Yet still, the doctoral students at Midwestern take a curriculum and instruction course as one of their selective courses, and it focuses mostly on the development and evaluation of curriculum materials in relation to the current reforms. What is common among the curriculum courses at the three programs is that they explicitly address both instructional models and the current reforms.

The emphasis given to curricula in the doctoral programs reflects the importance of curriculum reforms in the field of science education. Curriculum reforms have been an important feature in the field of science education in the US since the 1960s mainly due to the realization that other nations were getting ahead in scientific knowledge. The launching of the Sputnik in 1957 (Dickson, 2003) made Americans realize the need to improve teaching and learning of science in schools. This led to the development of science curriculum that placed more emphasis on content in the different subject areas of chemistry, biology and physics (De Boer, 1991). Reforms in science curriculum are still ongoing as evidenced by the most recent reforms of the 1990s were triggered by a realization that US students were performing poorly compared to their counterparts in other developed countries (AAAS, 1996; NRC, 1998; Roth et. al., 1999)

Another common feature across these programs is that they prepare graduates for jobs in academic research and teaching through coursework and assistantships. Although course emphasis differs across the programs, all three doctoral programs require students to take methodology courses and attend science education seminars. Each of the programs requires students to take at least 9 credits of research methodology courses. The methodology courses prepare doctoral students primarily to conduct their dissertation research as well as prepare them for future research in academia. Preparing doctoral students to conduct research has always been a part of the Research PhD (Buchanan &

Harubel, 1995). Anderson (1975) suggested that doctoral programs in science education should provide for in-depth training of students in one of three specialization areas in addition to general education namely: research and evaluation, development, and instructional leadership. In this case the doctoral programs are providing students with in-depth training in research and instructional leadership, which are necessary for one to become successful in academia.

The three science education doctoral programs in this study also require students to take a science education seminar where faculty and doctoral students meet to talk about their research or work together on research projects. Again these seminars differ in the content and how they are run at the three places. For example the seminars at City Ville mostly involve inviting guest speakers to talk about research, whereas the program at Midwestern and Southern Valley normally involves faculty and doctoral students working together on research projects. What is common across the three programs is that the science education seminar is a formal process for mentoring doctoral students in research and engagement in intellectual discussions of contemporary issues. The seminars focus on research presentations by faculty, students and invited guests. As mentioned previously, research is an essential part of the PhD degree and these seminars also serve the purpose of teaching doctoral students ways of presenting their research and communicating their ideas. It is critical for doctoral students to be competent in research because academic success is measured by how much one publishes (Russell & Korthagen, 1995).

Doctoral students are mentored into research through working as research assistants on research projects. Besides the research assistantships offered in the Science

Education Centers, other research assistantships are available to doctoral students at all three institutions. The numbers of available assistantships vary. Midwestern always has at least as many research assistantships as the number of doctoral students whereas the doctoral program at City Ville and Southern Valley have limited research assistantships and teaching assistantships. However, all the three doctoral programs offer research fellowships to doctoral fellows in their Science Education Centers.

Research assistantships in doctoral study serve dual purposes namely: to mentor doctoral students into the research community and to provide funding for doctoral studies. Midwestern University has the most number of research assistantships available to doctoral students in part due to the diversity of faculty areas of research. Because the program is located in a Curriculum and Instruction department, the science education faculty members work on joint projects with faculty in other specialty areas. As a consequence, doctoral students in science education often have experience working on an array of different projects that are related to science education. This interaction of science education students with faculty in other areas also explains the nature of the doctoral program at Midwestern as shown in Chapter 5. The students are exposed to different theoretical frameworks and research methodologies that enable them to conduct science education research from different perspectives. Conversely, City Ville does not offer many research assistantship opportunities and the students who get research assistantships work with professors in science education. This also influences the type of research that the students conduct.

The requirements highlighted above reflect the general nature of doctoral programs in the United States. What I found to be most interesting in the literature on doctoral studies is the fact that the structure and salient elements of the American PhD degree have remained unchanged since its inception in 1861 despite criticisms from all vintage points (Buchanan & Harubel, 1995). Not one of the elements has been dropped to shorten or to expedite matters in achieving the PhD, although transformations and substitutions have been made to these elements (Buchanan & Harubel, 1995). Failure to change the structure of the PhD can be explained partly by its origins and original purposes. The US PhD has its roots is a Germany where American scholars went to undertake doctoral studies in the arts, sciences, and theology. The German PhD degree was awarded as a capstone to a sustained educational experience from gymnasium (Germany's advanced level of secondary schooling) to university. The PhD was seen as the pursuit of pure knowledge through research. It was also seen as a professional degree in respective disciplines.

According to Buchanan and Harubel, (1995), the basic morphology of the original PhD included the following elements:

a) Specialized courses and residency of at least one year, including at least three years of doctoral enrollment.
b) Language requirement demonstrating reading knowledge of one or two foreign languages
c) Qualifying or comprehensive examinations
d) Dissertation
e) Oral examination in defense of dissertation and subject specialization

All but the language requirement have remained intact, and are all required by all three doctoral programs in this study, although there are minor variations. It is hard to tell why the structure of the doctoral programs has not undergone drastic changes since its inception. Perhaps the reason is that very few studies have focused on the curriculum of doctoral programs. In the case of the three doctoral programs in this study, it is clear that the current reforms and pedagogical styles such as inquiry have been added to the curriculum courses, which goes on to show that the structure of the doctoral programs is flexible enough to enable faculty to add and drop content without necessarily changing the structure of the program.

In summary, faculty at all three programs have responded to the reforms by incorporating them into their courses. However research faculty have the liberty to choose what they want to work on and in these three doctoral programs, their science education centers are providing varied and needed opportunities for faculty to mentor students in areas of research that they view as being important to improve science teaching and science learning. And since the foci of the three centers differ, the programs therefore differ correspondingly.

What Makes the Programs Unique: Differences Across the Three Doctoral Programs

Whereas some science educators have just focused on the goal of achieving excellence in science teaching and learning as defined by the current reforms, others have gone further to question who 'all' refers to. Table 7.2 below shows several differences across the programs such as: a) how the programs further interpret the reform goal, b) the focus of the three science education centers, c) special courses offered and d) mentoring experiences doctoral students get. In this section I am going to discuss the features that make each of the three programs unique.

Table 7.2: Differences across the three doctoral programs

Features	City Ville	Midwestern	Southern Valley
Interpretation of "Science for all"	-A plea for access -Identity formation -Social justice -Curricular justice	-A plea to question traditional practices -Improving science literacy among learners	-Deeper content understanding -Teaching authentic science -Understanding learners -Incorporating STS
Science Centers	Urban Science Education	Curriculum Materials in Science	Information Technology
Doctoral Coursework	Urban science education	Required courses on educational thought and practice	Philosophy theory
	Multi-cultural courses	Research practicum/teaching practicum	Knowing and learning in Mathematics and Science
	Science, Technology and Society	Technology in science	Technology
	History of science	Philosophy of science	History of science
	PCK Course		Advanced elementary science methods
Assistantships	-Limited teaching assistantships -Teach science labs -Research assistantships limited to urban science education	-Unlimited Teaching assistantships -Research assistantships in teacher education and science education -Field instruction	-Limited teaching assistantships -Research assistantships limited to science education
Program Focus	Social Justice	Teacher Education	Technology

The Case of City Ville Doctoral Program

Interpreting Science Literacy for all as a call to Achieving 'Social Justice' in Science Teaching:

City Ville is paying close attention to improving the education of students who have not been provided with the quality of science that would make them scientifically literate. These are students in poor urban schools and minorities (Atwater, 2005; Barton, 2003; Lee 2003; Malcolm, 2003). I see this as the way that faculty at City Ville further interpret the reform goal of achieving science literacy for all. Their actions show that they are thinking critically about the meaning of the word *all.* Evidence from course documents, interviews with faculty, and doctoral students at City Ville show that they view the reform goal of science literacy for all as a plea for making science accessible to all students (Malcolm, 2003). The doctoral program is taking a social justice approach (Griffiths, 2003) to working towards providing equal access to excellent science education to urban students.

Therefore, in addition to preparing doctoral students for excellence in science teaching through coursework and research as described earlier, the doctoral program at City Ville is also preparing its graduates to become leaders in preparing teachers for excellence in urban science teaching. The graduates from City Ville will become leaders in research and preparing teachers for science teaching in urban schools. The interview with Professor Gordon showed that urban schools need teachers who have a good understanding of urban youth, what experiences they bring to science learning, and how best to use resources in the city for science teaching. This observation is in agreement with the findings from the Leadership Development Study (Gallagher et. al., 2003) that highlighted the plight of urban schools science teaching and raised questions about appropriate responses to this issue in science education doctoral programs. Jablon (2002), in his study of science education also highlighted the need by the science education community to pay close attention to issues of diversity and urban education. The program at City Ville therefore attends to the importance of addressing urban science education as a social justice issue. If urban students continue to be ignored, then the reform goal of science literacy for all can never be achieved.

According to Connell (1993), social justice matters for everyone connected with the schools, mainly because schools are social institutions and a public asset, and it is important to question who gets its benefits. Although the education system is designed to benefit all students, only some students gain a high level of benefit from the system. In the case of schools in the City Ville area, lack of funding and high staff turn over results in urban students getting inferior science education (Interview with Professor Gordon, 2005). Another disadvantage for students in the City Ville area schools is that many teachers do not understand urban youth; hence they do not know how best to teach them for understanding. As a result, in many cases they burn out after a few years of teaching (Interview with Professor Gordon, 2005). Most teachers have not been trained to think past the deficit models; hence they stereotype urban students from low-income families as incapable of learning. Barton (2003) warned against stereotyping and highlights the need to understand urban students' backgrounds and the knowledge they bring to learning in order to make science meaningful to them.

The current reform goals of 'science literacy for all' are premised on the assumption that all students are getting a just education. However, in reality many people view education and social justice as separate entities and this is clearly shown by the separate government departments that oversee these issues (Connell, 1993). This explains why the reform documents do not take a social justice approach even though they highlight their goal as embodying "equity and excellence" (NRC, 1998). What makes the doctoral program at City Ville University unique is the fact that it has interpreted the reform goals from a social justice perspective, in which case science literacy for all means providing quality science education to students who have not had access previously. According to Brickhouse (1994) "science classes have been too strongly influenced by the needs of few students who will go on to become professionals, and qualified scientists, the needs of the majority are largely ignored". Thus, the philosophy of science teaching and learning in the City Ville program is that science literacy for all can only be achieved if we look at excellence in science education from the perspective of the disadvantaged students.

Science literacy for all can only be achieved if science content is viewed from different angles in order to make it meaningful to all students. One other thing that makes the doctoral program at City Ville unique is that the research being done in the Urban Science Education Center is focusing on developing a just science curriculum (Connell, 1993). Giving agency to urban youth, listening to, and accepting their ideas, and getting to know what experiences they bring has been used to develop and enrich curriculum used in urban classrooms. For example the Urban Ecology curriculum starts from the grocery store investigating the foods that students eat everyday and then connections to the environment are made. This curriculum does not compromise the content of ecology but it puts it in a context that students can identify with. Through this process, the urban youth can identify with science (Brickhouse, 1994). When students identify with science they feel they are capable of success (Brickhouse, 1994; Barton, 2003).

Although the perspective of social justice is within City Ville, the approach to research differs among the faculty. Professor Gordon and Professor Macarthur do not share the same views about the reforms, and they are engaged in different types of research. Professor Gordon's views seem to be influencing the nature of the doctoral program more than those of Professor Macarthur. There could be several reasons for this but the most obvious one is that Professor Gordon is the leader of the Science Education Center, which is funding science education fellows to study full time in urban classrooms and focusing on teaching science for social justice. City Ville is a private institution, and most doctoral students are part time; hence the current program has been designed mostly to suit the needs of the urban science education fellows. All the doctoral students interviewed in this study were science education fellows but two of the recent graduates did not work in the science education center. The experiences of the recent graduates who did not work in the Urban Science Education Center were different from those who did, showing that the program changed during the last five years to accommodate the Center and its research.

Funding played a major role in enabling Professor Gordon to enact her views of science teaching from a social justice approach. Through the Urban Science Education Center, Professor Gordon is advocating for curricular justice (Connell, 1993). According to Connell, curricula justice is based on three principles namely: considering the interests of the least advantaged, caring for the worst-off first, and specifically serving the interests of the least favored groups in society. Connell clearly articulated these principles by stating that, "This means that we think through economic issues from the standpoint of the poor not the rich. We think through gender from the standpoint of women and we think through race from the standpoint of indigenous and minority groups, we think through sexuality from the standpoint of gay people" (Connell, 2003).

Despite the challenges facing urban schools, Professor Gordon advocates for science for all urban youth by helping teachers realize how they can utilize resources in urban areas as tools for conducting meaningful science inquiry. She sees the need for defining a knowledge base for what teachers need to know and be able to do to teach science. Professor Gordon sees herself and her colleagues as having the ability to help urban teachers empower themselves through resources available in their community. Professor Gordon therefore sees science literacy as developing at the intersection of what happens in the school and what happens in the home. Therefore she sees the need to come up with curriculum that utilizes local knowledge and resources as a way of establishing better linkages between the daily experiences of urban youth in their homes and community and what goes on in places of science, such as informal science learning places and in the schools.

Professor Gordon's ideas are consistent with understanding the nature of science (Lederman, Lederman, & Bell, 2004), in that "Scientific knowledge is partially a product of human creative imagination and partially a function of human subjectivity. Scientific knowledge is culturally constructed." Therefore instead of seeing science as a bunch of facts that students should memorize, teachers should help students to be actively involved in figuring out and constructing their own knowledge.

On the other hand, Professor Macarthur's views about the reforms are that they need to be revised, and he feels strongly about the need to develop understanding of constructivist ideas in science pedagogy. His thinking is in line with several science educators who have translated the constructivist theories into inquiry-based instructional models. For example Bybee (1997) came up with the 5E inquiry model, and the National Research Council (1998) defined scientific inquiry and how it can be done. Recently science educators have come up with more complex guided inquiry models that take conceptual change into consideration. The Guided Inquiry and Instructional Model (Schwarz & Gwekwerere, under review) and the EPE model (Anderson, personal communication) are two examples.

Figure 7.1 shows the components of the City Ville doctoral program and the features that make it unique. The diagram is a pictorial depiction of the relationships that exists between the way faculty are interpreting the reforms and how the reforms are enacted in the program. I will describe the components of the diagram in the next section.

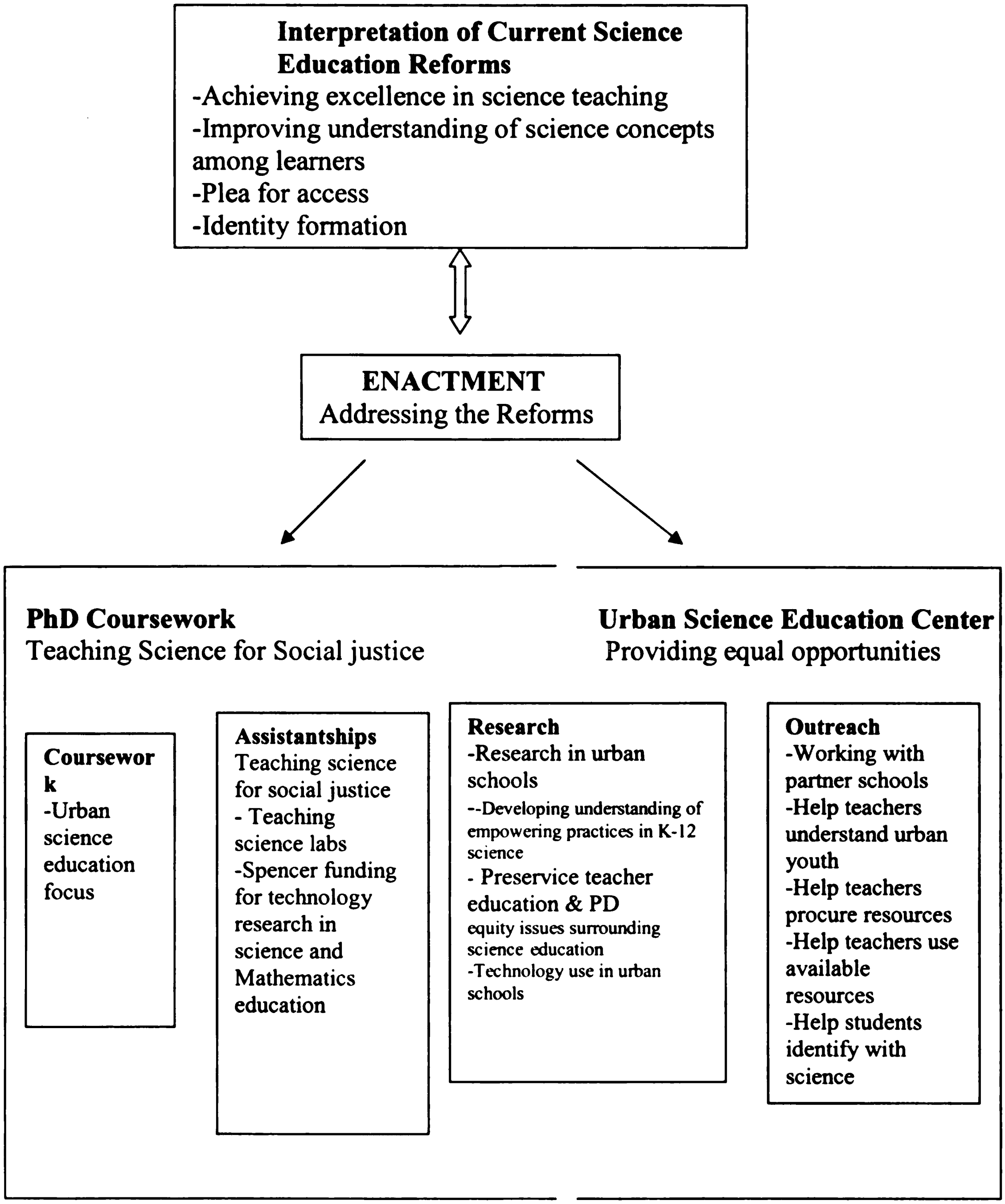


Figure 7.1: Response to current reforms by City Ville doctoral program

The doctoral program at City Ville is interpreting the current reforms at two levels. The first level is shared by all doctoral programs in this study and at this level science for all is interpreted as a call for achieving excellence in science teaching, and teaching science for understanding (White & Gunstone, 1992). They go on further to interpret the reforms as a 'plea for accesses' (Malcolm, 2003) and as 'identity formation' (Brickhouse, 1994). The diagram shows that the program is enacting these reforms through the doctoral coursework, assistantships and research and outreach work in the Urban Science Education Center. The doctoral coursework has an urban science education focus. The courses help students understand the urban education system and how to take action to improve urban science teaching. Although reforms do not drive the curriculum they are specifically addressed in the curriculum courses. The courses address issues of equity, the reforms and what is happening in urban schools. Barton (2003) showed the need to understand urban youth and to realize what science means to them. Students will therefore understand science if it is relevant and if they can apply it to their lives.

The doctoral program at City Ville has two major externally funded grant projects: the Spencer research grant which funds research on technology use in urban schools, and the Urban Science Education Center grants that fund research in urban schools. These grants provide research assistantships and doctoral students are mentored to conduct research in urban schools. However, there are limited numbers of research assistantships at City Ville and most doctoral students continue teaching in schools throughout their programs. The Spencer fellows and the Urban Science Education fellows work on the research projects and mostly are full time students. Research in the Urban

Science Education Center therefore serves a dual purpose, that of preparing doctoral students for future careers in research and as professional development for teachers in the urban schools. The doctoral students at City Ville therefore benefit from the new directions of the Urban Science Education Center and from their more traditional courses that are part of the university.

Overall analysis of the doctoral program at City Ville shows that it is developing critical thinkers by giving the doctoral students the opportunity to see the connection between their personal lives and the larger outside world within which they and others live (Kincheloe and Weil, 2004). By engaging doctoral students in asking such questions as: 'what experiences, knowledge, and skills do kids bring with them to school,' and 'what is the nature of the thought and intelligence that urban students bring with them to school to challenge and nurture,' the program provides a basic starting point for complex critical thinking which expands the boundaries of the field. Instead of just thinking about how to improve science pedagogy in the classrooms, they are thinking beyond the classroom, beyond the school, and focusing on what the student brings, what the students can contribute to the learning, and what teachers can do to nurture this intelligence. By taking a complex critical approach to interpreting the reform goals, the City Ville doctoral program is preparing leaders who will be able to address the challenge of providing equitable science education to urban and minority students in the United States.

The Case of Midwestern Doctoral Program

Interpreting Science Literacy for all as a Call to Achieving 'Equity in Science Teaching':

In addition to preparing doctoral students for excellence in science teaching through coursework and research, the doctoral program at Midwestern is preparing its graduates to become leaders in preparing teachers to become critical thinkers who question their practice, and the curriculum materials that support teaching. They are also being prepared to become leaders in curriculum development research and supporters of teachers' practices. According to an interview with Professor Atkinson, it was clear that the program at Midwestern sees the need for the science education community to question what science literacy for all means, who are 'all students' and what are the constraints to achieving the goal of science literacy for all (Gee, 1991). The research agenda of the doctoral program at Midwestern is to come up with solutions for achieving excellence in teaching diverse learners (Gilbert, & Yerrick, 2001) including all racial and linguistic minorities as well as students with learning disabilities.

Evidence from course document analysis and interviews with faculty and doctoral students show that the doctoral program at Midwestern further interprets the reform goal of science literacy for all as a plea for science educators to become more critical in terms of who are our students, what are the needs of the students, how do we meet their needs' and what are the solutions to achieving science literacy for all? The doctoral program at Midwestern is tackling a similar complex issue to the one that the program at City Ville is attending to. Their doctoral students showed that they take a complex approach to thinking (Kincheloe & Wei, 2004) about issues of equity. In the interviews, the doctoral students showed that their concern about science literacy goes beyond improving student understanding or test scores, but they take a global view of the education context as described by Wei (2004):

> Complex critical thinkers develop the ability to ask questions that expand the boundaries of the field. In a globalized, postcolonial world, we must move beyond monocultural standards of reason and become detectives of intelligence, finding cognitive forms that can make complex critical thinking more elastic *(p.9)*

Inequity was highlighted by interviewees from Midwestern as a hindrance to achieving science for all. Issues of inequity have persisted in the education system for a very long time. Kozol (1992) lamented the plight of poor urban schools that was caused by the way schools are funded. Since then, many others have shown that inequity has resulted in the creation of an achieving gap between well-funded urban schools and poorly funded suburban schools (Kozol, 1992, 2006; Oakes and Rogers, 2005).

Questioning the status quo and thinking critically about what science for all means seems to shape the nature of the courses and research that doctoral students at Midwestern are engaged in. Evidence from interviews with both faculty and doctoral students at Midwestern show that courses such as 'Investigating Scientific Literacy,' and 'Learning to Teach,' and the questions raised in these courses, shape the way that the professors, doctoral students, and recent graduates prepare teachers in their science methods courses. In an interview with one doctoral student, Jennifer talked about the importance of teachers questioning their practices and becoming critical and reflective thinkers. Professor Atkinson's course on science literacy and his research agenda show that he is engaged in asking critical questions about how 'science for all' can be achieved and how the constraints to achieving 'science literacy for all' can be overcome.

There are similarities between the way City Ville encourages urban teachers to be more critical when thinking about urban kids and the way the doctoral students at

Midwestern think about issues of equity. However, one big difference between the two programs is that, whereas City Ville is taking a social justice approach to address issues of inequity in urban school, the Midwestern doctoral program does not focus on any one minority group of students, but they talked about equity as it applies to all minority groups. As a result of questioning their practices, searching to understand the constraints for achieving 'science literacy for all', and acknowledging the challenge of addressing issues equity, the program at Midwestern has only begun to attain a solution for preparing science teachers for urban schools. They hired a new faculty member who specializes in teaching science for social justice. It is clear that Midwestern is working towards achieving the goal of 'science literacy for all' the way they interpret it---as a plea to achieve equity in science teaching.

The steps taken by the staff of the science education program at Midwestern to employ a professor who is knowledgeable about issues of equity and teaching science for social justice are aimed at producing teachers who are critical thinkers who can address the national goals of achieving 'science literacy for all'. This shows a belief among faculty at Midwestern that practitioners are capable of developing sophisticated cognitive abilities and that they can pass such rigorous modes of thinking along to their students. The need to develop teachers who think critically (Segall, 2002) is necessary when one considers the diverse nature of students in the schools. The education system has been failed by the assumption that 'one size fits all' (Brickhouse, 2003). Teachers need to know their learners and understand their diverse needs in order to achieve the reform goal of 'science literacy for all'. The current reforms have become a part of the teacher education focus of the doctoral program at Midwestern, but they have been adapted with a degree of questioning and skepticism, as they seek better ways to view curricular and instructional challenges.

Figure 7.2 shows the components of the doctoral program at Midwestern and the features that make it unique. The diagram is a pictorial depiction of the relationships that exists between the way faculty are interpreting the reforms and how the reforms are enacted in the program. I will provide a description of the program components in the next section.

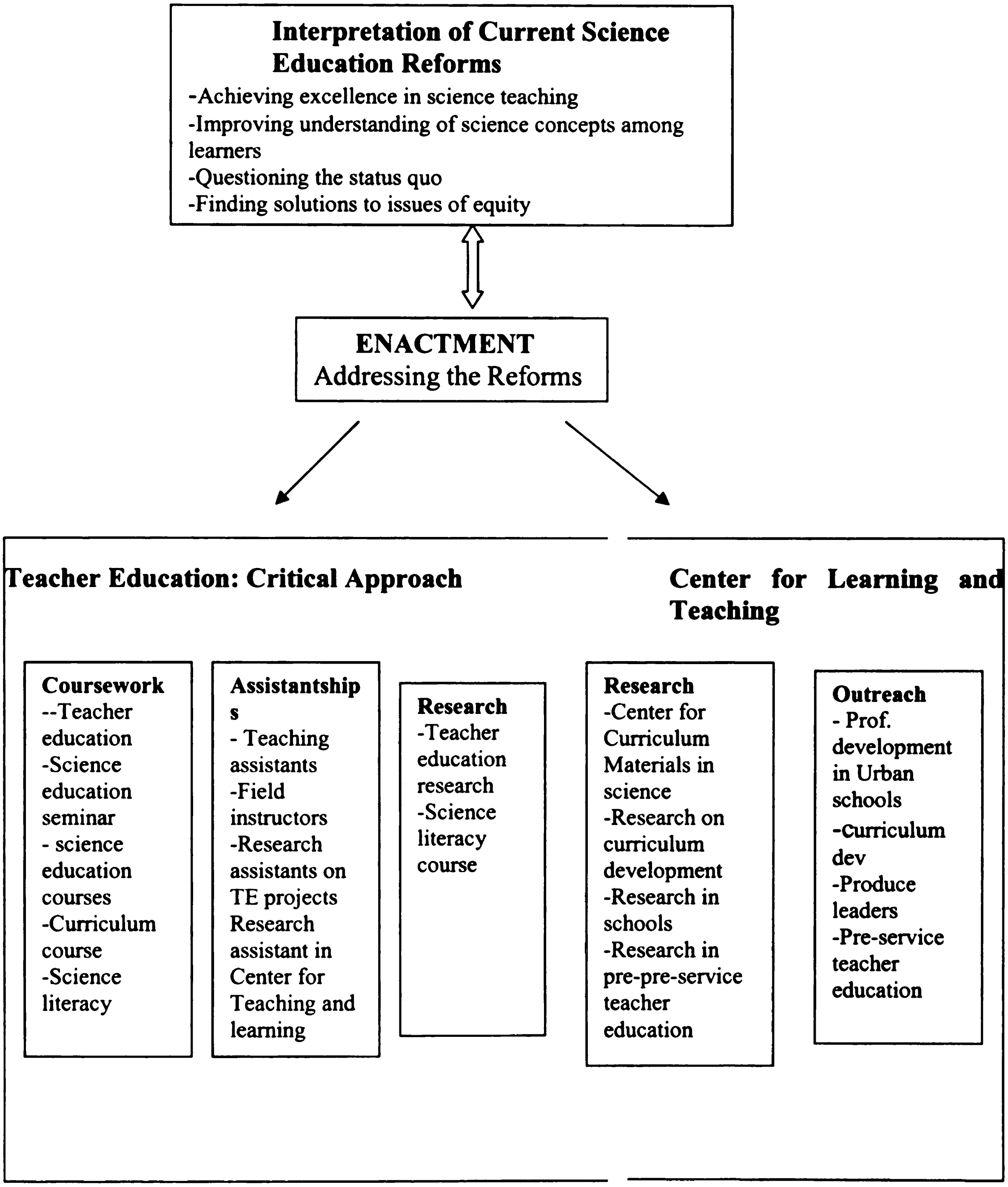


Figure7.2: Response to current reforms by Midwestern Doctoral Program

Similar to the program at City Ville, the program at Midwestern is interpreting the goals at two different levels. First, the reforms are interpreted as a call to achieve excellence in science teaching and improving understanding of science concepts among learners. Second, the doctoral program at Midwestern is preparing its doctoral students to take a critical look at what it means to achieve scientific literacy for all students, questioning the status quo, which is critically looking at the way science has always been taught and the assumptions that have been made about teaching all students. These reform interpretations are enacted in the doctoral programs through coursework, research and teaching assistantships in the regular teacher education program, and through research, outreach projects, and professional development in the Center for Learning and Teaching. The program therefore prepares doctoral students to become leaders who will champion reform goals by mentoring them to take a critical look at issues that are important to achieving science literacy for all.

One thing that makes the doctoral program at Midwestern unique among the three programs is that it provides extensive opportunities for doctoral students to teach science methods courses and for intensive collaborative with faculty on research projects. Doctoral students work closely with faculty and they apply the knowledge they learn from their courses and research experience. The doctoral students also have the opportunity to engage in a variety of research projects in teacher education, most of which focus on supporting teachers to teach inquiry-based science. The program promotes reforms in the schools through teacher development and a variety of teacher support activities.

The Case of Southern Valley Doctoral Program

Interpreting "Science Literacy for all" is a Call to Teaching Science for Understanding Through Authentic Science Experiences:

In addition to preparing doctoral students for excellence in science teaching through coursework and research, the doctoral program at Southern Valley is preparing its graduates to become leaders in preparing teachers to teach authentic science and to improve understanding of science through model-based reasoning and using technology to teach science. The graduates from Southern valley will become leaders in research on using computers to support authentic science teaching, model-based reasoning and understanding how people learn (Bransford, Brown, & Cocking, 2000).

From an interview with Professor Evans and Professor King, it became clear that the science education doctoral program at Southern Valley is taking a complex approach to achieving science literacy for all by not just focusing on traditional science teaching methods, but by focusing on innovations that will enhancing the mental envisioning and a deeper understanding of science content (Lehrer, R. & Schauble, 2000; Edelson, Gordin, & Pea, 1998; Woolnough, 2000). Over the past century, researchers have tried to reduce complexity of instructional processes by breaking them down into simpler pieces (Clarebout & Elen, (2006). This has resulted in simplistic solutions for complex instructional processes. By taking a complex approach to science teaching through model based reasoning and use of technology in teaching science, and using the how people learn framework in their coursework, the doctoral program at Southern Valley show that they fully acknowledge the complexity of learning and instruction (Clarebout & Elen, (2006). This reveals critical thinking on the part of the educators who see the need for integrating technology with knowledge of how people learn, inquiry teaching, and authentic science to make science meaningful and relevant to the students.

According to Edelson, Gordin, and Pea (1998) current theories hold that authentic learning activities are the key to developing understanding that will serve learners beyond the classroom. The faculty members appear to have adapted these practices of science to classrooms to provide the benefits of authenticity for science learning. Engaging students in authentic science experiences ensure equity in the classroom because it enables all students to engage in doing science regardless of their ability (Woolnough, 2000). Engaging students in doing open-ended research projects has been found to be effective in developing core skills in students, especially problem solving, communication and interpersonal skills that improve students' attitudes towards science (Woolnough, 2000). Roth (1995) also showed that engaging students in doing science is exciting as students get to see patterns in the data they collect from their own experiments. Going beyond the textbook and doing authentic science in the way practiced by scientists motivates all students to learn and understand science. Science instruction focused around scientific modeling helps learners develop deep understanding of subject matter, powerful scientific skills, and a strong understanding of the nature of science (Author, 2005; Carey & Smith, 1993; Feurzeig & Roberts, 1999; Lehrer & Schauble, 2000; NRC, 2000.

By bridging the gap between scientists, educators and students, the program at Midwestern is taking a critical approach to address issues that have not been addressed in traditional science teaching. Traditionally, the Colleges of Natural Sciences and Schools of Education have not worked in collaboration to prepare teachers with a good understanding of science. In fact literature shows that educators have always been viewed as being inferior to scientists (Lanier & Little, 1986) mainly because of the seemingly lack of rigor in education courses when compared to science courses. Education research has also been seen as less rigorous. Failure to work together between scientists and educators has led to problems of producing teachers who do not have strong content knowledge (Gallagher et. al., 2003). The program at Southern Valley is therefore addressing this problem as it strives to nurture the reform goals of achieving 'science literacy for all'.

The focus on authentic science teaching that is promoted by the doctoral program at Southern Valley engages students in thinking about science content in complex ways while also thinking about how to engage all students in doing science. The goal is to prepare doctoral students so that they equipped with the same kind of knowledge that scientists so that they will be able to teach authentic science in schools as well as prepare teachers to teach science in the same way. Teachers learn to conduct research in the lab together with science faculty and they learn to use technology to model scientific concepts. This interaction is beneficial to both graduate students and teachers and it provides a source of research questions and opportunities to conduct research that is meaningful in the context of the reform agenda as it is interpreted at Southern Valley.

Unlike the other two doctoral programs that are interpreting the reform goal of science literacy for all as a call to reach out to populations that have not been equally served in the community such as urban students, racial, linguistic minorities and students with learning disabilities, the program at Southern Valley is interpreting the reform goals as a call to address equity in the classroom by promoting authentic science experiences that engage all students in doing science. They are developing a deeper understanding of science among science teachers through engaging in model-based reasoning, authentic science practice in the lab (Woolnough, 2000; Roth, 1995). The understanding how people learn model used in their doctoral program is an essential element for constructivist teaching such as inquiry. Through the Center for Learning and Teaching, the doctoral students work closely with teachers, science doctoral students, and science faculty, hence they are mentored both in pedagogy and authentic science experiences. The doctoral students are mentored to become leaders in professional development through collaborate with and support teachers as they work with scientists to learn authentic science that they will take to their classrooms.

Figure 7.3 below shows that the doctoral program at Southern Valley interprets the goals of the current reforms as referring to achieving 'excellence in science teaching' through doing authentic science, using technology in science teaching, model-based reasoning and understanding how people learn as a way of developing a deeper content understanding among learners. The graduates are prepared to use technology in science teaching and understand how people learn through normal coursework, research, and interdisciplinary work in the Center for Learning and Teaching, and outreach work on teacher professional development. There is also research work that is specific to the Center. Unfortunately doctoral students who are not fellows in the center have little opportunity to work on this kind of research.

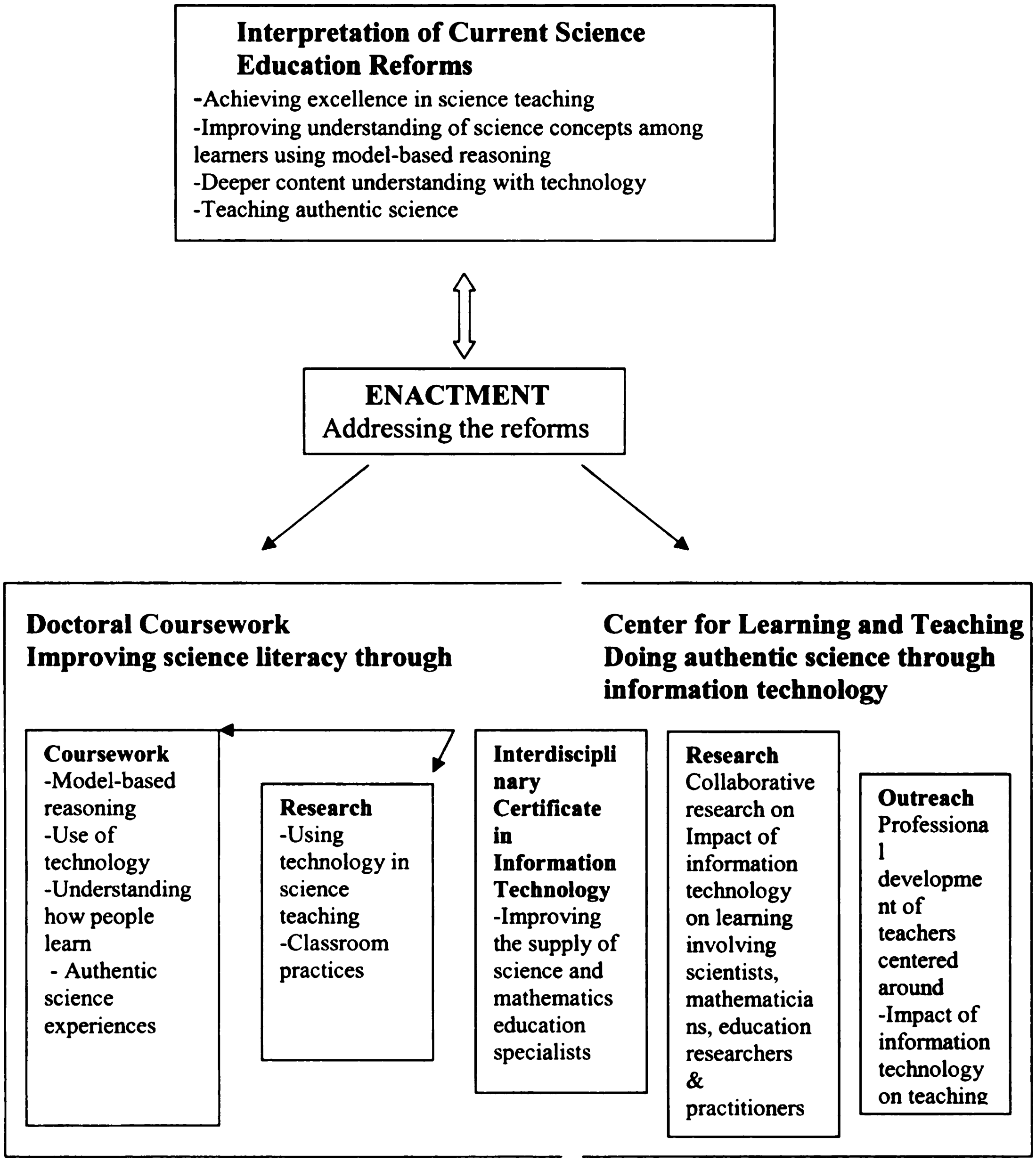


Figure 7.3: Response to current reforms by Southern Valley doctoral program

Science education doctoral students work together with science doctoral students, science faculty, and science education faculty to experience authentic science themselves and to enable more effective authentic experiences for teachers and learners with whom they work. The Center therefore brings together authentic science, technology, and inquiry-based teaching. The Center also recruits science teachers over the summer to gain the authentic science experience through working side by side with bench scientists so that they can bring the science experiences from the laboratory to the classroom.

Some cross-cutting themes across the doctoral programs

From the discussion of the three doctoral programs, I identified the following six crosscutting issues:

a) Current reforms occupy a significant part of the PhD curricula in these three institutions.

b) Programs exhibit different ways of interpreting the reform goals as seen in the overall focus of coursework and research.

c) Faculty views have a significant influence on the nature and content of the courses.

d) External funding has a strong influence on the capability and willingness of faculty to respond to innovations.

Each one of these points in discussed below.

Current reforms occupy a significant part of the PhD curricula in these three institutions.

Findings from this study show that all three doctoral programs are incorporating the current reforms in the framework of their courses and research. Faculty from the three doctoral programs and their students generally agreed that their programs were incorporating the current reforms in the framework of their courses. Faculty members from Southern Valley showed great enthusiasm for the reforms and talked about how the standards are embedded in all their courses. On the other hand, faculty members from Midwestern wanted their students not only to understand the reforms but also to take a critical look at the reforms. Faculty members from City Ville and Midwestern said that the reforms do not shape their programs and that they wanted doctoral students to look at the reforms critically. One-faculty member from City Ville mentioned that she takes a critical look at the standards and emphasized both pros and cons in her courses, but her colleague strongly felt that there is need to revise the reforms. Similarly, Professor Atkinson from Midwestern feels that the reforms should be revised, and some of the recent graduates concur. The faculty members who mentioned that the reforms need to be re-written had different reasons for that. The faculty member from City Ville strongly felt that there is need for science educators to come up with a new curriculum that is based on our understanding of students' cognitive abilities.

Generally when the interviewees were talking about the reforms they emphasized the National Science Education Standards (NSES) and only a couple of people talked about Project 2061 and the Benchmarks for Scientific Literacy (AAAS, 1993). However, the courses offered by the doctoral programs focus on both the NSES (NRC, 1996) and Benchmarks (AAAS, 1993). All three doctoral programs offer courses in curriculum and instruction. A common feature across these curriculum courses is that they trace the history of the science curricular reforms from the 1960s to the 1980s. The current reforms have become a major part of the doctoral curriculum for this particular reason.

The commitment shown by doctoral programs to attend to curricular issues shows their commitment to addressing national issues. Taylor and Tye (1975) describe the curriculum as involving intentions and transactions. There are transactions between citizens and the schools, between the schools districts and the government, and between teachers and their students. In these cases the doctoral programs are preparing doctoral students to address the curriculum issues in K-12 science in three different ways. For example the doctoral program at Midwestern is preparing doctoral students to be critical of the reforms as well as curriculum materials. One of the courses analyzed focused on reforms and analysis of curriculum materials. Through coursework and research done in the Center for Learning and Teaching, the program at Midwestern is serving the science curricula needs of K-12 science teaching and learning, where the textbooks have been found to be of low quality (Kesidou & Roseman, 2002).

According to Goodland planning curriculum is philosophical, political, and sociological/anthropological as well as psychological (Goodland, 1975). Curriculum development includes sensitive matters of policy and making of negotiations. In the curriculum values are articulated, goals are formulated and intentions find their way into the institutions. Some faculty and their students agreed with Goodland about the political nature of the reforms. Although faculty from Midwestern feel that the reforms need modification, they acknowledged that it will not be easy to change the standards because it is a political process that involves academics, politicians, business people and ordinary citizens.

Programs exhibit different ways of interpreting the reform goals as seen in the overall focus of coursework and research.

Analysis of the three programs' coursework, type of research doctoral students and faculty do and the views of faculty, doctoral students and recent graduates show that, the three doctoral programs are interpreting the reforms as a call to 'achieve excellence' in science teaching and 'improving understanding of science concepts' among learners. This interpretation is in accordance with the National Science Education Standards (NRC, 1996) and the Project 2061 Benchmarks for Science Literacy (AAAS, 1993) that highlighted what a scientifically literate person should know and be able to do. Teaching for understanding and bringing authentic science experiences to the classroom (Roth, 1995) through inquiry have been highlighted in the reforms. There is no doubt that the three doctoral programs are preparing their graduates to become leaders in preparing teachers for reform-based teaching. However, the focus and emphasis of the coursework and research also show that the doctoral programs further interpret the reform goals differently.

Through work done in the Urban Science Education Center, there is evidence that the program at City Ville interprets the reforms as a call to 'provide access to all' students (Malcolm, 2003) and as a call to 'teaching science for social justice' (Barton, 2003). Urban science education is complex because it involves social, cultural and economic issues as well as political issues that influence student learning. Several people have argued that the reforms alone will not address the challenges of achieving excellence in science learning and that there is need for equity in the way schools are funded and also to address socio-economic issues that influence student learning (Anderson 2003; Biddle 1997; Rothstein, 2004). In arguing to make science accessible to all students, Malcolm (2003) highlighted the fact that making science accessible to some students is not equivalent to making science accessible to all students.

Thus the doctoral program at City Ville is making efforts to find ways to tackle a complex issue of making science accessible to urban students by preparing students for urban science teaching and by making science relevant to urban students. The City Ville doctoral focus is in agreement with Lynch, (2001) who warned against the idea that one way of achieving science literacy fits all students. The program at City Ville focuses on making science accessible to students in urban schools who historically have not received similar quality of science education mainly due to lack of funding, lack of resources, and other socio-cultural issues. Griffiths (2003) and Connell (2003) have argued for the need to view education as a social justice issue. In keeping with these ideas, the program at City Ville emphasizes teaching science for social justice as a way of bringing equitable science to urban schools.

From analysis of the doctoral courses and research done at Midwestern, there is evidence that the program further interprets the reforms as a call to examine prevailing practices in science teaching and learning and assumptions about who our students are and how scientific literacy can be achieved for diverse learners. For example the course on 'investigating science literacy' explicitly engaged students in raising questions about issues of identity, diversity, language and race, nature of science and current practices of science teaching (Ogbu, 1992; Gilbert, & Yerrick, 2001). A similar critical approach is also found in other Teacher Education courses at Midwestern and this enables students to be critical about issues of power and the construction of scientific knowledge (Latour & Woolgar, 1986), and what literacy means for students who are not from the culture of power (Lemke, 1990; Gee, 1991; Halladay & Martin, 1994).

In addition to taking this approach in the courses, interviews with faculty from Midwestern showed that they encourage doctoral students to take a critical look at the reforms, and to think about modifying the reforms. This is in keeping with Kincheloe & Weil (2004) who advocate for a critical thinking approach to teaching. By thinking of science knowledge and literacy in the context of language, race and diversity, the doctoral program is taking a complex approach to achieving science literacy for all. Further aligned with Kincheloe and Weil (2004), Midwestern faculty argue for the need to teach critical thinking among students in order to produce graduates who can change the current practices that have led to unequal education.

Analysis of courses and interviews show evidence that the program at Southern Valley interprets the reform goals of science literacy as a call to achieve literacy for all through improving pedagogy by equipping doctoral students with a wide range of knowledge and skills in such areas as technology (Bransford, Brophy, & Williams, 2000), understanding learners (Bransford, Brown, & Cocking, 2000), assessment (Larkin, McDermott, & Simon, 1980) and community (Brown, Collins, & Duguid, 1989). This way of interpreting the reforms by the doctoral program shows their realization of the complex nature of instruction and learning (Clarebout & Elen, 2006). Preparing students to become scientifically literate as defined by the Benchmarks (AAAS, 1993) and the National Standards (NRC, 1998) calls for more complex and multi faceted ways of thinking about science. AAAS (1993) for example defines a scientifically literate person as one who:

- Is familiar with the natural world
- Understands some key concepts and principles of science

- Has capacity for scientific ways of thinking
- Knows that science, math and tech. are human enterprises with strengths & weaknesses
- Is able to use scientific knowledge for personal and social purposes

Developing these scientific qualities within a student requires complex ways of instruction such as the ones practiced by the doctoral program at Southern Valley. The program is making efforts to reach out to every student in the classroom not just those who are going to be scientists.

If the analysis of these different interpretations can be discussed in terms of buzzwords, then the three programs interpret the reforms in ways such as "teaching science for social justice," (Barton, 2003) "teaching science for equity" (Malcolm, 2003) and "teaching science for authentic experiences" (Roth, 1995). Similar buzzwords have dominated the science education literature for more than a decade now. In this case buzzwords are used as a way of focusing the intentions and interpretation of reforms within the three programs, and it also highlights the differences across the three programs. Science educators at the three institutions therefore share similar interpretation of the meaning of the reform goals by all other science educators as a call to 'achieving excellence in science teaching' and improving understanding of science concepts.

Although all three programs offer courses in technology, the focus of these courses is different. The technology courses at Southern Valley for example, focus on information technology and model-based reasoning. This is different from the focus of the technology courses offered at the other two institutions. The different foci of the technology courses reflect the different and unique nature of the three programs and this is also related to the way the different programs further interpret the reform goals of teaching 'science for all'. The doctoral program at Southern Valley for example puts more emphasis on deeper understanding of science concepts through model-based reasoning and authentic science teaching. The technology courses focus on how to use technology to create models in science, similar to the way scientists use technology in the process of knowledge creation. At Midwestern the technology course reflects an emphasis of the program on teacher education by focusing on technology tools that can support teachers to teach science. At City Ville, the technology course is called Science, Technology and Culture, which reflects the program's focus on urban science education.

Courses such as urban science education and multicultural education are unique to the City Ville doctoral program. These two courses define the unique nature of the doctoral program at City Ville, which is strongly influenced by a social justice approach. Due to its location in a large urban area, the program caters to the needs of its populations, which are different from the populations served by Midwestern and Southern Valley. This dedication to serving the poor urban schools reflects how City Ville further interprets the reform goal of 'science literacy for all' to mean enabling all students to have access to science regardless of their backgrounds. Focus is on how racially, ethnic, and linguistic minority students as well as poor students can identify with science. The urban science education courses take a social justice approach where focus is on urban students, what science means to them, and what is important for them to learn in science.

At Midwestern doctoral students are required to take courses on educational thought and practice and these comprise the substantial part of the student's program of study. Similar courses may be required at the other two institutions but they are a much less substantial part of the student's program of study. Whereas History of Science is a required course at the other two institutions, Midwestern does not offer a similar course, but instead students can take a philosophy of science course or an epistemologically based course as an elective. These courses on educational thought and practice give doctoral students a critical and holistic understanding of the education system. Questioning the status quo and assumptions in education is shown through the faculty and doctoral students' concerns about issues of equity and teaching science for understanding.

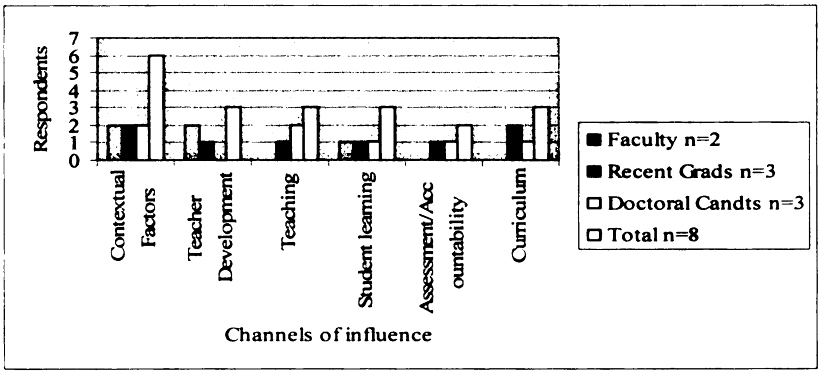
The programs at City Ville and Southern Valley offer courses in pedagogy and advanced elementary methods respectively. These courses prepare doctoral students for teaching science methods courses. However the program at Midwestern does not offer any course in pedagogy mainly because it has a teacher education focus, and most of the required doctoral courses focus on educational thought and practice. These courses engage students in reflecting on teachers' practices and understanding the profession of teaching within the context of science education. The program at Midwestern also provides doctoral students the opportunity to teach science methods courses for elementary and secondary teachers under the supervision of regular, science education faculty members. Doctoral students get experience to teach methods courses this way. The doctoral students at Midwestern also get formal mentoring through taking a required practicum course as they teach, and they also work closely with faculty who observe their teaching and give them feedback. Since the other two doctoral programs have limited funding for teaching assistants, not many doctoral students get to practice teaching in a similar way which explains why they have to take a pedagogy course.

Faculty views have a significant influence on the nature and content of the courses.

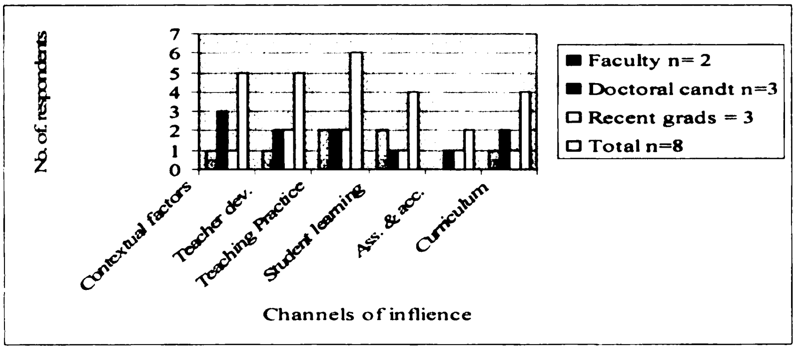
Comparison of faculty, doctoral candidates, and recent graduates' views about issues in science education showed that there is a relationship between faculty's views and the focus of the doctoral program. In other words, the issues that were emphasized by faculty to be important in science education are reflected in the focus and emphasis of the doctoral program. The following graphs that were generated in Chapters 4, 5, and 6 show the issues that were emphasized by faculty, doctoral students, and recent graduates as being important in the field of science education. The graphs were generated from interview data in response to the question: "What do you consider to have been the most important issues in the field of science education in the last five years?" The follow up question asked interviewees to elaborate on the issues they had highlighted. I analyzed the data using the framework for assessing the influence of the national standards on students learning described in Chapter 3. The three graphs provide a comparison of the three doctoral programs in terms of what the faculty, doctoral students and recent graduates consider as most important. In this section I will provide a discussion of the issues highlighted at each program and show how the views highlighted in the interviews are related to the nature of the doctoral program.

The interviewees from City Ville and Midwestern emphasized the importance of contextual factors in the field of science education. These contextual factors included issues such as equity, availability of resources, teacher salaries, and school funding. The interviewees believed that contextual issues are critical to achieving the national goal of science literacy for all. These views are reflected in the doctoral coursework at City Ville that focuses on Urban Science Education and their framework of 'teaching science for social justice'. Ideally, faculty and recent graduates from Southern Valley did not emphasize contextual factors in their conversations.

City Ville



Midwestern



Southern Valley

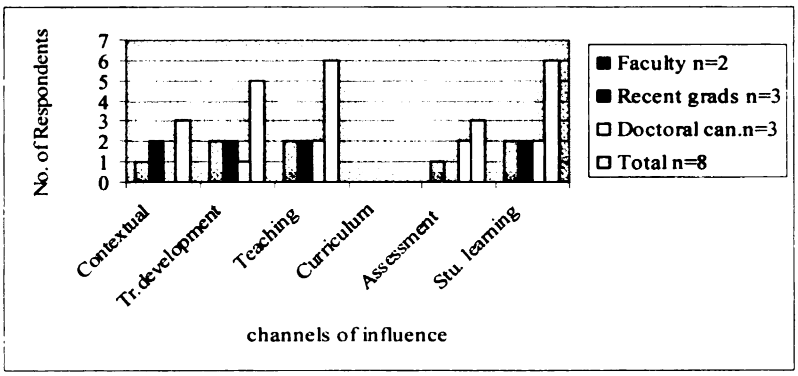


Figure 7. 4: Comparison of faculty views about the most important issues in science education across the programs

Although Midwestern does not have the same urban education focus as City Ville, their concern for contextual issues is reflected in the critical nature of the courses and the critical lens through which they analyze science education reforms. Faculty from Midwestern therefore shares similar views with faculty from City Ville about issues of equity and thinking about how to make science accessible to all students especially minorities and other students in poor urban schools. Whereas the faculty members at City Ville are taking action to address issues of equity through a social justice approach, the faculty members at Midwestern did not know how to address these issues.

The above graphs also show that faculty from Midwestern and Southern Valley emphasized issues related to teaching and students learning as important in the field of science education. Again these views are reflected in the focus and nature of courses offered at Midwestern and Southern Valley. This reflects the program focus at Midwestern, which is teacher education. During the interviews, faculty emphasized issues such as working with teachers in schools to improve science literacy among learners, teaching for understanding, teacher development, and introducing inquiry in schools. Both faculty at Midwestern and doctoral students viewed these issues as challenges confronting the field.

The program at Southern Valley focuses on improving pedagogy through use of technology, model-based reasoning and using authentic science. During interview conversations, the faculty and students emphasized improving achievement through doing authentic science, and understanding how people learn. The conversation with faculty confirmed their passion for model-based reasoning and using technology to improve teaching and learning of science. Doing authentic science is defined as "doing science the way scientists do it in the laboratory" (Roth, 1995).

Curriculum and assessment are two areas that were not emphasized that much by all interviewees. Faculty members from Midwestern are the only ones who emphasized the importance of issues of the curriculum in the field. This is reflective of the Learning and Teaching Center at Midwestern whose focus is on curriculum materials. The faculty and students from Midwestern did not mention any issues related to assessment in the interview whereas faculty and students from Southern Valley did not mention curriculum.

Faculty from City Ville did not mention curriculum and assessment although doctoral candidates and recent graduates did mention these issues. Generally speaking, the interviewees who talked about issues of assessment referred to high stakes testing and the NCLB policy. Doctoral students and recent graduates only, mentioned these issues but faculty in all cases did not mention them. This could reflect some resistance by faculty to deal with external policies that are posing a challenge to their practice. On the other hand, doctoral students see assessment as a real challenge confronting the reform goal of science literacy for all. This is mainly because the high stakes tests do not probe deeper understanding of science but mostly focus on multiple choice recall questions which are contrary to reform-based teaching.

Although faculty views play an important role in determining the content and emphasis of a course, there was is clear pattern in the relationship between the views of faculty and those of doctoral students and recent graduates. Whereas doctoral students at all three institutions generally agreed with their faculty's views and how reforms are incorporated in the coursework, some students disagreed with faculty and did not think the reforms were covered adequately. Other students' views were totally different from those of faculty. There were also different views among students and recent graduates. For example, all doctoral students at City Ville feel that they are getting adequate mentorship in research and teaching; for two of the recent graduates this was not their experience. One of the recent graduates Cathy felt that she did not get enough mentoring from her program, and she had to learn on the job. Such differences could partly be explained by changes in the program since Cathy graduated. Even Cathy mentioned that Professor Gordon joined the faculty just before she graduated and she would have wanted to work more with her on research projects.

This again confirms the fact that faculty's views and perspectives do have an influence on the nature and structure of a doctoral program. Faculty themselves are aware of the fact that they have different views about important issues in the field and what they should focus on in their courses and research. Professor Atkinson was excited about the fact that their program was going to hire a professor who focuses on issues of equity. Since there are many issues to be addressed in the field of science education, there is need for diversity in views and perspectives among faculty in order to address all these issues.

Faculty, doctoral students, and recent graduates shared similar concerns about leadership in the field and who should bring about change. It was clear that there is a need for combined efforts among politicians, business people, and science educators to address issues in the field of science education. Interviewees from City Ville and Midwestern emphasized the need for funding, materials and human resources, and increasing teacher salaries for all schools as steps towards achieving science literacy for all. On the other hand, interviewees from Southern Valley talked about the need to prepare teachers to be leaders, to educate education administrators and business leaders about ways to address issues in science education.

Generally the interviewees were satisfied with their programs, but they had suggestions for a few things that they felt needed to change in order to ensure that doctorates were well prepared. The interviewees from City Ville felt that their PhD curriculum needed to change in order to address current reforms more explicitly. Additionally, one recent graduate from Midwestern mentioned the need for more writing and publishing experiences in the doctoral program, and one doctoral student from the same program mentioned the need for more specific science education courses. Similarly, doctoral students at Southern Valley mentioned the need for more courses on classroom teaching, research, and multiple perspectives in education. One faculty member from Southern Valley wanted more teaching assistantships.

External funding has a strong influence on the capability and willingness of faculty to respond to innovations

The three programs offer research opportunities that equip doctoral students with knowledge and skills that will enable them to prepare teachers for reform-based teaching. Midwestern also adds the options that enable some of the graduates to work in curriculum and assessment. The three programs have externally funded Centers for Learning and Teaching or similar units that provide research funding and research mentoring opportunities to doctoral students. The Centers for Learning and Teaching provide funding for doctoral fellows to study and conduct research on a full time basis. Although these centers have different foci and goals, what is common among them is that they provide opportunities for some of the doctoral students to conduct research on teaching, learning, curriculum and assessment, and to work closely with teachers in the schools or on professional development projects on campus. The centers also have a common goal of producing leaders who are knowledgeable about research in their area of study.

By providing funding for doctoral studies through these Centers, these doctoral programs are able to partially support the personnel needs in the field. Findings from the Leadership Development Study (2003) showed that there is a need to produce more professional personnel and leaders in science education to replace faculty who are nearing retirement. Many senior science education faculty who are in leadership positions got their doctoral degrees between 1960 and 1970 when there was an increase in funding for science education doctoral programs. This resulted in high enrollments and production of graduates (Yager &Zehr, 1981). These numbers declined between 1970 and 1980 due to a major decline in externally funded projects and internal funding for graduate students. This trend continued well into the 1990s, with the result that science education programs have not managed to meet the personnel demands in the field. Findings from the Leadership Development Study (Gallagher et. al., 2003) showed that people who either have a partial or poor match for what the job requires are filling a sizeable number of science education positions. The study found some poor matches where positions that required a PhD in science education hired individuals with limited qualifications in science education such as a PhD in educational psychology, reading and literacy or educational administration (Gallagher et. al., 2003). This indicates a shortage in qualified personnel to fill existing positions in science education. The long term effect of this deficit may be a deficit in the field's leadership capabilities.

Funding for doctoral study remains a major constraint to enrollment and production of graduates in the field of science education. Deans and faculty members interviewed for the Leadership Development Study (2003) indicated that people are not willing to leave their secure teaching jobs to join doctoral studies where the allowances are low and in most cases not guaranteed. By providing guaranteed funding, the Centers at the three institutions are able to recruit students to study full time. For example, the Center for Learning and Teaching at Southern-Valley has enrolled 70 doctoral students who have guaranteed funding for full-time studies.

The Centers for Learning and Teaching are a five to ten year initiative that was established by the National Science Foundation with the goal of providing a "rich environment that melds research, teacher education, and education practice." So far 18 NSF funded Centers for Learning and Teaching have been awarded about $10 million each for a five-year period, about equally divided between science and mathematics. The Centers for Learning and Teaching initiative was a response to the need to produce more faculty members and develop leadership in the field. Each Center must address the following three equally important components: (1) Renewing and diversifying the cadre of leaders in STEM education, particularly the higher education faculty who educate STEM teachers and professionals in leadership positions at state and district-levels and other education organizations; (2) enhancing the content knowledge and pedagogical skills of current and future elementary and secondary teachers; and (3) supporting research into STEM education issues of national import.

The two Centers for Learning and Teaching, plus the Urban Science Center at City Ville, that are connected with the doctoral programs in this study, demonstrate these initiatives. For example the Urban Science Center at City Ville is developing leaders for excellence in urban science teaching and research; the Center for Learning and Teaching at Midwestern is developing leaders for research and improvement of science curriculum materials and teacher education related to curriculum; and the Center for Learning and Teaching at Southern Valley is developing leaders to improve science teaching and learning using technology and understanding how people learn. In all three programs, it is clear that the science education centers were established in response to the need for improving science teaching and learning in accordance with the reform goals of achieving excellence in science and teaching science for understanding.

The courses provide students with an understanding of the reforms and reform-based teaching, which emphasizes inquiry learning and understanding of science. This also shows the commitment of these three programs to preparing doctoral students for careers in teacher education. Science education seminars are also a common feature across these programs and these seminars also focus on contemporary issues in the field. The general structure of the seminars at the three places is that doctoral students meet with faculty to talk about research. This is a formal mentoring process for all the three programs where doctoral students learn about conducting research and presenting scholarly work in informal settings. All three programs also require students to take both qualitative and quantitative research methods courses. These courses prepare students for the dissertation, which is the culmination research project for the programs.

critical thinking allows for critique and improvement of doctoral programs respond to reforms

CHAPTER 8

CONCLUSION AND LESSONS LEARNED

Introduction

Doctoral programs play a significant role in preparing future leaders. Science Education doctoral programs play an even more significant role preparing leaders in a field that is critical to maintaining the national economic and scientific superiority in the face of global competition. The current science education reforms have the goal of achieving science literacy for all students and for this national goal to be achieved; teachers need support from science education faculty. In this qualitative study I investigated how three doctoral programs at major research universities are preparing their graduates for leadership in supporting teachers to achieve the national goal of science literacy for all.

Three science education doctoral programs participated in the study. Data collection took place through surveys, interviews and analysis of course documents. Two faculty members, three doctoral candidates and three recent graduates were interviewed from each of the programs. A case study design was used to investigate how science education faculty incorporated the reforms in their doctoral courses and how they interpreted the national reform goal of science literacy for all. Data analysis involved an interpretive approach and The National Research Council Framework for Investigating Influence of the National Standards on student learning (2002) and Kincheloe and Weil's framework of teaching critical thinking (2004) was used as tools for analyzing and interpreting the data.

Throughout this investigation I found that the current reforms occupy a significant part of the doctoral program curriculum as shown both in the coursework and research. However, the extent to which the reforms are incorporated in the courses and the way they are addressed depends on how the faculty members interpret the reforms and what they consider to be important in achieving the goal of science literacy for all. Faculty members interviewed in this study interpret the reform goals differently. Whereas three of the faculty members interpret science literacy for all as a call to achieve excellence in science teaching; two of them interpret the reform goals as a call to question who 'all student' refers to and what science literacy means for diverse learners. Yet still one faculty member interprets the reforms as a call to exercise social justice in science education.

Considering the Kincheloe and Weil's framework of critical thinking, the doctoral students at the different institutions are getting different experiences depending on the faculty members' focus and how they are interpreting the reforms. For example those students working with professors who are questioning the reforms and teaching science for social justice are prepared to take a more holistic approach to achieving the goal of science literacy for all. According to Kincheloe and Weil (2004) complex critical thinking incorporates the social, cultural, political and cognitive elements. In this case, professors who are engaging their doctoral students to think about what science means to urban youth, how teachers can effectively teach urban youth and questioning who all students refers to are acknowledging that good pedagogy alone cannot achieve the goal of science literacy for all. They are realizing that there are other factors that need to be considered in order to achieve science literacy for all. Considering Kincheloe and Weil's

(2004) definition of critical thinking, taking a global view of issues in teaching is defined as involving complex critical thinking.

On the other hand, professors who are focusing on improving pedagogy through model-based reasoning, doing authentic science, and understanding how people learn are working towards achieving science literacy for all as outlined in the reform documents (AAAS, 1993; NRC, 1996). These reform documents provide details of what students should know and be able to do. By preparing their doctoral students to have a deeper understanding of pedagogy that improves student learning, these professors are achieving the reform goal of ensuring that science is taught in a way that will make all students scientifically literate, not just those students who are going to be scientists. However, the program does not substantially incorporate the social, cultural, political and cognitive elements in their program. Considering Kincheloe and Weil's (2004) definition of critical thinking, failure to take a global view of issues in preparing teachers is defined as simplistic critical thinking.

Another finding from this study was that faculty members' views significantly influence the nature and content of the courses as well as the program focus. Faculty members who take a more simplistic view of the reform goals focus more on authentic science teaching and methodology and understanding how people learn which has come to define their program. On the other hand, faculty members who take a complex critical view of the reform goals focus on looking at issues of science education in relation to the complex education and socio-cultural influences on science learning.

A relationship also exists between faculty views and the views of their doctoral students. Many students agreed with the views of their faculty about what issues are important in science education. However, doctoral students and recent graduates at all institutions had some different views from their faculty about some issues they think are important. Faculty seemed to be more in-depth and focused in terms of the issues they think are important whereas doctoral students and recent graduates took a broader and somewhat shallower look at the issues in science education. It also became clear from the interviews that although there are some issues that all faculty agree are important, all hold different views about some issues that they feel the science education community needs to address. For example, while the faculty members at City Ville focus the contextual issues such as equity and urban science learning, the program at Southern Valley focuses on using technology as a tool to advance K-12 students' understanding of science and inquiry. Faculty at Southern Valley are embracing the reforms and preparing teachers to address issues of science literacy and at the same time the faculty at City Ville are also embracing the reforms and preparing teachers to address issues of science literacy for all.

These different views influence the emphasis that different faculty place on course content related to the reforms and this influences the experiences and meanings that doctoral students develop from the same courses taught by different professors. This also influenced the way the reforms are incorporated in the framework of the courses, for example, although all faculty members from the three programs said that reforms were imbedded in their courses, some doctoral students and recent graduates denied having taken courses that addressed the reforms.

The differences in faculty views also greatly influence the way they interpret the reform goals of science literacy for all. Analysis of the content of their courses and graduate students' research experiences shows that the way faculty interpret the reforms significantly influence how they incorporate the reforms in their courses and research. The National Science Education Standards define the reform goal of science literacy for all as embodying both excellence and equity. Findings from this study show that the way reforms are interpreted either emphasizes excellence only or both excellence and equity.

The ways the reforms are interpreted and enacted have implications both for practice and policy and I will talk about these implications in the next section. In the first chapter, I made it clear that this study is not meant to evaluate or compare doctoral program performance. My goal is to highlight the need for science education faculty to pay attention to doctoral study in relation to societal needs and to see how their programs are preparing their students to address these needs. There is also need for dialogue among faculty about how they are preparing doctoral students as a way of learning from each other.

Implications for Doctoral Preparation

Since the reform goal embodies both excellence and equity, there is a need for doctoral preparation to embrace both of these goals. This is mainly because doctoral graduates of today have the task of preparing teachers to achieve the reform goals. If doctoral preparation only focuses on achieving excellence in science teaching, then the equity part is ignored and doctoral students will continue to avoid these issues in their job of preparing teachers. If both excellence and equity are emphasized, the doctoral graduates will have the tools to work towards achieving both excellence and equity in science teaching. Interpreting the reform goals as achieving excellence through equity is one way that can enable doctoral programs to put equal emphasis on both excellence and equity as they prepare their students.

I find this to be a critical part of doctoral preparation because the science education reforms were written in response to issues that have been and are still major challenges in society today. The problem of low achievement among students is still reported in the most recent studies (*Luesdorf, 2006)* as they have been reported more than twenty years ago. Science literacy for all students is a societal problem that needs to be addressed by providing equitable and quality science to all students regardless of their social or cultural background. Most recent literature also shows that issues of equity still need to be addressed just as they did more than 20 years ago (Kozol, 2005). Hence one of the implications of findings from this study is that doctoral programs need to take the necessary steps to provide doctoral students with tools that will enable them to address both issues of excellence and equity in their own practice.

Findings from this study show that the faculty members are interpreting the reform goal of science for all either as a pedagogical issue, as an equity issue, or as a social justice issue. However what is notable about these three programs is that they are focusing on only one complex issue that is targeted at achieving science literacy for all. This makes me wonder whether it is not possible to focus on more than one complex issue at a time. For example, the program that is focusing on teaching science for social justice does not have an explicit emphasis on using technology, but authentic science is implicitly addressed in the inquiry and curricular that focuses on urban students. The program that is focusing on providing authentic science experiences and using technology does not have an explicit emphasis on making science accessible to cultural and linguistic minorities, although the issues of reaching out to diverse learners in the classroom are implicit in authentic science teaching.

It was clear from interviews with recent graduates and doctoral students that they feel strongly that issues of equity need to be addressed. They however, admitted that they did not know how to do it. If doctoral programs do not prepare students to meld equity with excellence, it becomes difficult for them to address these issues when they prepare teachers. There is therefore a need to sought ways to meld equity and excellence in doctoral preparation as a way of achieving science literacy for all.

There is evidence from these findings that faculty members at different institutions have specialty knowledge in one area that the others do not have. Professional development among faculty members has become popular in the natural sciences and other fields. Groups such as the Case Studies Center at the State University of New York (SUNY) Buffalo, New York run professional development for faculty at different universities. This is a model that can also be used in science education for faculty members to share their intellectual resources in these areas. Starting such professional development efforts for faculty will enable them to conduct research that focuses on melding equity with excellence in science teaching to achieve excellence with equity. This model can trickle down to the classroom level through teacher preparation.

One thing that most science educators may agree with is that it is hard enough just to achieve excellence in science teaching and achieving both excellence and equity is complex. Given the complex nature of the education system it becomes almost impossible to do both. Providing doctoral students with opportunities to develop complex critical thinking skills is one way that the doctoral programs in this study are hoping to work around this almost impossible task. Complex critical thinking skills enable one to think beyond the status quo, in other words thinking of science the way it has always been defined, written, and taught. These skills also enable future teacher educators to prepare teachers who take a complex critical thinking approach to science teaching.

Implications for Policy

In order for doctoral programs to be able to prepare graduates who are well prepared to address national issues of achieving excellence and equity in science teaching, sustainable sources of funding are needed. The three doctoral programs in this study all have received external funding for Science Centers. The National Science Foundation funds two of the centers and private foundations fund one of the centers. The work conducted in the centers is enabling the doctoral programs to provide students with experiences that they would otherwise not be able to do without funding. The funding of the centers enabled doctoral programs to provide doctoral fellows with full tuition and allowances. This enabled the program at Southern Valley for example to enroll as many as 70 students in their doctoral program.

Although the National Science Foundation originally planned to fund Centers for Learning and Teaching for 10 years, faculty from this study told me that they only received funding for 5 years, and there is no sign that the funding will be renewed for the next five years. There is general concern about what is going to happen after the NSF funding runs out. One of the faculty and students from Southern Valley feared that their doctoral program is going to go back to the old structure where the students did not get much mentoring in research. Recruiting doctoral students to doctoral programs has been cited as a major challenge by faculty and availability of funding is one way that has enabled doctoral programs to enroll increased numbers of American students. Funding for doctoral studies is necessary for achieving the national goal of science literacy for all.

Therefore, in order to prepare doctoral students who will be able to work towards achieving the national goal of excellence and equity in science teaching there is a great need for sustainable funding. Investment in doctoral study is important because it is an investment in future leadership.

Implications for Research

This study revealed that there is need for faculty members in science education to take a closer look at the reform goals and find ways to address both issues of excellence and equity. In the literature there has been a sizeable amount of research into efforts of achieving excellence in science teaching and learning. However, the issue of equity has not received the same amount of attention. Equal efforts are needed for finding ways to achieve equity and excellence in science teaching in order to achieve the national goal of science literacy for all.

There is also a need for research that focuses on doctoral preparation, paying particular attention to the content of the doctoral programs and how they are addressing different societal needs. Conducting research on doctoral program course content and research programs is one way that faculty can improve and strengthen their doctoral programs. Faculty can also learn from what others are accomplishing if literature on doctoral programs is readily available. College professors have contributed a great deal to doctoral studies and failure to have research that talks about how faculty have prepared doctoral students means this wisdom is not passed on to later generations.

Plans for Future Research

'Coming to America' was a 1988 Hollywood movie directed by John Landis which featured an African Prince, excited about coming to America for the first time and finding himself a bride in Queens, New York. In one episode when a girl (his bride to be) asked Prince Akeem what he did for a living, he lied and said that he was a student at the University of the United States. When I watched the movie again more than a decade later, I saw it in a different light. Prince Akeem's lying about studying at an American university showed how the voluntary movement of Africans to the United States has mostly been associated with studying at universities. Africans are still coming in large numbers to study at American universities. The Global Education Digest UIS (2006) showed that "tertiary students from sub-Saharan Africa are the most mobile in the world, with one out of every 16 – or 5.6 % - studying abroad." One may wonder how sustainable studying abroad is for Sub-Saharan Africans, considering their educational and economic needs? In this section I will show how my doctoral studies and particularly the experience and knowledge I gained from this study will guide my future research work in Sub-Saharan Africa.

When I came to the United States in 2000 to pursue a PhD in science education my goal was to get a higher degree that would enable me to offer the same level of education to other Zimbabweans. The reason why I came to study in the USA is because there was no science education doctoral program in my country. There are many more people like myself who would like to pursue a PhD but cannot secure funding. Since my 'Coming to America', I have become concerned about this situation, and I have always wondered what makes American PhD programs sustainable and what makes the doctoral programs what they are? Working on the Leadership Development Study three years ago made me even more aware of the variations among the science education doctoral programs in the United States. This raised more questions about how the doctoral programs were put together, what makes some courses more important than others, and generally what shapes the doctoral programs? I decided to conduct my dissertation study in this area in order for me to find answers some of these questions. To narrow my focus, I decided to investigate the influence of current science education reforms on doctoral programs. I looked into how three science education doctoral programs are interpreting and enacted the reforms in their courses and research. I also investigated how the views and perspectives of faculty shaped the doctoral programs.

Studying science education doctoral programs has been the most rewarding experience for me. This study gave me the opportunity to look at science education doctoral curricula from different science education programs. I also had the opportunity to talk to science education faculty from different universities, and listening to their views and ideas was one of the most enriching experiences I have ever had. My interviewing skills improved greatly through conducting this study, and it is an asset that I will certainly use in my research. I realized that I love talking and enjoy listening to people talk. People from all walks of life want to have their voices heard and interviews are a great method that provides rich data and I plan to continue using this method in the future.

Zimbabwean universities need to establish doctoral programs in science education. In 1980, with the establishment of a new, independent Zimbabwe, we set on a goal of educating all children. We made significant progress on that goal for several years, but have lost ground recently. I am confident that at some time in the future, we will recapture the educational goal that was set at independence. At that time, I plan to return to Zimbabwe and become involved in establishing doctoral programs. I also plan to conduct research that looks at the nation's societal needs and how education can meet these needs. I will conduct surveys and interview people from different sectors of the country to get a better sense of the direction science education need to take. From these data I hope to come up with ideas that can help reform and enhance science education in Zimbabwe. Although it may be a long time before I can begin to work on this, given the economic and political situation in Zimbabwe at the moment, this is what I plan to do when the climate stabilizes. There is a strong need for Zimbabwean professionals to plan ways to restore the crumbling structures and to create programs that will foster significant educational reform in my native land.

Issues of teaching science for understanding and achieving equity in science among all students are critical in Zimbabwe where students in different types of schools do not get the same quality of science education. This is mainly due to the long history of colonial education that left former white schools with well-equipped laboratories than former black only schools. Although the government made efforts to ensure that all students had access to science education, it did not have the financial resources to provide all schools with equipment that would be needed to provide authentic science experiences to all students. The implications from this study for the need to focus on melding equity with excellence also apply to the education system in Zimbabwe. Hence, this study was instrumental in helping me to think about issues that need to be addressed in science education in Zimbabwe. Doctoral programs in Zimbabwe will need to explicitly address issues of equity and excellence in science teaching.

APPENDICES

APPENDIX A

FACULTY QUESTIONNAIRE

Demographic Information

Name:____________________ Position Held:________________

Name of Institution:______________

No. Of years at this Institution:____________

Areas of Specialization: ____

Your department or unit:_________________________________

Mailing Address: ____

City_________________ State:_____ Zip code:_______

Phone_____________ Fax:_________

Email______________________

Some of the questions in this survey are similar to the ones that were asked during the 2001-02 survey of science education doctoral programs that you may have completed. This survey is meant to update the information from the previous survey as well as collect data that relates to the issue of reforms and doctoral study.
I am also requesting copies of your syllabi and reading lists of all the courses you taught on the science education Doctoral program.

Update on the Faculty Situation

1. Names of the faculty members in your science education department
2. Please provide the following staffing information about the faculty in science education during the past 5 years:

	2000	2001	2002	2003	2004
Number of faculty who resigned					
Number of faculty who retired					
Number of new faculty joining					
Number of positions advertised					

GRADUATE STUDENTS INFORMATION

3. Please complete the following table about the composition of students enrolled in your science education doctoral program:

	Number		Number
Students currently enrolled		Females	
Full time		Part time	
International students		White, non-Hispanic students	
Native-American and Alaska Native students		African-American students	
Asian-American students			

4. What level of science content background do your students normally have upon graduation? Can you equate it to:

____More than a Master's degree in science
____Masters Degree in science
____BS degree in science
____Less than a BS Degree in science
____No requirement is specified

5. How many doctorates in science education did your science education program grant in the past 5 years? __________
6. Below I have a table with names of graduates from your program who are identified as Science Education majors in the dissertation abstracts.
Please could you help me identify whether these graduates were Science Education majors or not, if not which departments they were from.

List of Science Education Doctoral Dissertations from Teachers College: 2000-2004

Year	Student	Dissertation title	Advisor name	Science Education major	Department they were from
				Y N	
				Y N	
				Y N	

7. Additional information about recent graduates and doctoral Candidates I am requesting:

Please note: I am going to interview three recent graduates and three doctoral candidates from your program as part of the study
Please could you provide me with names and contact information of 4 or 5 recent graduates from your program from the past five years who I can interview? I am also requesting for their study plans.

1.____
2.____
3.____
4.____
5.____

Please could you provide me with names and contact details of 4 or 5 doctoral candidates who are advanced in their program, preferably at dissertation stage.

1: ____
2. ____
3.____
4. ____
5. ____

Please can you send this information to Yovita Gwekwerere, 118 Erickson Hall, East Lansing, MI 48824.
If you have made any changes to the course syllabi for your science education doctoral program in the past 4 years, could you please send course descriptions and syllabi for the core courses in the program to the same address?

8. What positions have been taken by recent graduates from your program during the *past* 5 years

________College Teaching - Science Education

________College Teaching - Sciences
________College Teaching – Two year college

________K-12 Administration

________K-12 teaching

________Research

Course Requirements

For Questions 9, 10 and 11 use the following Key to show the type of content, type of research and focus of coursework/research:

IN Inquiry in science

SL Science Literacy

NOS Nature of science

ST Standards-based teaching

CI Curriculum issues

SE General Science Education

TE General Teacher Education

SM General Science Methods

RM Research methodology

Ph Philosophy of Science education/science

HS History of Science education/science

PI Policy Issues

Other - Specify

9. What is the full range of courses that your doctoral students take, how many credits does each course carry, which courses are selective and which ones are elective.

NB: In the last column, please use the key above to classify the focus of content.

Name of Course	No of credits	Required/Elective/ Recommended	Focus of Content

Research

10. List the research areas that faculty in your science education department are involved in.

NB: Please use the key above to classify the type of research

Research Area or topic	Type of Research

Doctoral Funding and Mentoring

10. What types of assistantships, fellowships and grants are available to doctoral students? How many are available and what is the focus of each.

Please use the key above to identify the focus of work.

	Total Number available	**Mentoring Support given to students**	**Focus of the work/Research**
Teaching assistantships			
Research Assistantships			
Fellowships			
Grants			

Please mail this completed questionnaire and requested materials and information to Yovita Gwekwerere, 118 Erickson Hall, Michigan State University, East Lansing MI 48824.

Thank you for your time and effort.

APPENDIX B

FACULTY INTERVIEW PROTOCOL

Faculty's Views about issues in Science Education

1. What do you consider to have been the most important issues confronting the field of science education in the past 10 years? What are your views about each of these issues?
2. What issues may be more important to the field of science education in the next 10 years?
3. As a science educator, what are your ideas about how these issues can be addressed?

Who should take leadership in addressing these issues? What knowledge, skills or other abilities should they possess?

Preparing future Leaders for the field

4. What roles are doctoral graduates from your program being prepared for? Does your program require all doctoral students to do teaching assistantships/practicum and research assistantships/practicum?
5. How are doctoral students from your program mentored in each of these areas:
   - Teaching assistantships
   - Research assistantships
   - Fellowships
6. In what direction would you want to see your doctoral program go, considering the issues you mentioned earlier?
7. As a science education community, what balance should exist between the work of preparing science education faculty, science teachers for the schools, and carrying out research related to science education?
8. Over the recent years, several reform documents have received attention by the science education community, for example the National Science Education Standards, Project 2061, and other Science education reforms. How are these reforms incorporated into the framework for courses and research in your doctoral program?

   Do you have discussions about these reforms in or outside your classes either pro or con? Would you want to see any changes in how your doctoral program deals with the reforms? If so how?

9. What are your views about these science education reforms from the past 10years; namely: Project 2061, and the National Science Education Standards?
10. What are your views about the No Child Left Behind and other recent policy developments? What is your reaction to the science education component of the No Child Left Behind?
11. Considering the achievement gap that exists among American schools today, do you see any of these reforms as closing/narrowing the gap?
    The science education community has responded to the National Science Education Standards in various ways. On one end there are optimists who have embraced the reforms while on the other there are skeptics and opponents and yet

others in between. What would you attribute these differences in opinions and views to and why?

Probe: In your view, what would be the most effective way to close this gap?

12. Finally, I would like to know what your ideas are about these issues in science teaching and learning at K-12 education:
    - How should science should be taught and learned effectively at K-12 level? Also why is there much widespread concern about low-level effectiveness in science teaching and learning?
      -What should be done to address these concerns?
    - How should doctoral programs respond to reform initiatives directly related to K-12 science learning?
    - How has your doctoral program changed or needs to change in order to accommodate these reforms?
    - Are other changes in doctoral programs desirable?

Thank you for your assistance in this study and for the time and expertise you have given in this interview. Do you have any last words you wish to give at this time?

Thanks again for you help.

APPENDIX C

RECENT GRADUATES INTERVIEW PROTOCOL

Thank you for agreeing to this interview. I appreciate your willingness to be a part of this study. Also thanks for returning the IRB Consent form.

Name (Optional)____________________

Current position________________________________

Institutional Affiliation ________________

Years in current position:__________

PhD institution__________________ PhD Graduation Date _____

Dissertation topic: ____

____

Date of Interview _________

Recent Graduates' Views about Issues Confronting Science Education

1. What do you consider to have been the most important issues in the field of science education during the past 10 years? What are your views about each of these issues? What issues may be more important to the science education community in the next 10 years?

2. As a field, do you think we are prepared to address these issues? Why?
Choose one issue that you may have attempted to address, and share your experiences/struggles addressing it. Share your successes/failures.

3. Who do you see as leaders in addressing these issues? What knowledge, skills or other abilities should they possess?

Preparing future Leadership in Science Education

4. What roles did your doctoral program prepare its graduates for?

5. Were the following a requirement of your doctoral program: teaching assistantships/ practicum, Research assistantships/practicum
   - Do you think science education programs should make teaching and research assistantships/practica compulsory for all doctoral students? Why/why not?

6. How were doctoral students from your program mentored in each of these areas:
   - Teaching assistantships
   - Research assistantships

7. In what direction would you want to see the doctoral program courses and research expectations go?

8. As a science education community, what balance you think should exist between the work of preparing science education faculty, science teachers for the schools, and carrying out research related to science education?

9. How were the reforms incorporated into the framework for courses and research in your doctoral program: the National Science Education Standards, Project 2061, and other Science education reforms?

Probe: Was there much discussion about these reforms either pro or con?

10. What are your views about the science education reforms from the past 10years; namely: Project 2061, and the National Science Education Standards?
11. What are your views about No Child Left Behind? Is your doctoral program or science education department concerned about the science education component of this reform?
12. Considering the achievement gap that exists among American schools today, do you see these reforms closing/narrowing the gap?
    Probe: What would be the most effective way to close this gap?
13. The following phrases have been used in the current reforms and have dominated the science education jargon of our time, what is your definition of each of these phrases:
    a. **The Nature of Science**
    b. **Teaching science for understanding?**
    c. **Science literacy for all**
    d. Scientifically literate citizens
    e. Inquiry
14. The science education community has responded to the National Science Education Standards in various ways. What would you attribute these differences in opinions and views to and why?
    Describe how the science education community from your doctoral program reacted to the NSES? Is this different from your current institution?
15. Finally, I would like to know what your ideas are about:
    - How science should be taught and learned effectively at K-12 level and why?
    - How doctoral programs should respond to reform initiatives influencing K-12 science learning?
    - How can your doctoral program be changed to accommodate these ideas?

Thank you for your assistance in this study and for the time and expertise you have given in this interview. Do you have any last words you wish to give at this time?
Thanks again for you help

APPENDIX D

DOCTORAL CANDIDATES INTERVIEW PROTOCOL

Thank you for agreeing to this interview. I appreciate your willingness to be a part of this study. Also thanks for returning the IRB Consent form.
Courses taken so far: Could you please send me a copy of the courses you have taken or your program plan if you have completed one. Also could you send me a copy of your CV. Thanks.

Doctoral Candidates' Views about issues Confronting Science Education

1. What do you consider to have been the most important issues in the field of science education during the past 10 years? What are your views about each of these issues?
2. What issues may be more important to the field of science education in the next 10 years?
3. As a future leader in the field of science education, what do you consider to be some of the more effective solutions to addressing these issues?
   Who do you see as leaders in addressing these issues? What knowledge, skills or other abilities should they possess?

Preparing future Leaders for the field

4. What roles are doctoral graduates from your program being prepared for?
5. In what direction would you want to see your doctoral program go, considering the issues you mentioned earlier?
6. As a science education community, what balance should exist between the work of preparing science education faculty, science teachers for the schools, and carrying out research related to science education?

Doctoral Study and Current Reform initiatives in Science Education

7. How were/are these reforms incorporated into the framework for courses and research in your doctoral program: the National Science Education Standards, Project 2061, and other Science education reforms?

Was there much discussion about these reforms either pro or con?

8. What are your views about the science education reforms from the past 10years; namely: Science for All Americans, Project 2061, and the National Science Education Standards?
9. What are your views about the No Child Left Behind policy and other recent policy developments? Is your doctoral program or science education department concerned about the science education component of this policy?
10. Considering the achievement gap that exists among American schools today, do you see these reforms closing/narrowing the gap?

Probe: What would be the most effective way to close this gap?

The following phrases have been used in the current reforms and are commonly used in the science education community, what is your definition of each of these phrases:

a. **The Nature of Science**
b. **Teaching science for understanding?**
c. **Science literacy for all**
d. **Scientifically literate citizens**

11. The science education community has responded to the National Science Education Standards in various ways. On one end there are optimists who have embraced the reforms while on the other there are skeptics and opponents and yet others in between. What would you attribute these differences in opinions and views to and why?
12. Finally, I would like to know what your ideas are about:
    - How science should be taught and learned effectively at K-12 level and why?
    - How doctoral programs should respond to reform initiatives influencing K-12 science learning?
    - How can your doctoral program be changed to accommodate these ideas?

Thank you for your assistance in this study and for the time and expertise you have given in this interview. Do you have any last words you wish to give at this time?

Thanks again for you help.

APPENDIX E

ADDITIONAL INTERVIEW QUESTIONS FOR CENTER FACULTY

Interview Questions

1. What were the key factors that prompted you to write a proposal for the Center for Learning and Teaching?

2. What Concerns were you hoping to address or what problems were you hoping to resolve? C) What do you feel made your proposal outstanding? D) How is your center addressing these problems?

2. How have the national reform efforts such as National Science Education Standards, Project 2061, No Child Left Behind and other programs influenced the work of your center? Are these reforms incorporated in the work you do in the center?

3. What have been the major obstacles in implementing your Center's work? How have you dealt with these obstacles?

4. How will your future doctoral graduates differ from those who earned their degrees prior to the establishment of your Center?
What is your final goal at the end of the project?

APPENDIX F

LETTER TO SENIOR FACULTY

Dear Professor xxx

This email is a follow up to a discussion I had with you some time ago about my dissertation study. I am inviting you to participate in an interview and data collection for my doctoral dissertation study entitled "Response to Current Reform Initiatives: ***Case Studies of How Three U. S. Science Education Doctoral Programs are Preparing Future Leaders for the Field***". The study is going to explore how science education doctoral programs are responding to the current reform initiatives as they prepare teacher educators, and why. I am planning to interview six-science education faculty, 9 doctoral candidates and 9 recent graduates from three different institutions. In addition to the interviews, I am also requesting you to complete a survey that I am using to gather information about your doctoral program. I am also requesting for course materials that have been used in the doctoral courses such as course syllabi, course descriptions, and reading lists.

My study includes a select group of science education doctoral programs that were part of the Leadership Development Study that was conducted by faculty at Michigan State University two years ago. Based on several criteria, I would like to include the science education doctoral program at Michigan State University as a part of this study.

I am hoping that this study of will yield systematic data that can serve as reference on faculty's views about current issues in science education, what they think about the current reform initiatives and how or whether the reforms impact the way doctorates are prepared.

To express your willingness to participate, please could you complete the enclosed consent form and return it to me. Please also send me a current copy of your curriculum vita when you return the consent form.

I am looking forward to learning more about your views and ideas about issues in science education. I will establish time for an interview soon. I anticipate that the interview will last about an hour and will be audio taped.

Attached Documents:
Dissertation summary
Consent form

Sincerely,
Yovita Gwekwerere
PhD Candidate
Michigan State University, College of Education

APPENDIX G

CONSENT FORM

Response to Science Education Reforms: The Case Studies of Three-Science Education Doctoral Programs in the United States.

You have been selected to participate in this study either as a science education faculty, recent graduate or doctoral candidate from a doctoral program that I am interested in studying for my doctoral dissertation. Your participation in this study is voluntary and you are free to discontinue participation at any time without penalty. Your privacy will be protected to the maximum extent allowable by law. I promise to preserve confidentiality of your responses. All data reporting will be anonymous. I will not use your name or the name of your institution in my final report or in any other forum.

The study investigates how a selected number of science education doctoral programs in the U.S. are responding to the current reform initiatives as they prepare future leaders in the field. Case studies of three science education doctoral programs that were selected from a group of 10 programs studied three years ago as part of the Leadership Development Study will be conducted. The study will investigate science educators' visions of the future of science education; how their doctoral programs are preparing future leaders, and how they are responding to the current reform initiatives and why? Data will be collected through questionnaires, face-to-face as well as telephone interviews with faculty, advanced doctoral candidates and recent graduates. The interviews will be audio taped and will last about half an hour. The tapes will be destroyed at the end of the study. I will also be requesting for course documents, including course syllabi, reading lists, program descriptions and doctoral program requirements for this study. These documents will be used solely for this study and will be destroyed at the end of the research.

If you desire further information about this research, you may call or write my dissertation committee chair Dr. James Gallagher at: College of Education, Michigan State University, 327 Erickson Hall, East Lansing, MI 48824-1034, Phone: (517) 432-4871.

For questions about your role as a subject in this research, you may contact Peter Vasilenko, Chair of the University Committee on Research Involving Human Subjects at Michigan State University; 202 Olds Hall, East Lansing, MI 48824-1034. E-mail: ucrihs@msu.edu Phone: (517) 355-2180. Fax: (517) 432-4503

To indicate your agreement to participate in this study, please either sign the following statement and return it to Yovita Gwekwerere at the following address: College of Education, Michigan State University, 118 Erickson Hall, East Lansing, MI 48824-1034, or send me an email to gwekwere@msu.edu with the following indication that you have given your informed consent:

I agree to participate in the study, "Response to Current Reform Initiatives: Case Studies of How Three U. S. Science Education Doctoral Programs are Preparing Future Leaders for the Field."

Name________________________________ Date__________________

I agree to be Audio taped in this study.

Name__________________________________ Date__________________

APPENDI H

LETTER TO RECENT GRADUATES

Dear Dr. xxx

Dr. _________ gave me your name as one of their recent graduates in science education who could help me with data collection for my study. I am inviting you to participate in an interview that is part of my doctoral dissertation study entitled: "Response to Current Reform Initiatives: ***Case Studies of How Three U. S. Science Education Doctoral Programs are Preparing Future Leaders for the Field***". The study is designed to explore the views of science education faculty, recent graduates and current doctoral candidates about how science education doctoral programs are responding to the current reform initiatives as they prepare new leaders in the field.

I am going to interview nine recent graduates who were identified by their faculty mentors as having a strong leadership promise in preparing teachers for the broader vision of science education. You are one of this select group. This study will yield systematic data that will serve as reference on what science educators think about the current reform initiatives and whether these reforms impact the preparation of science education doctorates and if so how.

I hope you will agree to be interviewed for this study. To express your willingness to participate, please complete the enclosed consent form and return it to me via e-mail (Our IRB permits returned e-mail forms with your typed name as sufficient consent.) Please also send me a current copy of your curriculum vita when you return the consent form.

We will establish a day and time for a telephone interview, as soon as I hear from you. I anticipate that the interview will last about an hour and half and will be audio taped.
I look forward to learning more about your background and aspirations in the near future.
Attached Documents:

Dissertation proposal summary
Consent form

Sincerely,
Yovita Gwekwerere
Doctoral Candidate

APPENDIX J

LETTER TO DOCTORAL CANDIDATES

Dear xxxx

Your professor Dr________ gave me your name as one of their doctoral candidates in science education who could help me with data collection for my study. I am inviting you to participate in interviews that are part of my doctoral dissertation study entitled "Response to Current Reform Initiatives: ***Case Studies of How Three U. S. Science Education Doctoral Programs are Preparing Future Leaders for the Field***". The study is a continuation of the Leadership Development study that Teachers College participated in 3 years ago. I am collecting data on 3 of the 10 programs previously studied to explore the views of doctoral candidates, recent graduates and faculty about how their science education doctoral programs are responding to the current reform initiatives that focus on reducing the achievement gap in K-12 science.

I hope you will agree to be interviewed for this study. To express your willingness to participate, please complete the enclosed consent form and return it to me via e-mail (Our IRB permits returned e-mail forms with your typed name as sufficient consent.) Please also send me a current copy of your curriculum vita and program plan (a list of the courses you have taken and plan to take for your program) when you return the consent form.

We will establish a day and time for a telephone interview as soon as I hear from you. I anticipate that the interview will last about an hour and half will be audio taped.

I am looking forward to learning more about your background and aspirations in the near future.

Attached Documents:
Dissertation proposal summary
Consent form

Sincerely,
Yovita Gwekwerere
Doctoral Candidate
College of Education, Michigan State University

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